Plate 7

(A) The computerized Central Process Control operates the metallurgical plant.

(B) Employees inside the Final Product Recovery area wear protective clothing at all times.

(C) An Environmental Officer taking radiation readings in the Final Product Recovery area.

Plate 8

(A) Aerial view of Arandis from the north-west, showing part of the town with typical Namib Desert scenery in the background.

(B) Aerial view of vegetation trial plots on the south-western side of the tailings impoundment.

(C) Seepage line below the tailings dam, with marginal stands of the common reed (*Phragmites australis*).

In 1987, the embankment was extended further to the west and north with the construction of a ring berm that surrounded the western and northern sides of the tailings dam and re-joined the high ground to the north (Figure 3.7). The first stage of the berm was constructed with sand and gravel excavated from nearby areas. The material was laid down with controlled moisture and compaction to form a structure with an upstream slope of 34°, a 6 m wide crest and a downstream slope of 33° at each face.

No under drainage, other than the natural streambed alluvium is provided and the face of the berm on the tailings pond side is covered with a high density polyethylene (HDPE) liner. In 1987 it was envisaged that it would be necessary to raise the elevation of this berm in stages, but a re-design of the tailings disposal method to the paddock method of construction (Figure 3.7) and the slimes cut-off wall constructed across the main pond. For both these reasons, slimes ingress into the main pond is drastically reduced and the current ring berm freeboard is expected to be sufficient for the life of the mine. At the end of November 1988, the tailings impoundment was 582 hectares in area (Grundling *et al.*, 1988).

The total length of the tailings embankment is approximately 7 000 m with a crest elevation varying from about 600 m at the end abutments to 612 m along the southern limb and 624 m along the eastern limb (Robinson & Eivemark, 1987).

3.6.2.2 *Tailings disposal*

Although the tailings produced at the Rössing Uranium Mine contain some fine material, they are still exceptionally coarse by standards in the industry. The typical size distribution of the tailings is shown in Figure 3.8. After washing, the tailings recombined, mixed with Return Dam Solution (RDS) and/or barren solution to a concentration of 50-58% solids by weight and are then pumped to the tailings impoundment (Plate 6).

Three tailings disposal pipelines are used to discharge tailings to the impoundment. Systems 1 and 2 each operate with 450 mm diameter rubber-lined mild steel pipes. Each of these two systems can accommodate the entire volume of tailings produced by the mill. System 1 has a total of 13 operating pumps, capable of transporting the tailings about 3500 m horizontally against a static head of about 65 m. System 2 has a similar number of pumps. Both systems have open-ended discharges. Each system can operate alone, with the second as a standby (Robinson & Eivemark, 1987).

System 3 consists of 350 mm diameter rubber-lined, mild steel pipe, which can accommodate the production of two rod mills, or half the total daily tailings production. This system is used on maintenance days or when the plant is reduced to half normal capacity. System 3 discharges tailings to the eastern area of the tailings impoundment closest to the mill, and operates with only 7 pumps (Robinson & Eivemark, 1987).

Pipeline velocity is maintained at the absolute minimum (Systems 1 and 2 are approximately 2,7 m sec^{-1}), depending on pulp rheology. At such low velocities, control is absolutely critical, but the beneficial effects of reduced evaporation and entrainment of transport solution (lower velocity, therefore less transport solution required), and reduced pipeline wear (i.e. increased life) are significant.

