4 BACKGROUND AND HISTORY OF URANIUM MINING IN AFRICA

4.1 Regional Context – Uranium Mining in Africa and SADC

Uranium deposits are found throughout Africa and currently, exploration is being carried out in 30 countries on the continent, 10 of which are members of the Southern African Development Community (SADC). However, there are only a few mines in actual operation at present. According to the uranium mining website, www.wise-uranium.org, these are:

Table 4.1: Operating uranium mines in Africa (as of 11/11/09)

Country	Mine name	Major shareholder
Malawi	Kayelekera Mine	Paladin Resources Ltd
Namibia	Rössing Uranium Mine	Rio Tinto
Namibia	Langer Heinrich	Paladin Resources Ltd
Namibia	Trekkopje (pilot stage)	Areva
Niger	Arlit	Areva
Niger	Akouta	Areva
RSA	Ezulwini	Ezulwini Mining Co (Pty) Ltd
RSA	Vaal River Area Mines	AngloGold Ashanti

However, with the worldwide increase in the demand for uranium, there are a number of projects throughout the continent which are in an advanced stage of development, especially in Niger, Central African Republic, Namibia (see section 4.3 below), South Africa, Tanzania, Malawi and Zambia. The large, near-surface deposits in Niger are relatively high grade (>0.1% U) and therefore there remains significant interest in this country in spite of the political difficulties that often beset the mines.

In South Africa, uranium is most usually associated with gold or copper ores. Up until the recent surge in the price of uranium, the generally low grades of uranium at the gold and copper mines did not make uranium extraction a commercially viable proposition. Therefore, it has been discarded as waste rock or in mill tailings. Thus, although the grades are typically low, ranging from 0.002 – 0.08% U, the resources are easily and cheaply extractable, which makes their future exploitation more attractive.

As in South Africa, the Zambian uranium ores are usually associated with copper, but due to a combination of public opposition to the development of a uranium processing industry in the country, and the lack of a national policy framework for uranium mining, Zambia only started to issue new licences in early 2009.

In addition to the operating mines and uranium projects which are currently under development, as described above, there is extensive exploration being carried out throughout the continent: for example, Niger issued more than 100 exploration permits in the last 2 years and Botswana issued 138 exploration licences for nuclear fuels in the same period. On the other hand, although Namibia granted 66 Exclusive Prospecting Licences (EPLs) for nuclear fuels up until 2007, the Ministry of Mines and Energy (MME) put a moratorium on granting any more EPLs until a policy on uranium exploration and mining has been developed.

Regionally, Namibia appears to be popular amongst the exploration companies for a range of technical, financial and regulatory reasons. The ore bodies are all found on or close to the surface which allows open cast mining; while the ore grades are not as high as those found in Niger, they are high enough to make large-scale mining economically viable; the infrastructure, although stretched, is considerably better than that found in many other African countries; the mines are located close to a port facilitating the import of process chemicals and the export of yellow cake; and there is a relatively straight forward regulatory framework in place to manage and control uranium mining and all related impacts.

Negative factors however, include an inadequate supply of naturally-occurring water in the central Namib and desalinated sea water will be expensive; regional power shortages; crumbling road infrastructure (many of the roads in the area were not built to accommodate heavy vehicles); port congestion and delays; overburdened health and educational facilities in the local towns; and a shortage of skills and government structures which have limited capacity to cope with the uranium rush. Many of these constraints can be addressed through a combination of political will, policy coordination, competent governance, proactive planning and government spending.

4.2 Types of Uranium Deposits in Namibia

The uranium deposits in the Erongo region are mainly confined to the Central Zone of the Damara Belt. Two main types of deposits are found, namely the 'granite type' sheeted leucogranite / alaskite-hosted primary deposits and the 'calcrete type' superficial secondary deposits (Figure 4.1).

The predominant primary uranium mineral in the leucogranites is uraninite (UO_2), however, betafite might be a major phase in some places. Beta-uranophane is usually the dominant secondary mineral in these granites. These uraniferous leucogranites, known as alaskites, occur preferentially in and around anticlinal and dome structures along the Khan and Swakop River valleys to the east of Swakopmund.

Secondary uranium deposits are found in the calcretes which occur in the coastal plain of the Namib Desert. The main uranium-bearing mineral in the calcretes is carnotite, a bright yellow potassium-uranium vanadate mineral. These deposits are related to fluvial environments within palaeo-valleys of ancient rivers that flowed westwards from the Great Escarpment during the upper Cretaceous and the lower Cenozoic periods (88 to 25 Ma). The carnotite is usually found in calcretised fluvial channels as thin films in cracks, disseminations and as coatings on sediment grains, it also occurs along grain boundaries forming a cavity fill, and is best developed in regions of high porosity (LHU, 2009; Roesener and Schreuder, 1992).

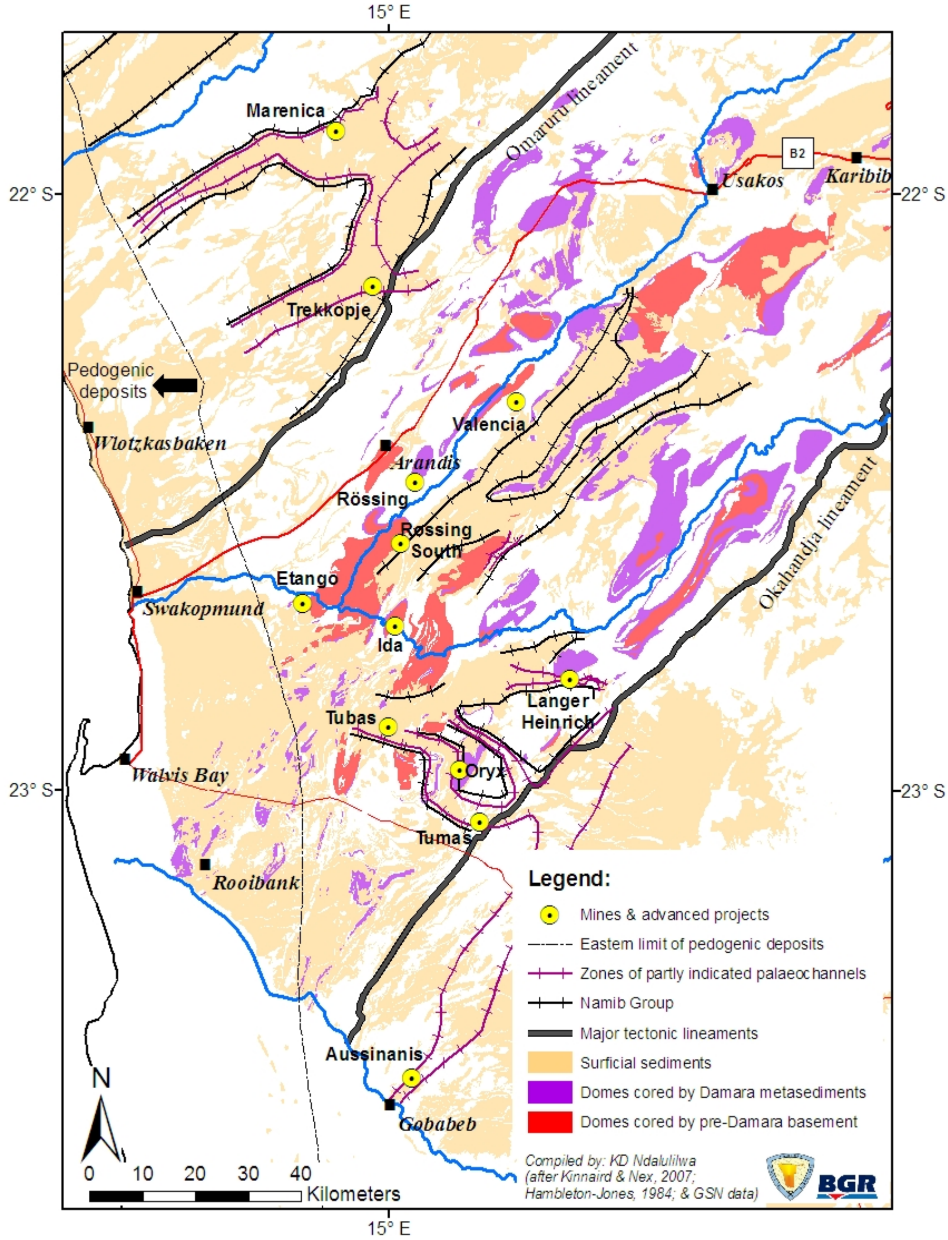

Figure 4.1: Part of the Central Zone of the Damara Belt showing domes and the location of the known uranium deposits (Geological Survey of Namibia, 2010).

4.3 History of Uranium Exploration and Mining in Namibia

Captain Peter Louw discovered radioactivity in the vicinity of the current Rössing mine in 1928. Anglo American Corporation subsequently carried out exploration in the area, but it was not until Rio Tinto acquired the exploration rights in the 1960s that a number of low-grade alaskite ore bodies were identified along the north side of the rugged Khan valley. After extensive test work, construction of the current Rössing mining plant and the development of the open pit started in 1974, with commissioning taking place in 1976 (Plate 4.1). Full production was only achieved in 1979 due to major teething problems in the plant.

Plate 4.1: Rössing, with almost 35 years of production, is the most established uranium mine in Namibia. In this photo, an ore truck passes under a scanner to determine the ore grade (photo Geological Survey).

Following the discovery of Rössing and the global increase in the demand for uranium for nuclear energy production during the 1960s and 1970s, several international mining companies actively started prospecting for uranium in Namibia e.g. Falconbridge and Elf-Aquitaine in addition to Rio Tinto. Furthermore, during the 1970s, the South African government had secretly embarked on the development of 6 atomic bombs under the guise of nuclear fuel enrichment. Thus there was significant interest in Namibia (then a South African Trust Territory) from South African mining companies to find primary sources of uranium to supplement the low-grade output from the South African gold mines. Thus companies such as Anglo American, General Mining and Gold Fields carried out extensive exploration for uranium in the central Namib up until the 1980s, but no new mines were ever developed. Thereafter the uranium price slowly declined and even the well-established Rössing Mine considered early closure several times during the 1990s and early 2000s (see Figure 3.2 in Chapter 3).

In addition to uranium, sporadic exploration and mining has been carried out in the central Namib for decades for a variety of minerals, notably gold, tin, copper, lead, zinc, fluorspar, tungsten, graphite, gypsum, lithium, semi-precious stones and dimension stone. Most of these mines were small and widely spread, both geographically and over time (Figure 4.2). Unfortunately, none of these mines was properly rehabilitated and evidence of mining in the form of tracks, debris, concrete plinths, excavations and waste rock dumps can still be seen today (Plate 4.2).

Plate 4.2: The Namib, like many other places in Namibia, carries debris and scars from mines that have long closed and now lie abandoned (photo Geological Survey).

4.3.1 Current mining activity in the Central Namib

Currently, there are three large mines in operation in the Erongo Region (Rössing Uranium Mine, Langer Heinrich Uranium and Navachab Gold Mine), and two uranium mines are under construction (Trekkopje and Valencia). In addition, there are nine licensed, small dimension stone operations throughout the region and artisanal mining operations are being carried out in the Spitzkoppe area targeting semi-precious stones (e.g. tourmaline, aquamarine, garnet, topaz and rose quartz). There are also two large salt works, one located north of Swakopmund and the other lies south of Walvis Bay, as well as six other smaller salt mining licence holders (Figure 4.2). The output, number of employees or contractors for the smaller mining operations in the region e.g. the gemstone and dimension stone mines, are unlikely to contribute significantly to the cumulative impacts of the Uranium Rush. However, the cumulative impact of their activities on the landscape and their contribution to the degradation of landscape quality is an important factor to be taken into consideration in this SEA.

The three large operating mines in the Erongo Region (Rössing, Langer Heinrich and Navachab) contribute a significant amount to the Namibian economy through employment, sub-contracting, wages and salaries and taxes (Table 4.2). The combined employment at these mines in 2008 of 1,834 represents almost 3.5% of the economically active working population of the Erongo region (based on 2001 census figures).

Research by Ashby (2009) at the Langer Heinrich mine found that the dependency ratio for workers:dependents on the mines is higher (1:4.3) than the average for the Erongo Region as determined in the 2001 census (1:3). Thus the number of dependents benefitting from employment at the 3 larger mines is approximately 7,886. The 2008 combined wages and salaries bill comes to N$453.3 million, but according to research work conducted at Langer Heinrich (Ashby, 2009), an average of N$919 of a worker’s salary is remitted ‘home’ to the northern communal areas of Namibia. Even so, approximately N$451.6 million is spent in the Erongo Region per year. From these 3 mines alone, the Namibian government collected N$876.4 million in taxes and/or royalties in 2008 and the mines had a collective annual turnover of N$5,635 million (2008).

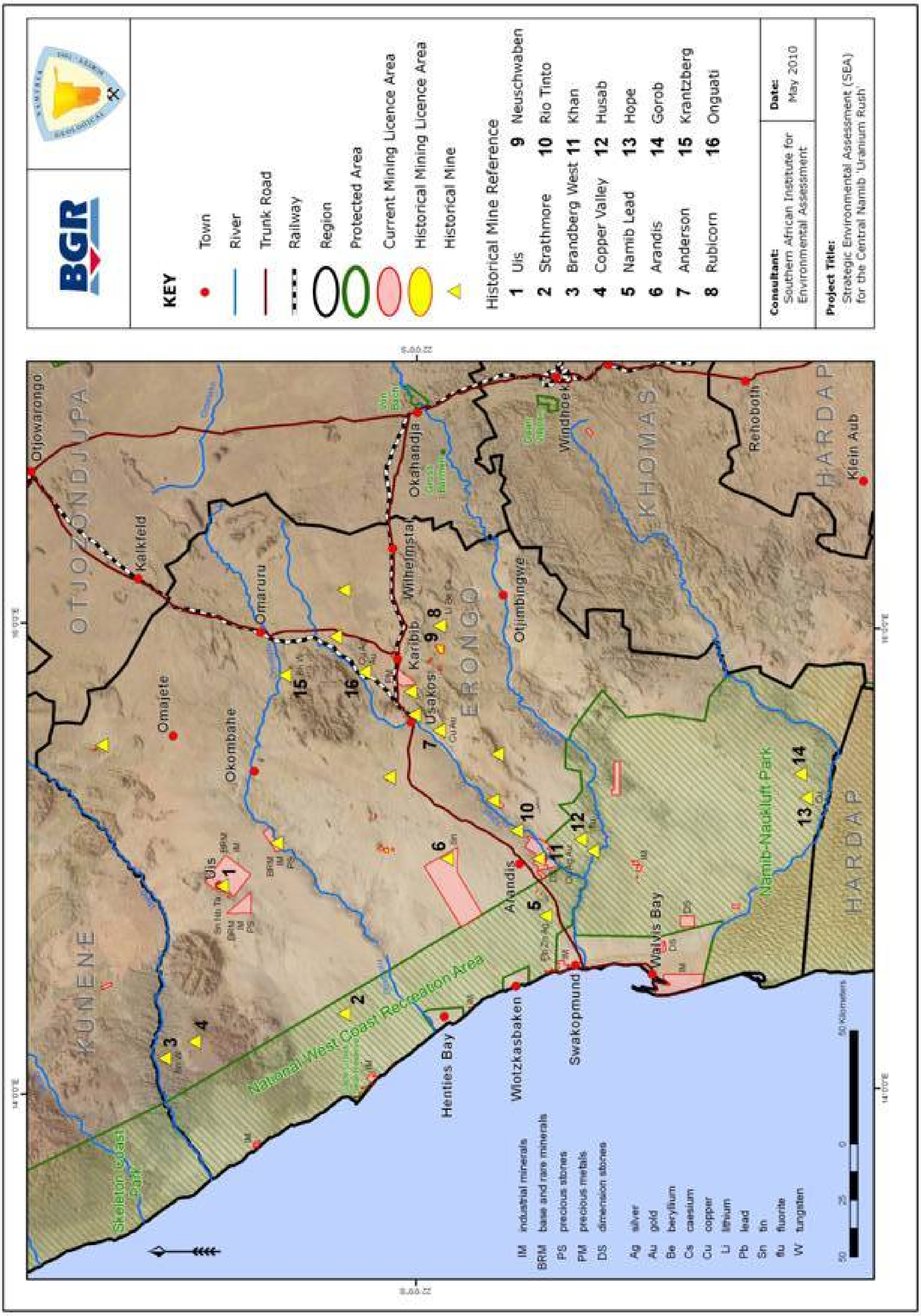

Figure 4.2: Current Mining Licences and Historical Mines in the Erongo Region

The two operating uranium mines produced a total of 4,843 t (10.7 Mlbs) of U_30_8 in 2008, elevating Namibia from the world's fifth to fourth largest producer (see Table 3.2). A target of 5,180 t (±11.6 Mlbs) U_3O_8 is expected in 2009 as Langer Heinrich ramps up production.

Table 4.2: Key statistics for the three large mines currently in operation in the Erongo Region for 2008

Name of mine	**Owner**	**Start date**	**Projec-ted closure date**	**Product output***	**No. of employ-ees***	**No. of sub-contrac -tors**	**Turn-over mill N$**	**Wages and salaries mill N$**	**Royalties and/or taxes mill N$**
ML28: Rössing Uranium Mine	Rössing Uranium Ltd	1976	2020	4,067 t or >9 Mlbs of U_3O_8	1,307	1,154	4,492	319.4	786.9
ML140: Langer Heinrich	Langer Heinrich Uranium Ltd (Paladin Energy)	2006	2024	776 t or 1.7 Mlbs of U_3O_8	167	415	713	50.7	16.8
Sub-total Uranium mines				*4,843 t or >10.7 Mlbs*	*1,474*	*1,569*	*5,205*	*370.1*	*803.7*
ML31: Navachab	Anglogold Namibia (Pty) Ltd	1989	2016	2,126 kg gold	360	138	430	83.2	72.7
TOTAL				**-**	**1,834**	**1,707**	**5,635**	**453.3**	**876.4**

* 2008 figures as reported in the Chamber of Mines 2008 Review

A brief overview of the three large operating mines and the two uranium mines currently under construction is given below.

4.3.1.1 Rössing Uranium Ltd

Rössing Uranium Ltd (RUL) mines uranium ore from 500 million year old granitic rock in the Namib Desert about 70km north-east of Swakopmund (Figure 4.2). The mining licence covers an area of 18 km^2 and the ancillary works area covers a further 5.95 km^2 giving a total mine footprint of 23.95 km^2 (Plate 4.3) (Rössing Annual Report, 2007). Uranium occurs in very low concentrations at Rössing (0.03% uranium) and therefore the mine has to operate on large tonnages. The open pit measures 3 km long by 1.2 km wide and 345 m deep. In 2008, Rössing produced more than 9 Mlbs of uranium oxide (U_3O_8), which comprises about 7.7% of the world's production of primary produced uranium (www.rössing.com). The uranium ore requires a sulphuric acid leach process to liberate the uranium from the host rock. In 2008, Rössing employed 1,307 people and had 1,154 sub-contractors working at the mine (Chamber of Mines 2008 Review).

During 2006, exploration began on known uranium occurrences within the mining licence area, with particular emphasis on the area known as SK, lying directly to the east of the current open pit. Development of the SK ore body and/or extending the existing pit could extend mine life to at least 2026 at the current level of production.

Plate 4.3: Aerial views of Rössing mine and part of the Rössing plant. Much of the total footprint of 24 km² is taken up by waste rock dumps (photo SAIEA and Rössing).

4.3.1.2 Langer Heinrich Uranium (Pty) Ltd

The Langer Heinrich Uranium Mine (LHU) is located some 80 km east of Walvis Bay and Swakopmund (Figure 4.3). Uranium mineralisation at Langer Heinrich is associated with the calcretisation of valley-fill fluvial sediments in an extensive palaeo-drainage system. The Cenozoic uranium mineralisation occurs as carnotite. The deposit occurs over a 15 km length in seven higher grade areas within a lower grade mineralised envelope. Mineralisation is near surface, between 1 to 30 m thick and is 50 to 1,100 m wide depending on the width of the palaeo-valley.

Site works began in September 2005 and the first commercial product shipment occurred in December 2006; Langer Heinrich thus became the second operating uranium mine in Namibia. The uranium is liberated using a tank-based alkaline leach process followed by an ion exchange process and roasting to produce the final U_3O_8 product.

Work is now nearing completion on the Stage II Expansion which will lift production from 1.7 Mlbs/a to 3.7 Mlbs/a. On 30 June 2009, Paladin announced Board approval of the Stage III Expansion, which will increase production to 5.2 Mlbs/a U_3O_8. The original target was 6 Mlbs/a, but uncertainties and likely delays in the construction and commissioning of the NamWater desalination plant has necessitated this reduction in the production target.

A fourth expansion is also planned, which will allow the mine to produce about 10 Mlbs/a U_3O_8 by 2014. This would require the installation of a second water pipeline and an upgrade to the existing power supply line (www.wise-uranium.org).