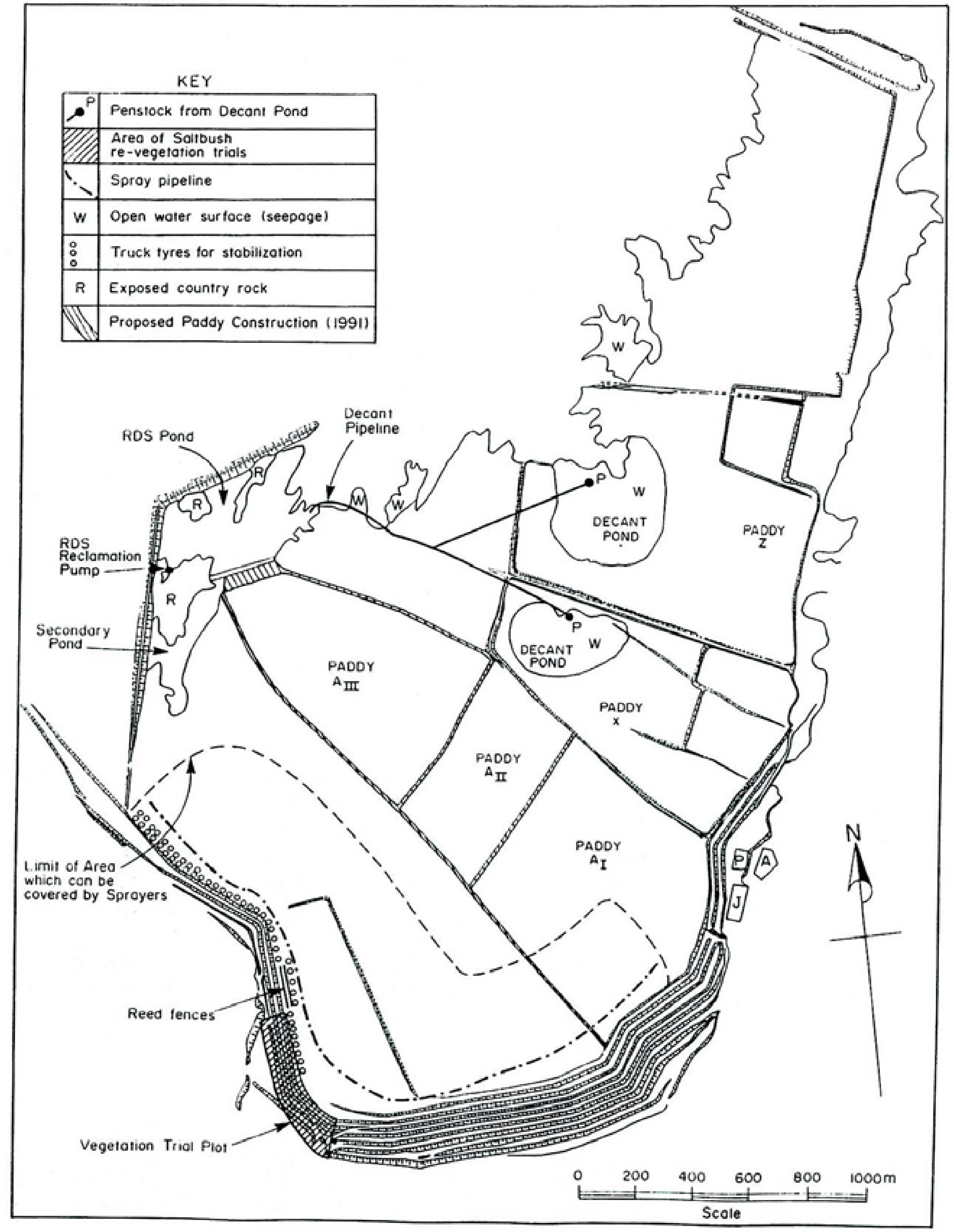

Figure 3.7: Plan of the Rössing Uranium Mine tailings dam showing the main construction features, positions of paddocks, decant ponds, lakes Andrew (A), Jeff (J) and Preg (P), and dust suppressing measures. The proposed layout of Paddy A is shown as at October 1990. (Drawn from information supplied by C. Brent).

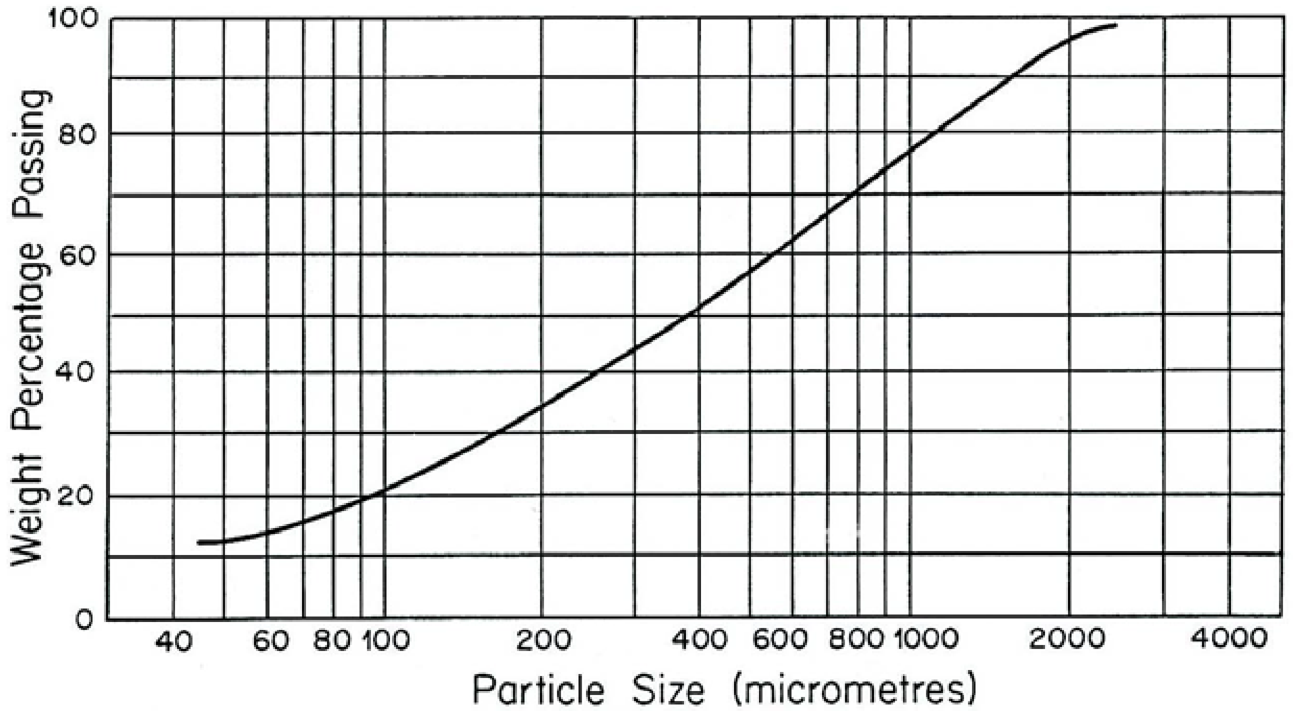

Figure 3.8: Typical distribution of grain sizes shown by tailings at Rössing Uranium Mine; (Drawn from information supplied by M.T.R. Smit, 1990).

Originally discharge was continued at each location until the build-up of tailings almost dams the runoff to the pond. The disposal point was then shifted and the drained tailings bull-dozed into a one metre raise of the embankment. The tailings pipeline was then moved on top of the raise and the process repeated until a full bench height of 6 m achieved. Typical construction time for a 200 m length of 6 m high bench was in the order of 3 months (Robinson & Eivemark, 1987).

Since 1989, the construction method has changed to the paddock method. Essentially, this comprises of building small dams inside the big dam on a cyclical basis. The effects are the creation of one or two small inner clear solution ponds in the impoundment from where the liquid gravitates to the main pond, and smaller wetted beach areas. This has resulted in significant decreases in evaporation and entrainment losses and a consequent decrease in freshwater consumption. A plan view of the Rössing Uranium Mine tailings impoundment as at August 1990 is shown in Figure 3.7, while a typical east-west profile is shown in Figure 3.9.