In 2008, Langer Heinrich employed 167 people and 415 sub-contractors (Chamber of Mines 2008 Review).

4.3.1.3 Navachab Gold Mine

Navachab Gold Mine is located 170 km north-west of Windhoek, 10 km south-west of Karibib and 135 km north-east of Swakopmund (Figure 4.2). It is wholly owned by Anglo Gold Ashanti Namibia. Production commenced in 1989 on ML31, with a life of mine to 2016. However ongoing drilling programmes and a feasibility study into extending the pit and constructing a new DMS plant has extended the life of mine to at least 2023. Gold is found in replacement skarn and sheeted quartz veins in the Damaran Orogenic Belt. Ore is mined from an open pit and treated in a typical cyanide leach plant (Plate 4.4). Production in 2008 totalled 2,126 kg of gold bullion (68,000 oz), slightly down on the 2007 total of 2,496 kg. The Navachab Mine employed 360 people in 2008 and 138 sub-contractors (Chamber of Mines 2008 Review).

Plate 4.4: Navachab Gold Mine open pit (photo Geological Survey).

4.3.1.4 Trekkopje Uranium Mine

The Trekkopje deposit owned by Areva Resources Namibia, located some 70 km north-east of Swakopmund (Figure 4.3), is a shallow, high tonnage, low grade uranium deposit hosted by calcretised palaeo-channels. The main mineralisation covers an area of approximately 16 km by 4 km. Trekkopje will be a shallow, open pit mining operation using conventional truck and shovel methods with limited drilling and blasting. Proven reserves have been estimated at over 300 Mt U_3O_8 at an average grade of 150 ppm (Uramin, May 2007), yielding an estimated 8.5 Mlbs of uranium oxide per annum. At full production, the Trekkopje Mine will be processing 100,000 tonnes of crushed ore per day, based on the stripping ratio of 1:15.

The process route for the Trekkopje ore is via an alkaline heap leach process. Commissioning of a pilot plant commenced in July 2008 and full production is anticipated to commence in 2011 with a life of mine initially estimated to be 11-12 years. Currently Areva Resources Namibia employs 140 people, but it is expected that approximately 320 more jobs will be filled by the end of June 2010 (www.cogema.fr).

The Trekkopje mine is currently under construction, as shown in Plate 4.5.


Plate 4.5: Trekkopje mini heap leach pad and storage tanks for the 'pregnant leach', during early trial stages of the mine design and construction in 2008 (photo Geological Survey).

3.3.1.4 Valencia Uranium (Pty) Limited

Valencia Uranium (Pty) Limited, a wholly owned subsidiary of Forsys Metals Corporation listed on both the Canadian and Namibian Stock Exchanges, is currently finalising the definition of the open pit of the Valencia Uranium Mine (Plate 4.6). The site for the proposed mine is located on the privately owned farm Valencia (No. 122), approximately 80 km inland from Swakopmund, 25 km from Rössing Uranium Mine and 50 km south-west of Usakos (Figure 4.3). The Mining Licence (ML149) was granted in August 2008 and is valid for 25 years.

The proposed Valencia Uranium Mine will utilise traditional surface mining techniques of drilling and blasting in an open pit to extract the low grade alaskite uranium ore. Most probably the pit will develop to a maximum size of approximately 1,400 m long, 700 m wide and 360 m deep. The preliminary geotechnical surveys and pit design work at Valencia Uranium have defined a probable reserve of 117 Mt of ore (at an average grade of 125 ppm) and 122.4 million tonnes of waste rock (Snowden, 2007). Haul trucks of 150 t will typically be used to haul waste rock to spoil sites and ore to the crusher. The operation will have a run of mine (RoM) capacity of one million tonnes per month with a life of mine of only 9 years, based on proven resources (Digby Wells and Associates, 2008). Construction is currently on hold pending funding and so the earliest date of commissioning is now expected to be in 2012.

Plate 4.6: Percussion drilling samples during definition of the proposed pit of Valencia mine (photo Geological Survey).

4.3.2 Current exploration activity in the central Namib

In terms of exploration activity, the database of the Ministry of Mines and Energy (MME) lists a total of 78 exclusive prospecting licences (EPLs) for nuclear fuels in Namibia. Of these, there are 33 current EPLs in the central Namib and 3 applications are pending renewal (Figure 4.4). A further six EPL application decisions are pending, but as mentioned earlier, no new EPLs have been granted by MME since 2007. The companies with the most advanced projects are described briefly below.

4.3.2.1 Bannerman Resources Ltd

Bannerman Resources Ltd is an Australian company, listed on both the Namibian and Australian stock exchanges. The company has interests in two key properties in Namibia: their principal and most significant asset is their 80% interest in the Etango Project (EPL 3345) situated on the south bank of the Swakop River near Goanikontes (Figure 4.5); and the second prospect is EPL 3346, known as Swakop River, which is located at Bloedkoppie east of Langer Heinrich mine (Figure 4.4).

Bannerman is currently focused on accelerating the feasibility study on the Etango Project. This EPL measures 500 km^2 and is located some 35 km east of Swakopmund in an area known in the tourist trade as the ‘Moon Landscape’. The EPL contains 8 prospects, known as: Anomaly A, Ompo, Oshiveli, Onkelo, Ombepo, Anomaly B, Rössingberg, and Ombuga. Drilling is being conducted on most of these prospects, but sufficient work has been done on Anomaly A, Oshiveli and Onkelo to allow a preliminary feasibility study to be undertaken. As of February 2009, the total resource from Anomaly A and Oshiveli was estimated to be 126.6 Mlbs U_3O_8, with an indicated JORC Code[1] resource of 195.5 Mt grading at 207 ppm (89.2 Mlbs of metal) and an inferred resource of 87 Mt at 195 ppm U_3O_8 (37.4 Mlbs of metal). Drilling is continuing on the Oshiveli, Onkelo, Rössingberg and Ombuga prospects, but more drilling is planned for Anomaly A to define the resource at depth and along strike to the north and south, where indications are promising.

The uranium throughout this prospect is found in alaskites, similar to those found at Rössing. The mineralisation is also low grade and therefore the development of this prospect is likely to be a large tonnage operation similar to Rössing. Several process route options are being considered: an acid leach, heap leaching and flotation. The pre-feasibility study was completed by December 2009, and the Bankable Feasibility Study was completed by mid 2010. Projected mine commissioning is in 2013 and a mining licence has been applied for.

[1] The Australasian Joint Ore Reserves Committee (JORC) is sponsored by the Australian mining industry and its professional organisations. The Code for Reporting of Mineral Resources and Ore Reserves (the JORC Code) is widely accepted as a standard for professional reporting purposes. It was first published in 1989, with the latest revised version being published late in 2004. Since 1989 and 1992 respectively, it has been incorporated in the Listing Rules of the Australian and New Zealand Stock Exchanges, making compliance mandatory for listing public companies in Australia and New Zealand (www.jorc.com).

4.3.2.2 Extract Resources

Extract Resources is an Australian and Toronto Stock Exchange listed uranium exploration company, whose primary interest is in Namibia. Rössing Uranium Ltd holds almost 20% of the shares. The Company's principal asset is its 100% owned Husab Uranium Project which contains two known uranium Prospects: Rössing South and Ida Dome (Figures 4.4 and 4.5) (www.extractresources.com). The Rössing South deposit (EPL 3138) is interpreted as being an extension of the same stratigraphy that hosts the Rössing mine, and striking from Rössing mine 15 km onto the Husab Project, buried under some 30 m of desert sands.

The Rössing South deposit was initially drilled in 2007 and chemical assay results in February 2008 confirmed the discovery. By February 2009, Zone 1 of the deposit was found to contain an initial resource of 108 Mlbs at 430 ppm U_3O_8 and Zone 2 was expected to show 69-106 Mlbs U_3O_8.

Additional zones of high grade alaskite confirm that Rössing South is the highest grade, granite-hosted uranium deposit in Namibia and possibly one of the largest deposits in the world (Extract Resources, February 2010).

4.3.2.3 Reptile Uranium Ltd

Probably the next most advanced project in terms of resource definition and effort is that of Reptile Uranium Namibia (Pty) Ltd (RUN). RUN is a wholly owned subsidiary of Deep Yellow Ltd, an Australian and Namibian stock exchange listed company. It is interesting to note that Paladin Energy Ltd owns a 19.29% stake of Deep Yellow and therefore future linkages with the Langer Heinrich operating uranium mining project are possible.

RUN holds 100% of four contiguous Exclusive Prospecting Licences (EPLs) covering 2,681 km^2 and three additional adjoining EPLs covering 1,323 km^2 where it is earning 65% in JV with Nova Energy Namibia. The areas contain historical discoveries of gypcrete, calcrete and sand-hosted secondary uranium mineralisation. Exploration by RUN has increased the extent of these and also delineated new areas of primary alaskite hosted and skarn hosted uranium (and iron) mineralisation.

The deposit types, processing and products (roughly in order of development) can be summarised as follows:

- Inca uraniferous magnetite - primary mineralisation in hardrock; requires drill and blast and crushing/milling followed by processing in an acid plant. Products: uranium and iron.

- Tubas Red Sand - secondary uranium mineralisation in free-digging and milling sand and gravel, with processing in an acid or alkali plant. Products: uranium and vanadium.

  Together these two prospects are known as the **Omahola Project** with a projected annual U_3O_8 production of 2-3 Mlbs, with about 2-3 Mlbs of vanadium and 100,000-300,000 tonnes of iron as by-products.

- M62 Iron Project was discovered from airborne magnetic surveys and subsequent limited RC drilling and diamond drilling to 500 metre depths indicated that it may be a substantial source of magnetite/iron. Beneficiation tests as part of a scoping study are being undertaken and given that it is located between 25 and 30 km from Walvis Bay it may be economically viable to export.

- The Eastern palaeo-channels comprising Tumas, S-Bend, Oryx and Tubas contain secondary uranium mineralisation in free-digging and milling sand and gravel, or in cases where the material is too well cemented, drilling and blasting will be required. This would be followed by crushing/milling and processing in an alkali plant. From interpretation of airborne electromagnetic (AEM) surveys, the Tumas - Tubas palaeo-channel system can now be traced for a cumulative total of 80 km of which only about 15 km has been investigated in detail by drilling; an additional 35 km by previous explorers and/or RUN and 30 km remain untested. Products include uranium and vanadium.

- Aussinanis and Ripnes sheet-wash areas contain secondary uranium mineralisation in free-digging and milling sand and gravel, or in cases where the material is too well cemented, drilling and blasting will be required. This would be followed by crushing/milling and processing in an alkali plant. Products include: uranium (between 1.5 and 2 Mlbs of U_3O_8 per annum) and vanadium (between 2-3 Mlbs/a).