3.6.2.3 *Tailings pond management*

Seepage from the tailings impoundment occurs through the embankment and through the foundation materials (Plate 8). Earlier studies (Dames & Moore, 1981, 1982a, 1982b, 1984b, 1985; Knight, Dames & Moore, 1987b) have indicated that in addition to seepage into Pinnacle Gorge, a significant quantity of water also escapes into Panner Gorge. The details of seepage control are described in Section 3.6.2.4.

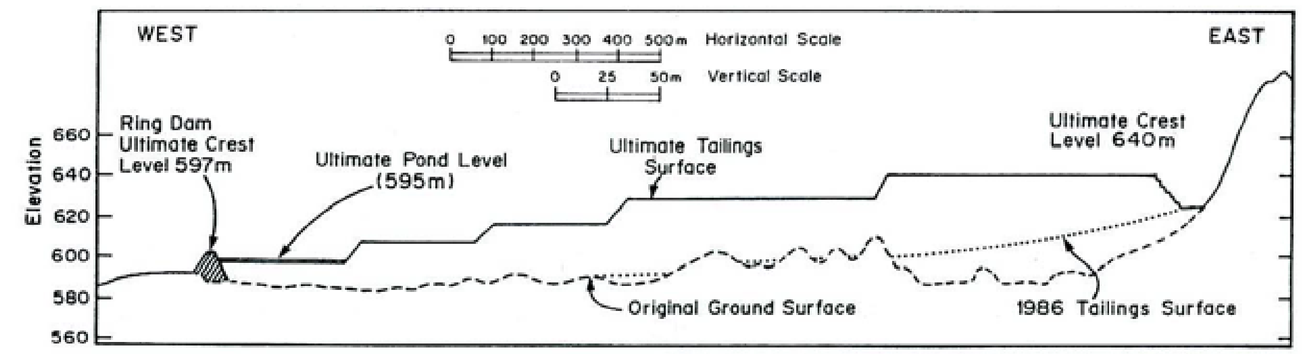

Figure 3.9: Typical east-west profile of the tailings impoundment at Rössing Uranium Mine; (Drawn from data provided by C. Brent in September 1990).

Control of the water level in the tailings pond is achieved by the Return Dam Solution (RDS) recycle, which allows extra uranium to be extracted from the liquid in the tailings pond (Section 3.5.2.2). The acidity of the tailings pond water in contact with the tailings leaches a small amount of residual uranium from the tailings, holding this in solution in the pond water. The leached uranium is extracted by passing tailings water through the RDS plant (Robinson & Eivemark, 1987). The tailings water, (known as RDS solution), is pumped from the tailings pond at up to 19 000 m^3 day^{-1} through one 400 mm diameter HDPE pipeline located around the perimeter of the tailings dam. Barren solution from the RDS process is used for tailings transportation and for flushing the tailings pipelines (Robinson & Eivemark, 1987). A portion of the RDS solution (ca. 9 000 m^3 day^{-1}) bypasses the RDS plant and is added to the rodmills instead of fresh water.

Closure of the western and northern berm walls in 1987 was designed to prevent further northward migration of the tailings pond up the alluvial valleys where seepage would be excessive. Localization of the tailings pond assists in controlling the location and size of the pond and also promotes a reduction of seepage by sealing off the foundation material through settling of slimes into the alluvium and fractured rock surface below the pond (Robinson & Eivemark, 1987). Any reduction in the area of the pond surface reduces evaporative losses and contributes to significant water savings (Kesler, 1987).

3.6.2.4 *Seepage control measures*

Seepage control systems are based on tailings pond management and the interception and recovery of seepage in the valleys downstream from the tailings impoundment (IAEA, 1981; Vernon, 1981; Robinson & Eivemark, 1987; Robertson *et al.*, 1987). The waste rock starter dam for the tailings impoundment acts as a toe drain and effectively controls the level of the phreatic surface within the dam. Great care is taken to ensure that the phreatic surface never rises above the toe of the Tailings Impoundment since this could lead to the dangerous situation where the wall of the Tailings Impoundment would collapse. Seepage from the tailings impoundment is focused down two small valleys and collects in the Seepage Dam (Figures 3.10 and 3.11). Downstream of the seepage dam a cut-off trench extends through the alluvium sediments to bedrock. Water from this cut-off trench is pumped to the Seepage Dam.

3.6.2.4.1 Seepage dam

The Seepage Dam is an earth-fill structure, 110 m long and 20 m high at maximum section. The upstream slope of the dam is faced with a synthetic liner covered with soil for protection. A cutoff trench extends through the alluvial sediments beneath the dam to bedrock. Water collected behind the Seepage Dam is pumped to the Seepage Dam. From the Seepage Dam, seepage is returned to a holding pond at the plant site. From the holding pond, the recycled seepage is distributed to the rodmills and the gland seals on the tailings pumps, and is also used for mixing with tailings slurry and for washdown (Robinson & Eivemark, 1987).

In addition to seepage collected along Pinnacle Gorge, the Seepage Dam also receives water pumped from the mine pond near the open pit (Figure 3.10) and part of the discharge from the dewatering wells located at the head of Panner Gorge (Robinson & Eivemark, 1987).

3.6.2.4.2 Cutoff trenches

A number of cutoff trenches have been excavated across major seepage paths (Figure 3.10). In 8 locations, cutoff trenches have been excavated through the alluvium and blasted into bedrock to create collection sumps for intercepting seepage. These seepage collection trenches are identified in Table 3.1. Each trench is equipped with a collection tank and transfer pump to facilitate recycling of the intercepted seepage (Robinson & Eivemark, 1987).

The trenches closest to the tailings impoundment have been located to intercept seepage through the alluvial sediments lining the valley bottoms. Those trenches at greater distances from the tailings impoundment intercept seepage which has travelled through the deeper, fractured bedrock units before emerging into the drainage gorges, along with any seepage which may bypass the upper trenches (Robinson & Eivemark, 1987).

TABLE 3.1: Locations and characteristics of cutoff trenches at Rössing Uranium Mine; (after Robinson & Eivemark, 1987). (Data on discharge volumes supplied by Mr P. Marais).

Trench	Distance from Tailings (m)	Recent Rate of Discharge (m^3 day^{-1})	Destination of Discharge
1. Upper Panner Drain	500	280-300	Seepage Dam
2. Lower Panner #1	5300		
3. Lower Panner #2	5800	225	Mine Pond
4. Upper Pinnacle Gorge	1700	280-300	Seepage Dam
5. Lower Pinnacle #1	5200		
6. Lower Pinnacle #2	5700	60	Mine Pond
7. Boulder Gorge	1500	160	Mine Pond
8. Dome Gorge	1500	160	Irrigation

3.6.2.4.3 Dewatering wells

Rössing Uranium Mine has designed its seepage interception network of wells around boreholes having a minimum yield of 0.5 m^3 hr^{-1}. The main well field is located near the western end of the

southern limb of the tailings dam (Figure 3.10). This well field, near the head of Panner Gorge, consists of 26 wells each 0.2 m in diameter and with depths varying between 20 and 100 m. The majority of the productive wells are developed in the Rössing marbles, which form the main aquifer. Each well is fitted with a pump equipped with an automatic shut-off valve. The discharge from the wells is pumped to the Seepage Dam at a cumulative rate of about 800 m^3 day^{-1} (Robinson & Eivemark, 1987).

3.6.2.4.4 Monitoring programme

Seepage flows and groundwater quality are monitored regularly as part of the environmental control activities conducted by the Rössing Uranium Mine. This monitoring programme also forms an important component of the conditions laid down by the Namibian Department of Water Affairs in Rössing's permits for water abstraction and use on the mine property. The Department of Water Affairs monitor the quality of groundwater in the region at random intervals and also obtain monthly returns from Rössing, listing the results of chemical analyses of groundwater samples. Since 1979, the numerous wells and cutoff trenches around the mine property are sampled on a regular basis to test for SO_4, Cl, F, U, pH, TDS and other indicators of seepage water. The results obtained to date have been used to assist in the evaluation of the hydrogeological properties of the alluvium and rock formations of the site (Robinson & Eivemark, 1987).

Because of the chloride background levels in the natural groundwater of the area, and the neutralizing effects of the limestone tailings and marble bedrock formations, a SO_4/Cl ratio has been found to be a key indicator of seepage water at monitoring locations. Based on the use of key indicators, a computer programme (designated TARGET) has been developed to evaluate groundwater and seepage flows in the area and to provide an accurate means to establish average hydraulic properties of the various formations (Robinson & Eivemark, 1987). In addition, the neutralizing or buffering effect of the formations on the radioactive and acid tailings water as it seeps through the aquifers has been established. Details of these impacts are described in Section 4. The TARGET programme has also been used to predict future groundwater movements, evaluate the suitability of additional seepage control measures, and predict if, and when, different levels of particular chemical components will reach various positions within the local groundwater regime (Robinson & Eivemark, 1987). In addition, the TARGET programme has facilitated predictions of the likely effects of mine closure and reclamation measures.

The monitoring programme has shown that the Seepage Dam retains about 80 % of the total seepage from the tailings impoundment. An additional 5 % is collected in the wells and collection trenches of Panner Gorge, 4 % is collected in the Dome/Boulder Gorge system, 6 % is collected below the dam in the Pinnacle Gorge system and up to 5 % bypasses the seepage collection system. Estimates of the total daily seepage loss (approximately 300 m^3) are difficult to refine since total water volumes are in the order of 45 000 m^3 day^{-1} (Robinson & Eivemark, 1987).

Nevertheless, the monitoring programme has shown that contaminated seepage water is either collected or neutralized by the time it passes the collection system and reaches the Khan River It is also apparent that the pump-back system is so efficient that some flow-through groundwater is also collected, slightly lowering the level of the regional groundwater table. It is therefore possible that the actual quantity of contaminated seepage water that bypasses the collection system is lower than the estimate of 300 m^3 day^{-1}. Estimates of the time taken by the pollution front to reach particular monitoring positions has allowed the gross average permeabilities of the different alluvium and bedrock formations to be determined (Table 3.2).