4.3.2.4 Others

Other than the companies discussed above, the following companies currently hold EPLs for uranium in the Central Namib (see Figure 4.4 for locations):

Australian Companies:

Erongo Energy Ltd (EPLs 3453, 3454, 3477)

West Australian Metals (formerly Marenica Minerals) (EPL 3287)

Toro Energy Ltd (formerly Nova Energy) (now in a JV with Deep Yellow (Reptile) (EPLs 3668, 3669, 3670)

Swakop Uranium (owned by Extract Resources) (EPLs 3138, 3439, 3327, 3328)

Green Mineral Resources (70% owned by Africa Uranium and 30% Bastos Foundation) (EPL 3664).

Canadian Companies:

Cheetah Minerals (owned by Manica, which is 51% owned by Pitchstone Exploration) (EPLs 3516, 3517, 3518)

Xemplar Energy Corp (formerly Namura) (EPLs 3569, 3570, 3571)

Dunefield Mining (owned by Forsys) (EPLs 3635, 3636, 3632, 3637, 3638)

Russian Companies

SWA Uranium Mines (owned by Arlan 75% and VTB Capital 25% with Atomredmetzoloto) (EPLs 3850, 3851)

Chinese Companies

Zhonghe Resources Namibia (EPLs 3600, 3602)

British Virgin Islands

Petunia Investments 3 (100% owned by Barlow Holdings Ltd) (EPL 3780).

Most of these companies are at the early stages of exploration, conducting airborne and ground radiometric surveys, geological mapping, radon surveys and reconnaissance drilling with variable effort. West Australian Metals is probably the most advanced, since they have recently started diamond drilling on their Marenica prospect, south-west of Klein Spitzkoppe.

There is a reasonable expectation that some of these exploration projects may actually be converted into operating mines, but there is considerable uncertainty as to which ones, how many and when. However, based on current information we have been able to build four possible development scenarios, as described in section 4.5 below.