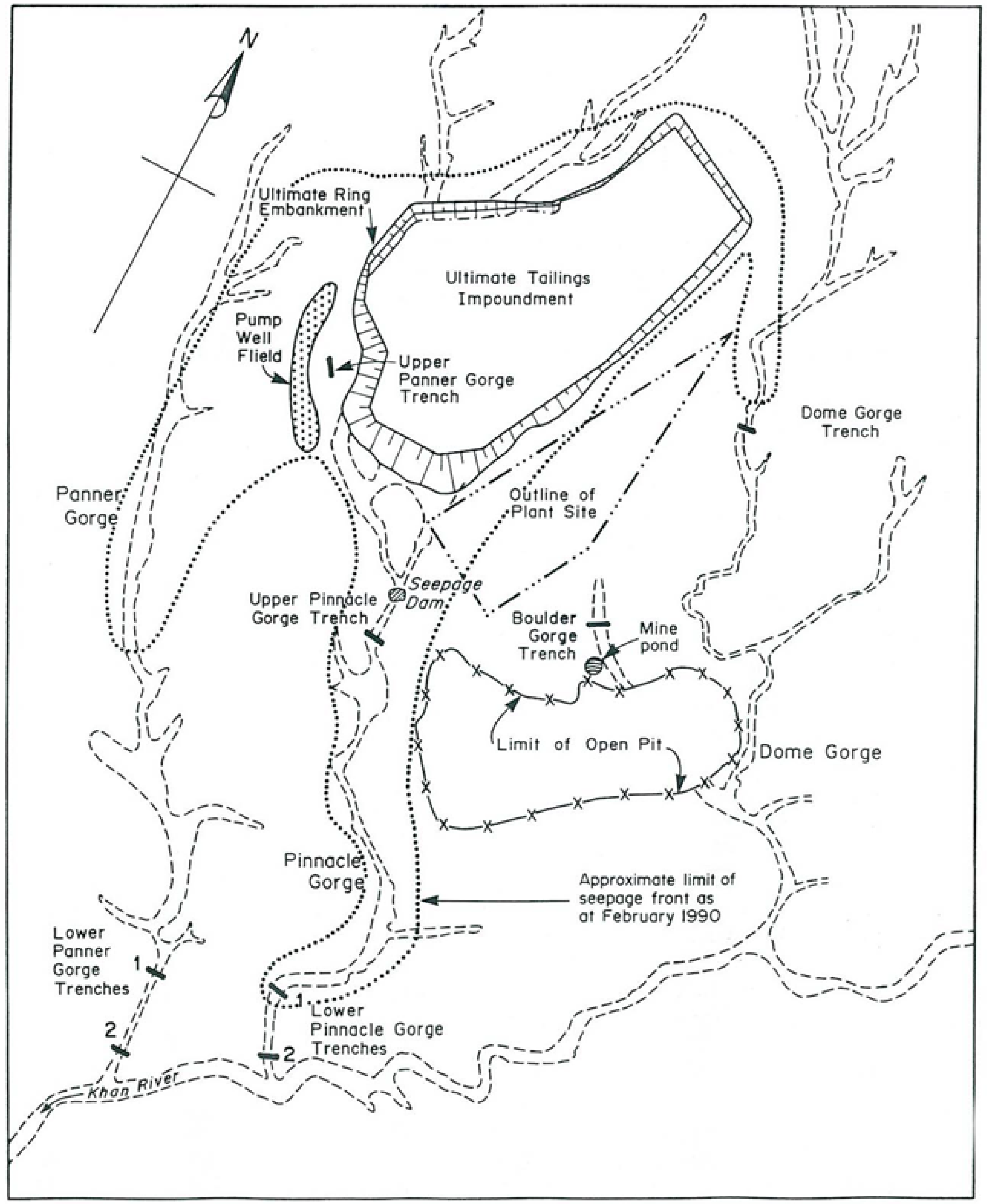

Figure 3.10: Diagrammatic map of the seepage control systems at Rössing Uranium Mine; (redrawn from Robinson & Eivemark, 1987). The approximate position of the seepage fronts as at February 1990 are also indicated (information supplied by C. Brent and P. Marais).

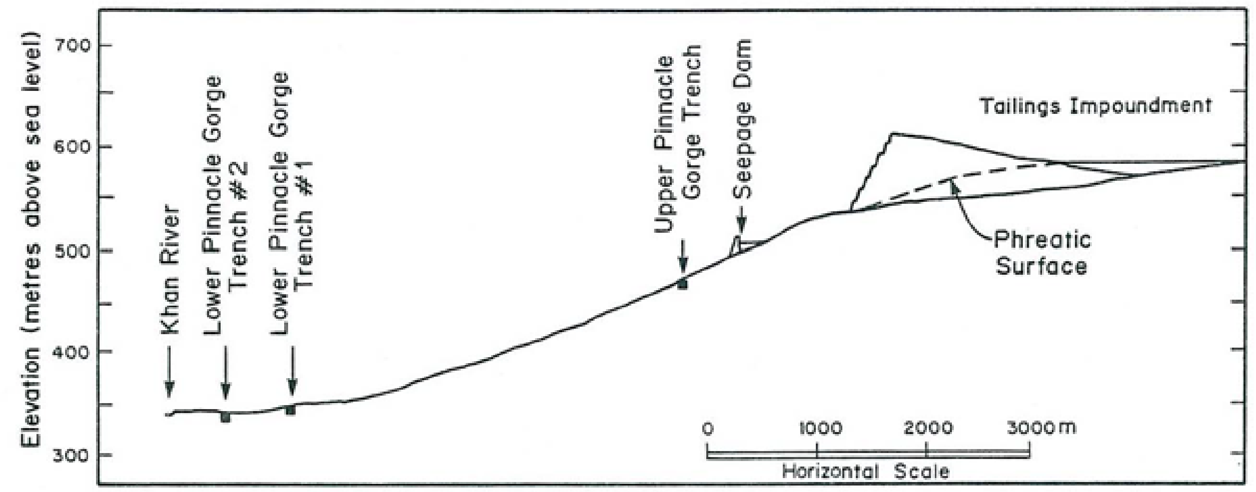

Figure 3.11: Longitudinal profile along Pinnacle Gorge, showing the positions of the Seepage Dam and cutoff trenches in relation to the tailings impoundment; (redrawn from Robinson & Eivemark, 1987).

TABLE 3.2: Average permeability values of different alluvium and rock formations; (after Robinson & Eivemark, 1987).

Formation	Permeability (cm sec^{-1})
Tailings Slimes	10^{-5}
Coarse Tailings	10^{-3} to 10^{-4}
Alluvial Soils	5×10^{-2}
Rössing Marbles	2×10^{-3}
Intrusive Alaskites	9×10^{-5}
Unfractured Rock	10^{-7}

3.6.3 Control of Dust and Radiation Emissions

The other major monitoring activities associated with the disposal of tailings at Rössing Uranium Mine focus on the movement of dust, radon gas and radiation into the atmosphere.

3.6.3.1 *Quantifying dust and radiation emissions*

About 85 % of the total radioactivity of the ore ends up in the tailings impoundment, with the uranium daughter elements thorium-230, radium-226, radon-222 and lead-210 being the most important (Dames & Moore, 1984b; Kesler, 1987). Both thorium-230 and radium-226 have very long half-lives while radon-222 and is daughter products are potential hazards through inhalation. Radon emanation rates for the tailings impoundment average 0,8 Bq m^{-2} sec^{-1} (Strydom *et al.*, 1988), compared with an average background value of 0.02 Bq m^{-2} sec^{-1}. The principal decay modes of uranium-238 and the half-lives of the daughter products are shown in Table 3.3.

Routine monitoring for dust and radioactivity is conducted at a series of fixed collectors located within the mine property and in the town of Arandis to the north-west of the Rössing Uranium Mine. Most of the dust and radioactivity measured near the mine is derived from the tailings impoundment, with additional amounts derived from the open pit, waste rock and ore dumps and the ore processing facilities (Dames & Moore, 1984a; 1984b). In contrast, the dust measured in Arandis is derived from the open desert, whilst the radioactivity is mostly from rocks in and around the town; only a small proportion is derived from the mining operation (de Beer, 1990).

As part of Rössing's environmental health and safety monitoring programme, additional monitoring of respirable dust and radioactivity is carried out regularly (Plate 7), with the high risk areas being monitored on a weekly basis and other areas less frequently. This monitoring is designed to determine the levels of exposure experienced by Rössing employees and to ensure the safety of all working conditions (Swiegers & Jooste, 1987). The details of the environmental health and safety monitoring programme are given in Section 3.9.

TABLE 3.3: Uranium-238 principal decay modes and the half-lives and energy emissions of the daughter products; (after Dames & Moore (1984b)).

Radionuclides	Half-Life*	Alpha Engergy (MeV)	Beta Energy (MeV)	Gamma Energy (MeV)
Uranium-238	4.5 x 10^9 y	4.20	0.19	0.09
Thorium-234	24.1 d	-	1.32	1.00
Protactinium-234	6.7 h	-	1.13	-
Uranium-234	2.47 x 10^5 y	4.77	-	0.05
Thorium-230	8.0 x 10^4 y	4.68	-	0.07
Radium-226	1.62 x 10^3 y	4.78	-	0.19
Radon-222	3.82 d	5.49	-	0.51
Polonium-218	3.05 m	6.00	-	-
Astatine-218	1.5 - 2.0 s	6.63	-	-
Lead-214	26.8 m	-	1.03	0.35
Bismuth-214	19.7 m	5.45	3.26	0.61
Polonium-214	1.6 x 10^{-4} s	7.69	-	0.80
Thallium-210	1.32 m	-	1.90	0.80
Lead-210	22 y	3.72	0.06	0.05
Bismuth-210	5 d	4.65	1.16	-
Polonium-210	138 d	5.31	-	0.80
Thallium-206	4.2 m	-	1.15	-
Lead-206	Stable	-	-	-

*: y = years; d = days; h = hours; m = minutes; s = seconds.

3.6.3.2 *Control measures*

In the open pit, water is used to control dust during operations and so ensure that employees are not exposed to safety and health hazards. Large volumes of water are collected for daily spraying onto roads, the exposed rock faces and rock piles. The optimum daily quantity of water required to maintain satisfactory environmental conditions is approximately 2500 m^3 day^{-1}. The water used

consists mainly of brack water pumped from the Khan River bed and de-greased washdown water from the mine workshops and garages, plus a small quantity of effluent from the activated sludge sewage treatment plant.

In addition to the open pit, dust suppression is also carried out continuously at transfer points in the crushing circuit by confinement and exhaust ventilation. Where necessary, overhead sprayers are used to spray crushed ore with recycled seepage water. Employees working in dusty areas are provided with air-conditioned vehicle cabins or personal respirators.

The strong east winds appear to be the main cause of dust dispersion from the tailings impoundment. Several experiments have been conducted to evaluate a variety of different techniques for short- and medium-term control of dust and radon emission from the tailings. Growth trials with different species of plants (Plate 8) met with little success due to the high water requirements of most species. The single exception was salt-bush, which responded well to irrigation with saline seepage water. However, it is unlikely that vegetation planted on the tailings impoundment will survive in the long term (Kesler, 1987).

Promising results have been obtained with chemical stabilizing sprays and the deposition of an alluvium cover. Chemical sprays only provide a relatively short-term protection against wind-erosion while an alluvium cover of 150 mm reduces dust dispersion and attenuates radon emissions by approximately 50 % (Kesler, 1987). Further investigations of different depths of alluvium cover are required if this technique is to be implemented successfully.

3.7 Infrastructure

The establishment and operation of any mine in a desert environment presents the developer with unique problems. The environmental extremes and enormous scale of operations at the Rössing Uranium Mine, coupled with the great distances between towns, has emphasized the vital importance of sound infrastructure. The location of the major infrastructure components at the Rössing Uranium Mine is shown in Figure 3.1.

3.7.1 Water Supplies

The virtual absence of surface waters in the vicinity of Rössing, coupled with the saline nature of underground water supplies, accentuated the need to provide the mine with an assured supply of good quality water. This led to the extension of the Central Namib State Water Scheme (Section 2.7.3) and the construction of a 65 km long pipeline to supply water from Swakopmund (Figure 2.6). This pipeline is mounted on trestles for ease of access and maintenance, and is equipped with three booster pumping stations between Swakopmund and the main water reservoir at the mine. The pipeline is located a short distance to the south of the main Swakopmund - Usakos road and is visible from the road for most of its length.

Freshwater consumption at the mine has varied considerably since the start of mining operations. A detailed water balance as at January 1989 is shown in Figure 3.12. Concerted efforts to reduce water consumption through improved layout and operation of the tailings dam, plus increased usage of recycled seepage and tailings water, has had a profound impact on total water consumption at Rössing. Freshwater usage at the mine dropped from 0.67 m^3 per tonne of milled ore in 1980 to 0.36 m^3 per tonne in 1985, effectively reducing total water consumption from 30 000 m^3 day^{-1} to 12 000 m^3 day^{-1} (Figure 3.13).