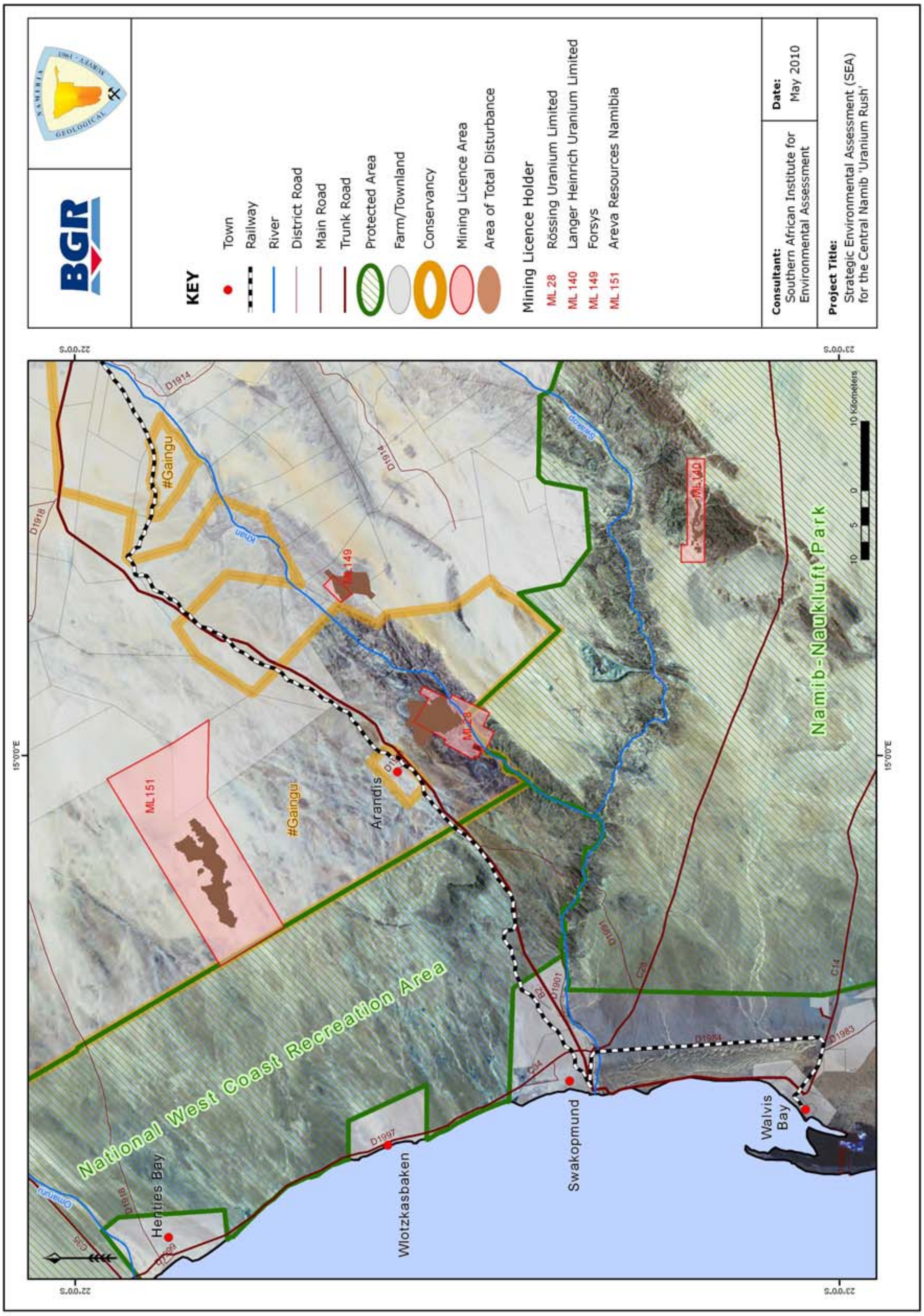

Figure 4.3: Scenario 1 mines

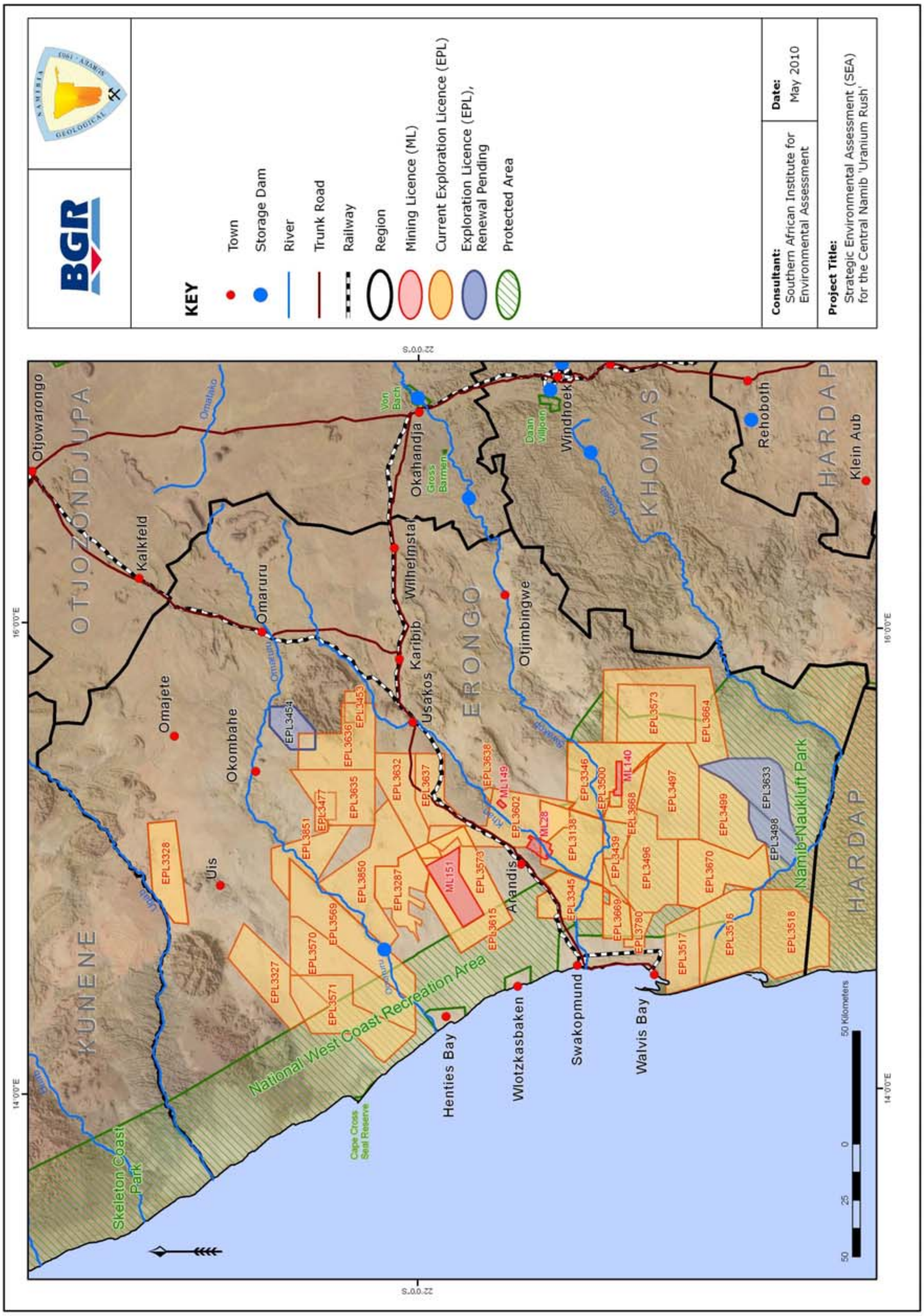

Figure 4.4: Uranium EPLs in the Erongo Region

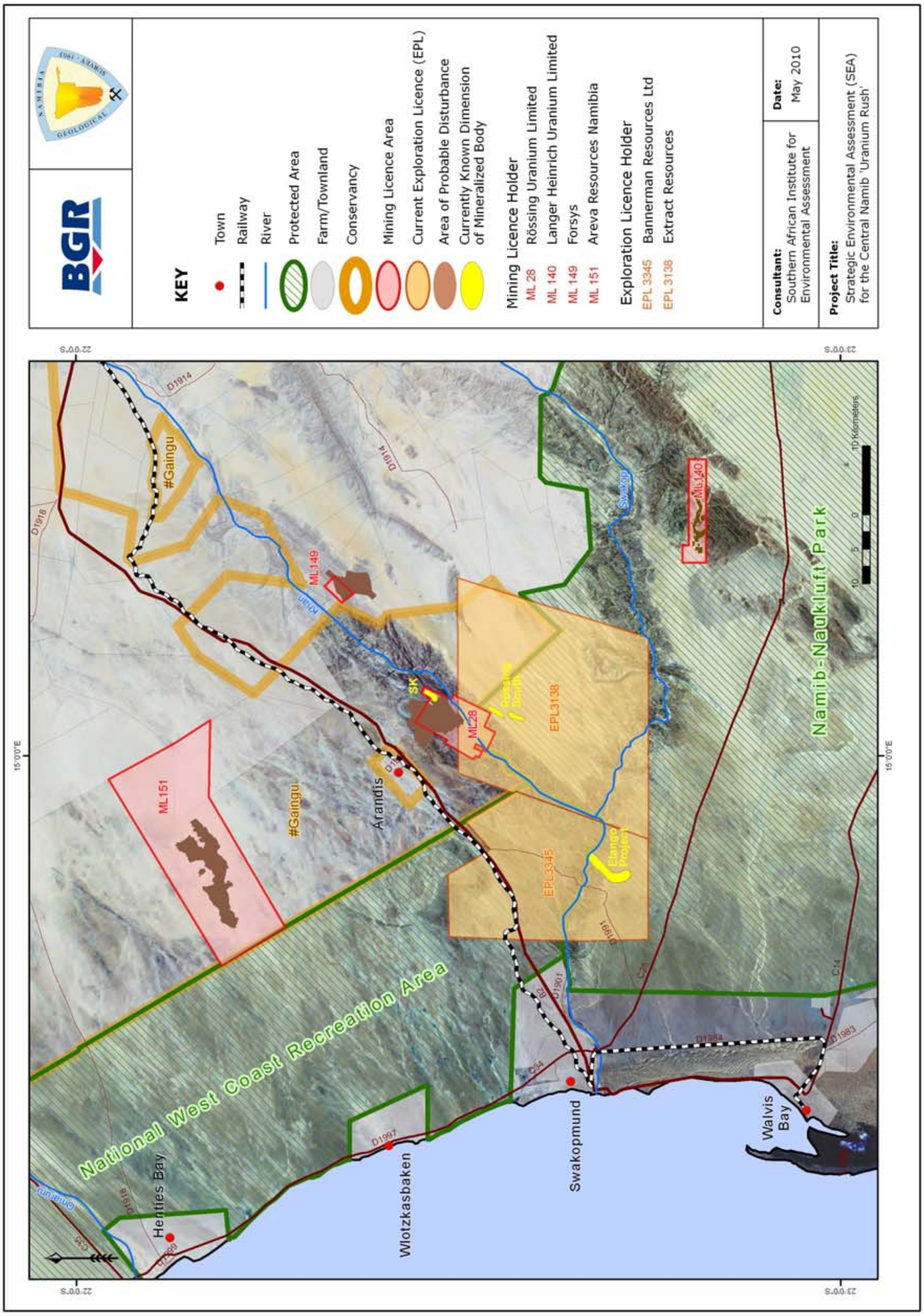

Figure 4.5: Scenario 2: Probable additional mines in yellow

4.4 Overview of Associated Industrial Developments

There are a number of industrial developments that are being built or planned to support the Uranium Rush. It is unlikely that these developments would have taken place in the absence of the uranium mines and so they are considered as part of the direct cumulative impacts of the Uranium Rush

4.4.1 Walvis Bay Power Station

In view of the expected increase in demand for electricity at the coast due to the uranium rush and other coastal developments, combined with the current electricity shortage within the SADC region as a whole, NamPower has recently investigated a number of new supply options. There are two possible alternatives to supply base load power on a long-term basis in the Erongo Region: generation of power by an Independent Power Producer from Compressed Natural Gas (CNG) imported to Walvis Bay from the Kudu Gas Field; and a coal-fired power station at Walvis Bay. NamPower has conducted several investigations into the coal-fired power station option, looking at several different locations and sizes. For the sake of scenario planning for this SEA, we have assumed that a 200 MW station would be sufficient to meet the demands of Scenario 1 mines; a 400 MW station would be needed for Scenario 2 and an 800 MW station would be required for Scenario 3 (see section 7.5).

4.4.2 Desalination Plants

Areva Resources Namibia has commissioned a desalination plant at Wlotzkasbaken, approximately 30km north of Swakopmund - a first for Southern Africa – that supplies sufficient water to support the mining operations at Trekkopje Mine, approximately 40 km inland. The plant has the capacity to produce 20 Mm^3/a of potable water. State-of-the-art technology was introduced which entails screen filtration, ultra filtration, reversed osmosis and chemical treatment.

NamWater is also investigating the possibility of constructing a desalination plant near Mile 6 on the northern outskirts of the Swakopmund municipal area. The plant is expected to be commissioned in 2012 and will have a capacity to produce 25 Mm^3/a of potable water. This water will be expensive but the water will be allocated to all the existing and future mines.

The Trekkopje desalination plant was designed and built to accommodate a second intake pipeline and space for modular extensions to the plant in anticipation that NamWater would ‘share’ the facility. Unfortunately, NamWater has pulled out of negotiations with Areva for various reasons and is still pursuing its own desalination plant at Mile 6. All the proposed new mines, except Trekkopje are dependent on being supplied with water by NamWater, but there are insufficient freshwater resources available. Thus the development of these mines is completely dependent on Namwater completing the construction of its desalination plant before they can start full operations.

Since Valencia, Etango and Rössing South plan to start production in 2012/2013, there is not much time left to build a new desalination plant (see section 7.4). From a strategic perspective, where one of the goals of this SEA is to minimise the footprint of all developments and to optimise the use of facilities, and given that water supply is on the critical path, it is strongly recommended that NamWater reconsiders the joint use of the Wlotzkasbaken desalination plant.

4.4.3 Gecko Mining and Chemicals

The Gecko Group envisages a substantial investment in Namibia that, to a large extent, is directly linked to the central Namib Uranium Rush. The project in its entirety encompasses several different mines for a variety of minerals throughout Namibia and in its territorial waters, several factories for the manufacture of chemicals, loading and offloading facilities at the Port of Walvis Bay, the transportation of raw materials and products, and all associated infrastructure such as power, water, access roads etc.

The primary products proposed to be supplied to the uranium mines comprise:

- Sulphuric acid from a 3,600 t/d acid plant near Swakopmund using imported sulphur prills;
- 150,000 tpa soda ash and 175,000 tpa bicarbonate from a soda ash plant near Swakopmund using salt mined near Cape Cross; and
- Caustic soda from a plant to be built at Arandis using soda ash mined at Otjivalunda as the input.

The support industries described above (power station, desalination plants and chemical plants) will require power, water, import/export facilities, rail and road transportation routes, and skilled and unskilled labour. They will also contribute to air pollution, noise, dust, waste and traffic. Thus they will collectively add to the cumulative impacts of the uranium mines and will largely be competing for the same limited resources and services. It is for this reason that we have included these industries in the scenarios set out below.

4.5 Uranium Rush Mining Scenarios

From the analysis of the forces and dynamics of the Uranium Rush presented in Chapter 3, we may assume that the main short- to medium-term drivers behind the uranium rush, (namely concerns about uranium supply security due to diminishing secondary uranium supplies and typically long lead times involved in expanding primary uranium production capacity), are unlikely to go away over the next 10-15 years. It is also reasonable to assume that the rate at which new uranium production capacity is brought on stream in Namibia by 2020 will depend primarily on how fast each individual project manages to make progress towards getting the feasibility study and environmental impact assessment completed and approved, obtaining a mining licence and commencing mining operations. This, in turn, will depend on a range of project-specific factors including the attractiveness of the project, the seriousness of the investor, the quality of project management, the degree to which the project manages to establish good working relations with and be accepted by local stakeholders, etc.

Thus bearing in mind the global forces and from an analysis of the current mining and prospecting situation, we have developed four possible scenarios for the purposes of this SEA. The scenarios are not restricted to the number of uranium mines, but rather a more holistic picture of development has been described for the Erongo Region, including other large-scale mines and mining-related industrial developments.

Scenario 1: 'Below-expectations' (1-4 mines operating by 2020)

In addition to the two uranium mines already in operation, the two other projects which have received their Mining Licences, Trekkopje and Valencia, will commence operation in 2010-12, but no further mines will be started up before 2020. Under this scenario, it is also assumed that some of the planned mine expansions will not take place during the forecast period due to depressed uranium prices. The uranium mines in Scenario 1 are shown on Figure 4.3 and include:

- Rössing
- Langer Heinrich (Stages I and II only)
- Trekkopje
- Valencia

In addition, cognisance needs to be given to the other large mining projects in the area, which under this scenario is only Navachab Gold Mine. With regard to other related industrial developments directly linked to the Uranium Rush, the projects already under construction or most likely to proceed will include:

- Trekkopje desalination plant; and
- 200 MW coal-fired power station at Walvis Bay.

In this scenario, it is unlikely that the NamWater desalination plant would be built, nor would it be economic for Gecko to develop its mining and chemical plant.

Under Scenario 1, the joint production of Rössing, Langer Heinrich, Trekkopje and Valencia will keep output at about 23-25 Mlbs/a U_3O_8 up to 2020 and beyond (see Table 4.3 and Figure 4.6). Direct employment in the region will reach about 4,000 during the period 2011-12, boosted by the construction phases of Trekkopje, Valencia, and the power station, but it will reduce to less than 3,500 for the rest of the period (Table 4.4 and Figure 4.7).