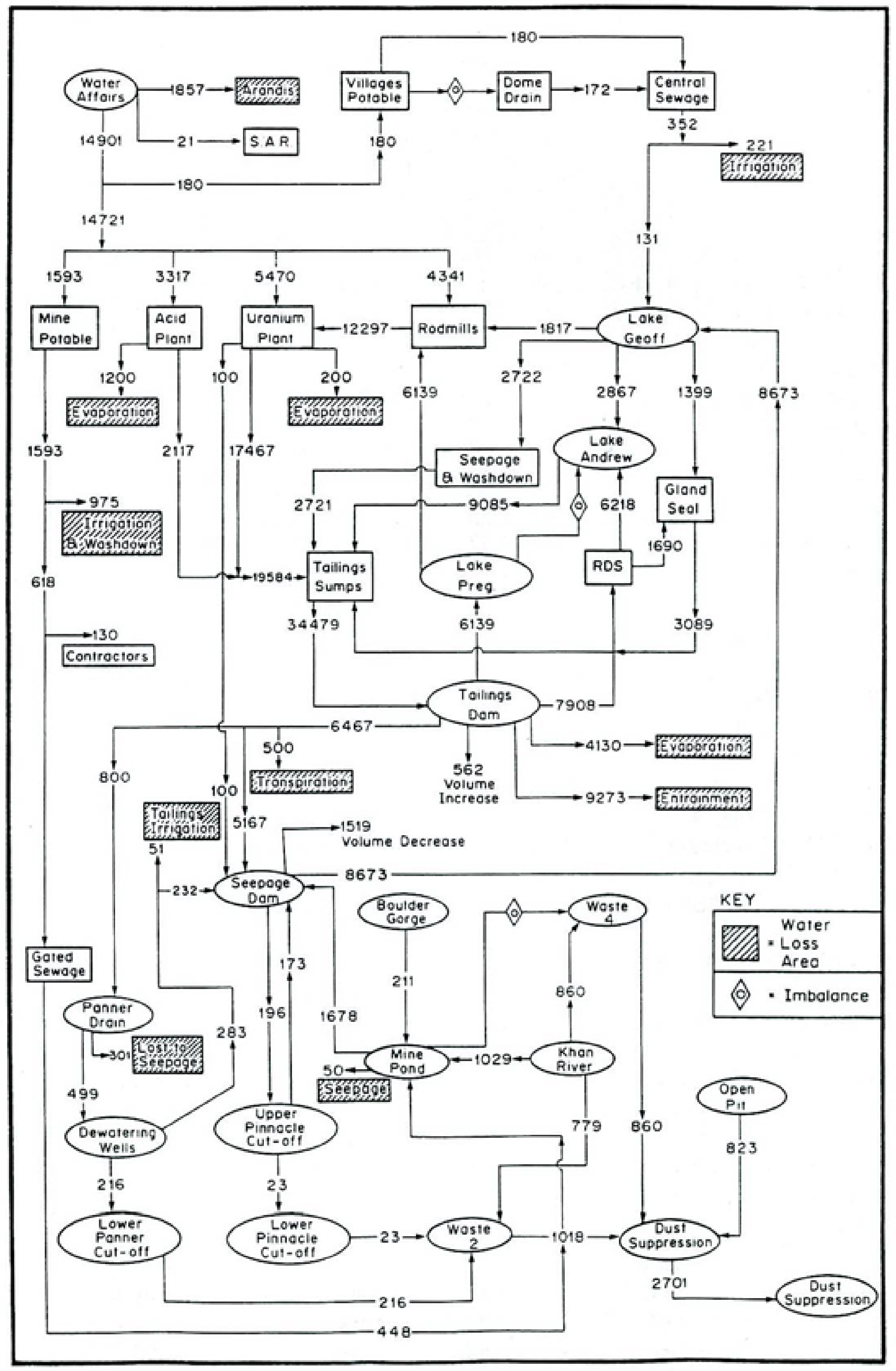

Figure 3.12: Detailed water balance for the Rössing Uranium Mine as at January 1990; all values are in cubic metres per day, important areas of water loss are shaded. (Drawn from data supplied by C. Brent, 1990).