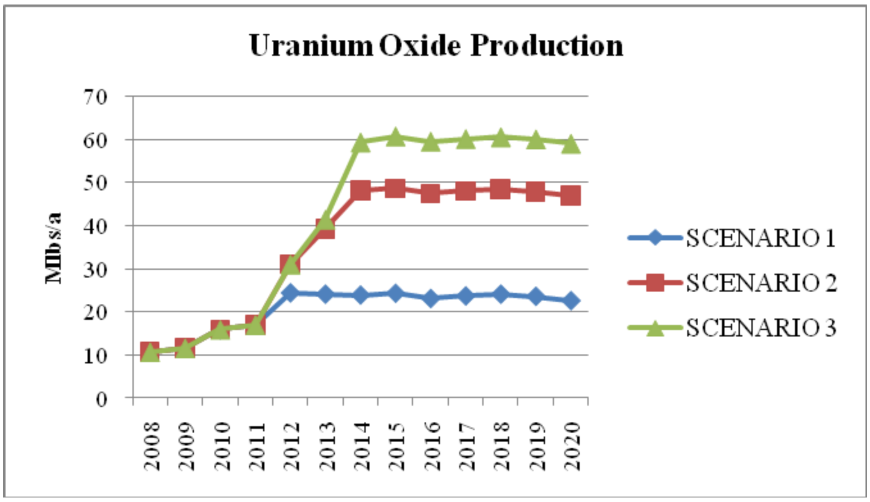

Figure 4.6: Uranium production per scenario over time

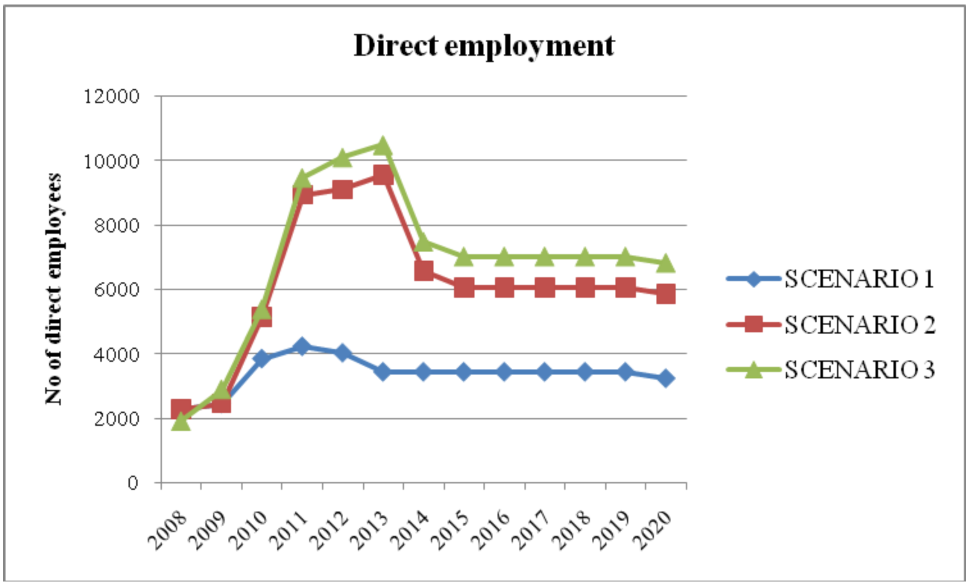

Figure 4.7: Direct employment arising from construction and operation of uranium mines and associated industries per scenario over time

<u>Scenario 2: 'In-line-with-expectations'</u> (5-7 mines operating by 2020)

In addition to the 4 mines with Mining Licences identified under Scenario 1, one or two more companies will successfully bring their mines on stream by 2013. It is also assumed that uranium prices will be buoyant and that the existing mines will press ahead with their significant expansion projects. The mines and expansions under this scenario are shown on Figure 4.5 and include:

- Rössing plus expansion
- Langer Heinrich (Stages I, II and III only)
- Trekkopje
- Valencia
- Rössing South (Husab Project)
- Etango Project.

Under this medium growth scenario, it is possible that only one more non-uranium mine (e.g. Kalahari Minerals' re-commissioning of the Namib Lead mine) may be developed in the Erongo region by 2020 in addition to the existing Navachab Gold Mine.

Under Scenario 2, there is a strong possibility that several of the related industrial developments will be commissioned to meet the increased needs from the uranium mines. The envisaged projects will or might include:

- Trekkopje desalination plant;
- NamWater desalination plant;

- 400 MW coal-fired or CNG power station at Walvis Bay;
- Gecko Mining and Chemicals operations.

From Table 4.3 and Figure 4.6, it can be seen that there will be a significant increase in uranium oxide production from 2012, when Langer Heinrich implements its Stage III expansion. Uranium oxide output is expected to peak at over 48 Mlbs/a in 2014, when all 6 mines are at full production. This will drop off slightly if Valencia does not extend its current mine life beyond 2020, to around 47 Mlbs/a U_3O_8 (see Table 4.3 and Figure 4.6).

Under Scenario 2, there will be a massive demand for employment from 2010 (>5,000), rising to around 9,000 in the period 2011-13, due to the simultaneous construction of 4 mines, a power station, the NamWater desalination plant, the Walvis Bay power station and the Gecko Chemicals plants. This number will decrease once these facilities are in operation to around 6,100 (Figure 4.7 and Table 4.4). Compared to the 2008 direct employment figure in the uranium mining industry in the central Namib of some 1,834, these numbers represent a significant increase. It should also be noted that many other jobs will be created in a range of service industries and other sectors e.g. the Port of Walvis Bay, housing construction, banking, schools, clinics, shops etc. If a multiplier of 8 is assumed[2], the total number of new jobs generated in the economy could be much higher, possibly in the order of 48,000.

Scenario 3: 'Above-expectations' (8-12 mines operating by 2020)

In addition to mines which may be operating by 2015 (as per Scenario 2), at least two more companies may be successful in bringing their uranium deposits into production before 2020 and the existing mines will increase production from expansion projects. It is not clear at this point which of the current EPLs might be developed into a mine before 2020, but at present, the most likely combination is shown on Figure 4.8 and includes:

- Rössing plus expansion
- Langer Heinrich (Stages I-IV)
- Trekkopje and extensions
- Valencia and extensions
- Rössing South (Husab Project)
- Etango Project
- Omahola Project (Inca and Tubas Red Sand)
- Marenica.
- Other developments on Reptile EPLs.

[2] Gerrie Muller (Metago), pers comm.

Table 4.3: Cumulative uranium oxide production in million pounds per annum per scenario over time

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
SCENARIO 1	**10.7**	**11.6**	**15.9**	**17**	**24.4**	**24.1**	**23.9**	**24.3**	**23.1**	**23.7**	**24.1**	**23.6**	**22.6**
Rössing Uranium Ltd	9	9	9	9	9	9	9	9	9	9	9	9	9
Langer Heinrich (Stage I & II)	1.7	2.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
Trekkopje	0	0	3.3	4.4	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
Valencia	0	0	0	0	3.3	3	2.8	3.2	2	2.6	3	2.5	1.5
SCENARIO 2	**10.7**	**11.6**	**15.9**	**17**	**31**	**39.2**	**48.2**	**48.6**	**47.4**	**48**	**48.4**	**47.9**	**46.9**
Rössing plus expansion	9	9	9	9	10	11	11	11	11	11	11	11	11
Langer Heinrich (Stages I, II & III)	1.7	2.6	3.6	3.6	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2
Trekkopje	0	0	3.3	4.4	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
Valencia	0	0	0	0	3.3	3	2.8	3.2	2	2.6	3	2.5	1.5
Etango	0	0	0	0	4	4	5.7	5.7	5.7	5.7	5.7	5.7	5.7
Rössing South (Husab) (Zones 1 & 2)	0	0	0	0	0	7.5	15	15	15	15	15	15	15
SCENARIO 3	**10.7**	**11.6**	**15.9**	**17**	**31**	**41.4**	**59.3**	**60.7**	**59.5**	**60.1**	**60.5**	**60**	**59**
Rössing plus expansion	9	9	9	9	10	11	11	11	11	11	11	11	11
Langer Heinrich (Stages I to IV)	1.7	2.6	3.6	3.6	5.2	5.2	10	10	10	10	10	10	10
Trekkopje	0	0	3.3	4.4	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
Valencia	0	0	0	0	3.3	3	2.8	3.2	2	2.6	3	2.5	1.5
Etango	0	0	0	0	4	4	5.7	5.7	5.7	5.7	5.7	5.7	5.7
Rössing South (Husab) (Zones 1 & 2)	0	0	0	0	0	7.5	15	15	15	15	15	15	15
Omahola Project	0	0	0	0	0	2.2	3.3	3.3	3.3	3.3	3.3	3.3	3.3
Marenica	0	0	0	0	0	0	3	4	4	4	4	4	4

Table 4.4: Direct employment from the uranium mines and associated industries per scenario over time

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
SCENARIO 1	**2274**	**2460**	**3852**	**4232**	**4032**	**3442**	**3442**	**3442**	**3442**	**3442**	**3442**	**3442**	**3242**
Rössing Uranium Ltd	1307	1300	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
Langer Heinrich (Stage I & II)	167	360	432	432	432	432	432	432	432	432	432	432	432
Trekkopje	*140*	*140*	460	460	460	460	460	460	460	460	460	460	460
Valencia	0	0	*800*	*800*	600	600	600	600	600	600	600	600	400
Navachab	360	360	360	360	360	360	360	360	360	360	360	360	360
Trekkopje Desalination plant	*300*	*300*	*300*	30	30	30	30	30	30	30	30	30	30
200 MW power station	0	0	0	*650*	*650*	60	60	60	60	60	60	60	60
SCENARIO 2	**2274**	**2460**	**5152**	**8932**	**9097**	**9563**	**6563**	**6063**	**6063**	**6063**	**6063**	**6063**	**5863**
Rössing plus expansion	1307	1300	1500	1500	1600	1600	1600	1600	1600	1600	1600	1600	1600
Langer Heinrich (Stages I, II & III)	167	360	432	432	522	522	522	522	522	522	522	522	522
Trekkopje	*140*	*140*	460	460	460	460	460	460	460	460	460	460	460
Valencia	0	0	*800*	*800*	600	600	600	600	600	600	600	600	400
Etango	0	0	*1000*	*1000*	500	500	500	500	500	500	500	500	500
Rössing South (Husab) (Zones 1 & 2)	0	0	0	*1500*	*1500*	1000	1000	1000	1000	1000	1000	1000	1000
Navachab	360	360	360	360	360	360	360	360	360	360	360	360	360
Namib Lead mine	0	0	0	*800*	*800*	300	300	300	300	300	300	300	300
Trekkopje desalination plant	*300*	*300*	*300*	30	30	30	30	30	30	30	30	30	30
NamWater desalination plant	0	0	*300*	*300*	30	30	30	30	30	30	30	30	30
400 MW power station	0	0	0	*650*	*650*	116	116	116	116	116	116	116	116
Gecko Chemicals plant	0	0	0	*1000*	*2000*	*4000*	*1000*	500	500	500	500	500	500
Gecko caustic plant	0	0	0	*100*	45	45	45	45	45	45	45	45	45
SCENARIO 3	**1914**	**2900**	**5392**	**9472**	**10107**	**10491**	**7491**	**7031**	**7031**	**7031**	**7031**	**7031**	**6831**
Rössing plus expansion	1307	1300	1500	1500	1600	1600	1600	1600	1600	1600	1600	1600	1600
Langer Heinrich (Stages I to IV)	167	360	432	432	522	522	522	522	522	522	522	522	522
Trekkopje	*140*	*140*	460	460	460	460	460	500	500	500	500	500	500
Valencia	0	0	*800*	*800*	600	600	600	600	600	600	600	600	400
Etango	0	0	*800*	*800*	500	500	500	500	500	500	500	500	500
Rössing South (Husab) (Zones 1 & 2)	0	0	0	*1500*	*1500*	1000	1000	1000	1000	1000	1000	1000	1000
Omahola Project and M62 Iron ore	0	0	0	*800*	*800*	600	600	600	600	600	600	600	600
Marenica	0	0	0	*800*	*800*	600	600	600	600	600	600	600	600
Namib Lead mine		*800*	*800*	300	300	300	300	300	300	300	300	300	300
Trekkopje desalination plant	*300*	*300*	*300*	30	30	30	30	30	30	30	30	30	30
NamWater desalination plant	0	0	*300*	*300*	300	30	30	30	30	30	30	30	30
800 MW power station	0	0	0	*650*	*650*	204	204	204	204	204	204	204	204
Gecko Chemicals plant	0	0	0	*1000*	*2000*	*4000*	*1000*	500	500	500	500	500	500
Gecko caustic plant	0	0	*0*	*100*	45	45	45	45	45	45	45	45	45

Numbers in *italics* indicate construction employment

The increase in projects in Scenario 3 does not necessarily mean that there will be a concomitant increase in the number of processing plants because it is likely that the existing mines will seek ore body extensions (e.g. Langer Heinrich, Rössing, Trekkopje) and use their existing plants to process the ore. Furthermore, synergies could be established between say Trekkopje and Marenica as well as Reptile and Langer Heinrich, where the same type of ore might be toll processed at the existing plant, or where companies may form mergers and acquisitions to capitalise on economies of scale.

Under Scenario 3, it is assumed that the world will have recovered from the economic recession faster than predicted and that metals prices will be rising. It is possible therefore that in addition to the existing Navachab Mine and the likely development of the Namib Lead mine by Kalahari Minerals, another mine could be developed by 2020 (e.g. Kalahari Minerals' Ubib copper-gold project near Navachab, or Reptile's M62 iron ore project near the Omahola Project).

Under Scenario 3, the proposed (or actual) associated industrial developments will be essential to meet the increased needs from the uranium mines and other developments. The existing and envisaged projects will include:

- Trekkopje desalination plant;
- NamWater desalination plant;
- 800 MW coal-fired or CNG power station at Walvis Bay;
- Gecko Mining and Chemicals operations.

Under this scenario, there will be a period from 2015-2019 when there will be 8 mines in production, with an output of about 60 Mlbs/a U_3O_8 being attained (see Table 4.3 and Figure 4.6). Even considering a rapid increase in demand for uranium, it is unlikely that the market could sustain such an output and as a consequence there may well be an oversupply. This might trigger a drop in prices and more marginal (low-grade) mines may face closure as a result, or new deposits may not be developed. The ability of the market to absorb production may well be the main regulating force determining how many mines can be sustainable at a given time in Namibia.

Under Scenario 3, employment will peak at over 9,000 for the main three year construction period (2011-2013), thereafter it will stabilise at around 7,000, reflecting the full operation of 8 mines, 2 desalination plants, an 800 MW power station and 3 chemical plants. Although employment may drop off slightly after 2019, it will remain high (>6,000) for the foreseeable future (Figure 4.7 and Table 4.4).

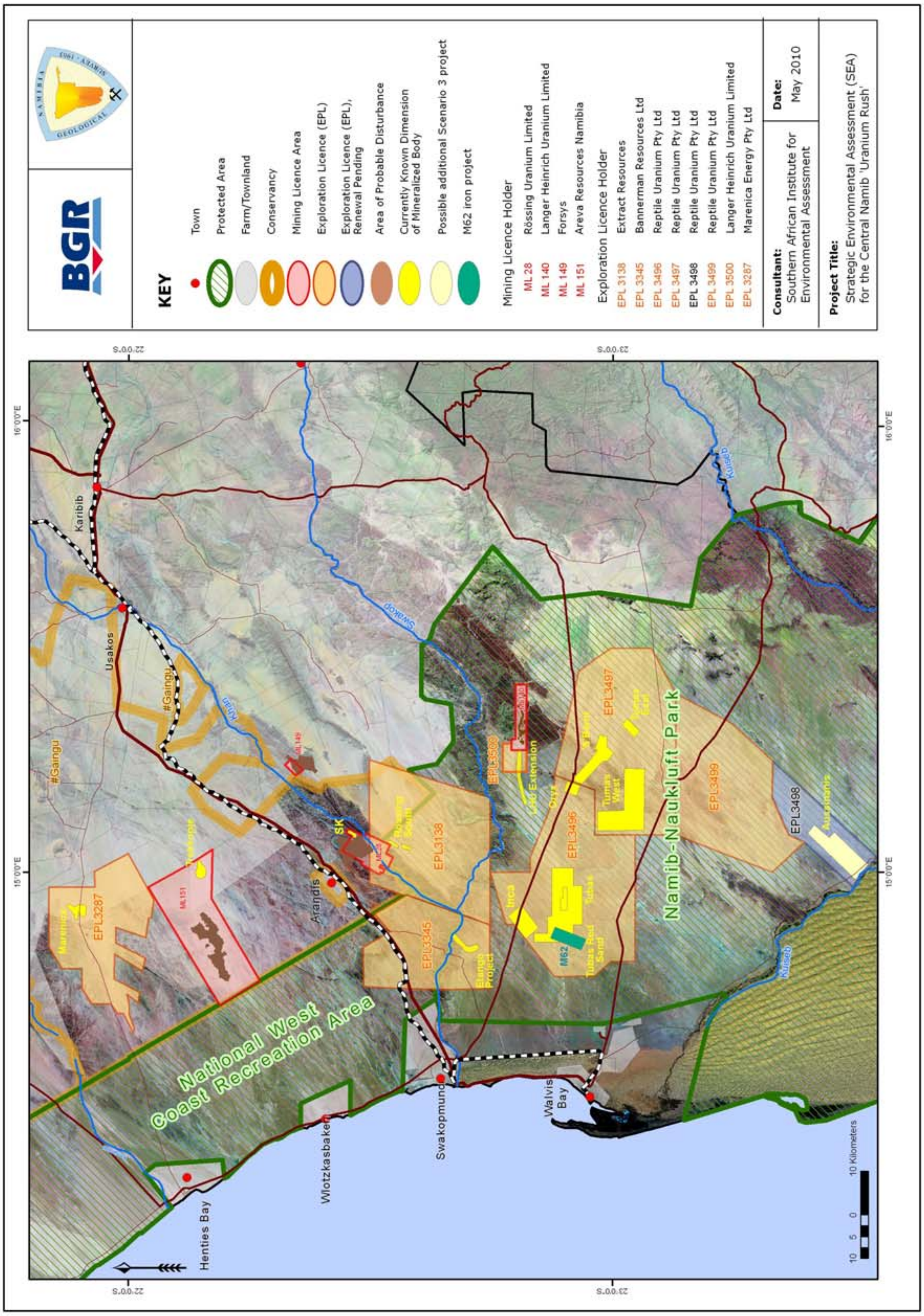

Figure 4.8: Scenario 3 mines

<u>Scenario 4: "Boom-bust" scenario</u> (5-12 mines operating and then shutting down in a hurried, unplanned fashion before 2020).

The fourth scenario is termed the 'boom and bust scenario' whereby a number of mines first open and then shut down in a hurried, unplanned fashion, without any remedial or stabilisation measures, leaving the mines and all associated infrastructure behind. This scenario could be triggered by one or more global drivers such as a significant drop in uranium prices.

This scenario would also affect some of the associated industrial developments at the coast which will have been built specifically for the uranium rush. While alternative users could be found for, say, the power generated by the new power station (even through energy exports if economic), some industries may also have to close down e.g. the Gecko chemical plants, unless overseas buyers could be found for their products.

This would have devastating consequences for the thousands of people and businesses directly and indirectly employed in the uranium rush and would put a severe dent in Namibian GDP, foreign exchange earnings and income from taxes and royalties. It would also mean that the government will have over-capitalised on infrastructure (roads, power generation and transmission, water supplies) and community facilities (schools, clinics) etc.

4.6 Overview of Typical Mining Operations

4.6.1 <u>Description of prospecting activities</u>

Prospecting involves a range of activities which become progressively more intrusive as the ore body is defined to a greater degree of accuracy. The early stages of exploration include activities such as airborne radiometric surveys, radon cap surveys, and surface grab rock sampling. Once the site shows a degree of prospectivity, the next stage involves reconnaissance drilling on a fairly widely spaced grid. This requires the establishment and presence of a small exploration camp, usually located on or nearby the EPL and which comprises a few temporary structures e.g. caravans, shipping containers, and a core yard. The camp requires power (generators) and water (usually boreholes or water tankers) and generates a small amount of domestic and industrial waste. Issues include litter, local loss of vegetation, noise, poaching, localised pollution from diesel tanks and oil spillage.

If the reconnaissance drilling results look promising, a more intensive drilling programme will be pursued to more clearly delineate the lateral and vertical extent of the ore body. The drill hole spacings are on a 50 m grid and often more than one rig will be operating at a time. At this stage, the exploration company may take a bulk sample for detailed lab testing to determine the best metallurgical process route.

4.6.2 <u>Description of construction activities</u>

Construction of a large mine is a big operation, requiring land clearing, bulk earthworks, the establishment of a construction camp to house up to 1,500-2,000 workers, laydown areas, workshops and the entire area needs to be fenced off.

Once the bulk earthworks have been completed, all the structural, mechanical and electrical components of the plant need to be constructed e.g. crushing circuit, process plant, offices, workshops, etc. These activities are often noisy and generate a considerable amount of waste.

The uranium deposits will require the development of the open pit, with surface blasting, removal of overburden, construction of haul roads etc. The shallow secondary deposits will require slightly less work and may not require blasting during the initial stages. The impacts include noise, vibration, dust and light at night.

One of the biggest impacts is that every component required for the construction of the mine needs to be brought to site using existing roads, railways and ports. During the peak of construction this can result in hundreds of vehicles per day (see section 7.3). The impacts include: traffic congestion, increased accident risk, deterioration of the road surface, port congestion, vehicle fumes, dust, noise and so on.

Water is required during construction for mixing concrete, dust suppression, washdown, drinking, ablution facilities and change houses. Often this water is supplied from groundwater while the permanent water pipeline is being built. Excess groundwater abstraction can lead to a local drop in water table level and reduced yields for other local users, e.g. farmers.

The new mine will require both power and water which will be brought to the mine via transmission lines and water pipelines respectively. Infrastructure on site will include a substation and step-down transformers for the electricity supply and a bulk water reservoir and pump stations for the water.

A considerable amount of waste is generated on a construction site including hazardous and non-hazardous waste. Non-hazardous waste usually includes all office waste, canteen waste, as well as all industrial waste such as scrap metal, wooden pallets, offcuts, packaging, construction rubble, waste concrete etc. Much of this waste can be recycled but the rest needs to be disposed of in a properly constructed waste disposal site. Most of the hazardous waste on a construction site comprises tyres, vehicle batteries, fluorescent tubes, oily rags, contaminated soil, chemical containers, solvents and so on. Much of this can be recycled via the original suppliers, but the remaining waste needs to be removed from site to the registered hazardous waste site in Walvis Bay. Issues therefore include the safe storage of these wastes until they are removed from site and the capacity of the Walvis Bay hazardous waste cell to receive such wastes.

At peak construction there will be many different contractors working on site, each of whom will require skilled and unskilled labour. Some contractors may bring their own workforce, while others will hire local labour. At the peak, there may be up to 2,000 workers on the site.

In addition to the main building contractors, there will be need for a range of support services such as banking, legal, accounting, catering, cleaning, office equipment, telephony, computer services, accommodation etc. Most of these services will be sourced from local towns, but national and even international suppliers may be used in the absence of local contractors.

4.6.3 Description of mining and processing activities

4.6.3.1 Mining

In Namibia, both uranium ore types occur on and close to the surface in the central Namib and therefore can be mined from surface as open cast or open pit operations. The hard rock alaskites generally extend to depth and are typically mined in an open pit using drilling and blasting techniques. These pits can become quite large – for example, the current Rössing pit is over 3 km long, 1.2 km wide and about 345 m deep (Plate 4.7) (www.Rössing.com). The alaskite pits are developed *downwards* and will remain as permanent deep holes in the ground surrounded by huge waste rock dumps.

Secondary calcrete-hosted uranium mineralisation tends to occur at shallower depths but over larger areas and requires slightly less drilling and blasting because the surface material can be mechanically excavated in some circumstances. The Langer Heinrich pit for example will only reach a maximum of 30m deep and the Trekkopje pit (Klein Trekkopje deposit) is planned to be 15 km long by 1-3 km wide and up to a maximum of 30 m deep (Turgis Consulting, 2008). The shallower calcrete pits have much less waste rock and can be backfilled with tailings and overburden as the pit proceeds *laterally*. This has significant implications in terms of the total mine footprint, with the calcrete mines having a much larger area of disturbance during operations but with a smaller final footprint.

Plate 4.7: The Rössing pit is about 3 x 1.2 km in size, and 345 m deep. This, and the surrounding waste rock dumps, are permanent features that cannot be rehabilitated to the original landscape. The channel of the Khan River is visible top right (photo P.Tarr).

It can be seen from Figure 4.1 that the alaskite deposits are all aligned in a broad north-east to south-west corridor in the leucogranites associated with the Khan and Swakop Rivers. This zone has been referred to by some as 'Alaskite Alley'. Development of these mines would have significant impacts on both the river valleys in terms of groundwater resources, and visual impacts, since the rugged topography associated with this same geology is a major tourism attraction (see section 7.6).

The secondary deposits on the other hand, are all associated with shallow palaeo- and current drainage lines which traverse the gravel plains to the north and south of the Khan-Swakop drainage system (Figure 4.1). These plains appear featureless, but they in fact support a relatively high biodiversity, including lichens, plants, birds, mammals and reptiles (section 7.7). Of particular significance is the occurrence of the protected, rare and ancient Welwitschia plants in these drainage lines (Plate 4.8).

The typical direct impacts resulting from open pit/cast mining are:

- Noise (blasting, hauling);
- Vibration (blasting);

- Dust (blasting, excavating, loading, hauling, waste rock dumps);
- Radon emissions (blasting, excavating, loading, low grade stockpile);
- Pollution of groundwater (runoff/seepage from waste rock dumps and open pit);
- Visual impact (open pit and waste rock dumps);
- Loss of biodiversity (open pit and waste rock dumps);
- Light.

Noise and vibration are localised and sporadic impacts, but dust, radon, groundwater pollution, loss of biodiversity and visual impact could all contribute to a regional cumulative impact, if not properly controlled through on-site environmental management plans. The visual impact might have an impact on tourism, especially where current tourism activities overlap with existing and proposed mines e.g. Etango (Moon Landscape), Rössing South (Welwitschia Flats), Langer Heinrich (Bloedkoppie) or where several mines may be located in a relatively small area: Rössing, Rössing South, Etango, and Tubas (Figure 4.8).

Plate 4.8: A Namib biodiversity icon, the Welwitschia plant, is found near proposed uranium mines . Etango and Rössing South are likely to have the greatest impact on tourists coming to the Namib to see this plant (photo P.Tarr).

Although Rössing Mine attracts some 2,000 tourists per year (www.Rössing.com) to see the huge open pit, there are few additional opportunities for synergies between mining and tourism, and tourism offsets need to be investigated by each mine where current tourist activities will be affected. This presents an opportunity for future collaboration between mining, tourism and nature conservation to develop and protect new sites of tourist interest.

4.6.3.2 Ore processing

Irrespective of the rock type, the ore has to be crushed to a finer size before the uranium can be extracted. Typically, ore is delivered to the primary crushers from the open pit via haul truck although some mines may place the primary crushers in the pit and haul crushed rock to surface. Crushing circuits usually have several stages (typically up to 4) in which the ore is progressively reduced to a fine particle size. In spite of noise attenuation systems and dust extraction systems, crushers usually have noise, radon and dust impacts. All workers in the crushers have to wear respirators to minimise their exposure to radiation and particulates. These impacts are all localised and do not have regional implications.

4.6.3.3 Ore processing and refining

The other major difference between the alaskite ore bodies and the calcrete deposits lies in the processing method: alaskite ores require acid leaching, while the calcrete ores are extracted using an alkaline leaching process. These processes are briefly described below.

- **Leaching** in closed tanks or in open heaps with sulphuric acid or with sodium bicarbonate;
- **Cycloning and thickening** in tanks to separate the barren solids from the uranium-bearing solution ('pregnant' solution). The solids go to the tailings dam (see section 4.6.3.4 below);
- **Continuous ion exchange (CIX)** where the uranium ions in the pregnant solution are adsorbed onto specially formulated resin beads. The beads are then washed with an acid wash to produce a more concentrated uranium solution;
- **Solvent extraction (SX)** is where the acidic eluate from CIX is mixed with an organic solvent and then a neutral aqueous ammonium sulphate solution;
- **Precipitation** is where gaseous ammonia is added to the solution to raise the pH and thus precipitate the ammonium diuranate which is then thickened and filtered to form a yellow paste called 'yellow cake';
- **Final roasting** drives off the ammonia to leave uranium oxide (U_3O_8), which is packed into metal drums for shipment overseas for further conversion and enrichment before it can be used in power generation facilities.

Several new mines are investigating the possibility of using the 'heap leach' process whereby ore is placed onto a lined pad and acid or alkaline chemicals are sprayed onto the heap and the leachate is then collected from collection systems around the pad. Once the uranium has been leached out, the residue is removed from the pad and discarded on an engineered dump. In addition to the above, other process routes are being considered by Bannerman and Extract Resources as part of their feasibility studies.

4.6.3.4 Mining and process wastes and emissions

The mining and processing plants produce a variety of different waste streams in liquid, solid and gaseous forms. Liquid wastes include sewage effluent, grey water, contaminated runoff from the plant and mine area, process effluents, tailings dam return water and seepage. Most liquid waste can be recycled or re-used and all the mines in the desert environment of the central Namib should have a policy of zero liquid effluent. For example, Rössing has reduced its freshwater requirement per tonne of uranium oxide produced by 46% since 1981 due to continual increases in the use of recycled water through various technological advances.

Solid wastes generated from the mine include waste rock and tailings. The processing plant produces low-grade radioactive tailings or heap leach residues, baghouse dust and a range of hazardous and non-hazardous industrial wastes. Other wastes are generated in the workshops, offices, mine clinic and the canteen.

Several operations on a mine produce gaseous emissions, such as sulphur dioxide from the acid plant (if there is one), and roaster, as well as fumes (CO, CO_2 and NOx) from vehicles, chemical processes in the plant etc. Particulate emissions arise from wind action on unconsolidated surfaces such as the tailings dams, disturbed ground and gravel roads, as well as from vehicle entrainment of dust on gravel roads.

4.6.4 Closure and rehabilitation

On closure, all structural elements will be removed from site, including foundations and concrete plinths. Access roads will be ripped and graded over and all external infrastructure such as pipelines and powerlines will be removed. However, in the case of alaskite mines, the open pit, waste rock dumps, and tailings dam or heap leach residue facility will remain. In this desert environment, surface stabilisation by means of revegetation is a very slow process and therefore the mines must leave these facilities in a safe, stable and non-polluting state. One of the challenges with uranium mines is to minimise the radon exhalation and dust emissions from the tailings dam. This has been done at some mines by covering the surface and sides of the dam with a thick layer of waste rock, but the long-term effectiveness of this needs further research and monitoring.

In the case of the shallow calcrete mine pits, it is possible to backfill the pits with tailings (or heap leach residue) and waste rock as the pit progresses laterally, thus reducing the final footprint considerably.

Irrespective of the closure method employed, it will not be possible to utilise the closed mine sites for any future beneficial use and they will be permanently closed to the public on account of the radiation and safety risks inherent on such sites.

Planned closure of a mine should start during the planning and feasibility stages prior to mine commissioning to ensure that it is implemented in a logical, cost-effective and equitable manner. This includes ongoing planning of waste rock disposal to minimise the visual impact, use of future waste rock sites for the construction camp, ongoing rehabilitation of disturbed areas during construction and so on. Once the mine is in operation, the closure plans need to be regularly updated and the required actions implemented such as the timeous notification of closure to all employees, re-skilling programmes and a planned programme of retrenchment. Production is then progressively scaled down over a period of a year or two prior to actual closure.

In the event of Scenario 4: Boom and Bust, mine closure will be rapid and largely unplanned. Unscrupulous operators or those without a sufficiently large rehabilitation bond will tend to walk away from the operation without undertaking any of the costly rehabilitation work described above. This would leave the mine and process plant in an unsafe and polluting state. Furthermore, the workforce would not be given due warning of closure and retrenchment would be immediate. If all the mines were to close within a short period of time, the government would be left with a huge legacy of pollution and land degradation and the economies of the towns of Swakopmund and Walvis Bay would collapse. It would also mean that some of the industries set up to support the uranium rush (such as the desalination plants, the coal-fired power station at Walvis Bay and the Gecko Chemicals plants) would either have to close down or rapidly find other customers in order to survive. The cumulative effects would be extremely severe.