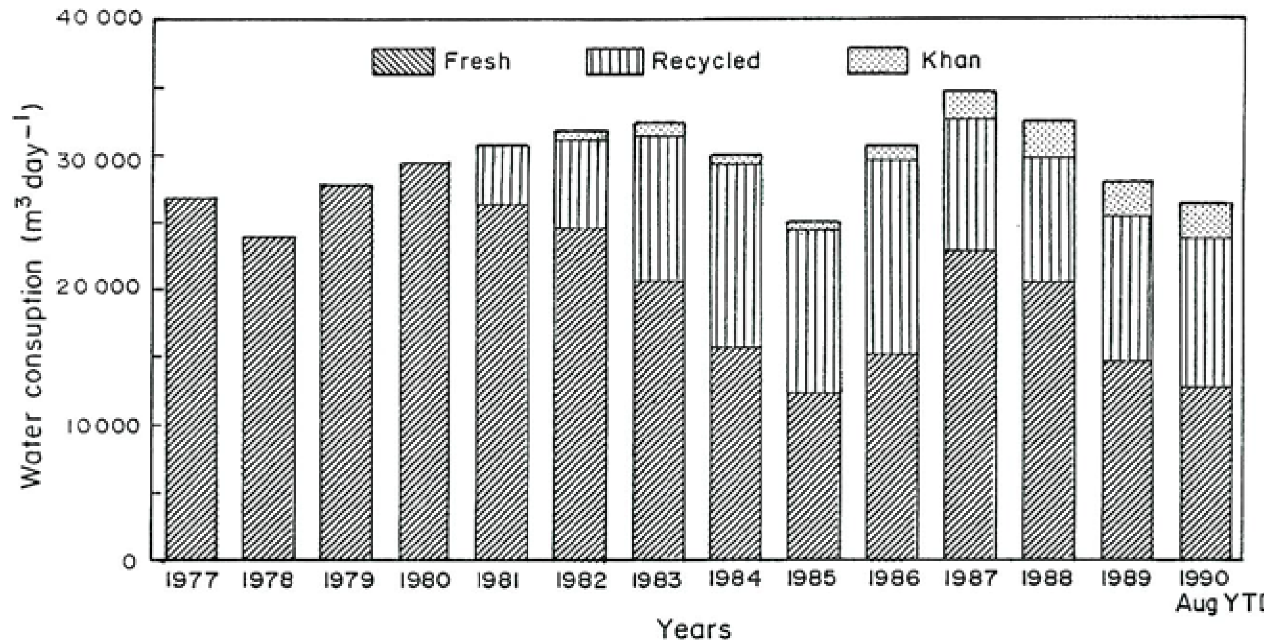

Figure 3.13: Total water consumption at the Rössing Uranium Mine (excluding Arandis) for the period 1977 to 1990, showing quantities of freshwater, recycled water and water pumped from the bed of the Khan River. All values are in cubic metres per day. (Drawn from data provided by C. Brent and P. Marais).

However, since 1985, it became evident that excessive recycling of water introduced several deleterious effects, including ionic competition within the continuous ion exchange plant. The need to optimize uranium extraction and maintain pumping velocities led to a slight reduction in the quantity of water recycled and an increase in freshwater usage (Kesler, 1987; Figure 3.13).

At present (August, 1990), Rössing obtains approximately 12 500 m^3 of freshwater per day from the pipeline, while up to a further 3 000 m^3 per day of saline water is pumped from the bed of the Khan River in terms of an extraction permit issued by the Department of Water Affairs (Robertson & McPhail, 1989).

3.7.2 Power Supply

3.7.2.1 *Rössing mine*

Electrical power is supplied to the Rössing Uranium Mine via a single circuit 220 kV overhead transmission line from a SWAWEK switching station at Omburu, some 250 km to the north east. At Rössing, SWAWEK have installed a switching sub-station which serves as a power distribution point for Rössing Mine and the nearby town of Arandis, before power supplies are fed to the coastal towns of Swakopmund, Walvis Bay and Henties Bay.

The supply to Rössing is stepped down to 11 kV and cabled to the Rössing main sub-station. From this sub-station power is distributed to all areas of the mine via overhead transmission lines or underground cables. In total, 47 km of overhead cables and 26.5 km of underground cables have been installed at the Rössing Mine. The maximum power demand of Rössing Mine averages 38 MW and power consumption 21 million kWhrs per month.

The open pit area is served by two 11 kV transmission lines via a sub-station which also distributes to the primary crusher, mine workshops and service yards. An 11 kV ring feed around the open pit perimeter serves the shovels and drill rigs. A separate 22 kV overhead transmission line is provided for trolley assist operations in the open pit. Step-up and step-down transformers are utilized at each end to limit the voltage drop on the transmission line.

Power for the coarse ore conveyer and the compressor house is supplied from the overhead line serving the open pit area. A separate sub-station distributes power to the HEF plant and the ammonium nitrate store via underground cables. Electrical power for the secondary crushers, leaching plant, boiler plant, acid plant and the ion exchange plant is supplied by underground cable. The tailings pump stations are served by two 11 kV overhead transmission lines. A sub-station located at tailings station 5 distributes power via an overhead line to pump stations 6, 8 and 9. From pump station 6 there are two overhead transmission lines, the first one serves the borehole pumps at seepage control while the second line serves the Return Dam Solution pumps. The tailings plant thickeners are served by two electrical circuits, each supplied by two underground cables. An 11 kV switching sub-station located near the tailings area supplies the rotoscoops, thickeners and tailings pumps.

In addition, four 1.7 MW diesel-driven emergency generators have been installed in an area adjacent to the main Rössing switching sub-station. These machines supply emergency power in the event of a power failure to the leaching plant, boiler plant and acid plant.

3.7.2.2 *Arandis township*

Power is supplied to the town of Arandis via a 22 kV overhead transmission line from the Rössing sub-station. This sub-station consists of 11 incoming lines and two outgoing circuits; a switching sub-station controls the protection of the transformer and associated equipment. The maximum power demand of Arandis averages 1800 kW.

The power reticulation system within Arandis consists of an 11 kV underground cable laid out in a ring system with seventeen 350 KVA mini-sub-stations connected within the ring. These sub-stations provide 380 volt 3 phase power which is cabled to metering kiosks before distribution to individual households. The 11 kV underground cable is buried at a depth of 1 m and has a total length of 8 kilometres.

In addition to their electricity supply, all houses in the town of Arandis are equipped with solar-powered water heaters.

3.7.3 Transportation

Efficient and reliable transportation systems are vital components of the infrastructure. Namibia is fortunate that there is a well-developed transport network with excellent roads, extensive rail links and both commercial and private air services through most of the country.

3.7.3.1 *Roads*

Namibia possesses more kilometres of roads per person than any other country in Africa. Major centres are linked by double-width tarred roads while secondary roads in the farming areas are graded and surfaced with gravel. At the coast, the so-called "salt roads", which consist of a mixture of kaolin clay and sea salt, are graded and rolled to provide a firm surface similar to that of a macadamized road.

The main Swakopmund - Usakos road passes within 6 km of the Rössing Uranium Mine (Figure 3.1). This double-width tarred road greatly facilitated both the initial exploration and development phases of the mine. An additional double- width tarred road has been constructed between the nearby town of Arandis and the mine, providing convenient access to the site. A total of some 30 km of additional untarred roads have been constructed between various points on the mine property and mining grant to allow access. The on-site tarring programme has macadamized all heavily-used roads around the periphery of the open pit and the processing plant. All untarred roads in and near the open pit are sprayed with brack water each day to reduce dust levels.

3.7.3.2 *Railways*

A single track, standard gauge railway line links the town of Swakopmund with Usakos, Karibib, Okahandja and Windhoek, passing within 8 km of the Rössing Uranium Mine. This railway system is operated by the Namibian National Transport Corporation Limited and, since 1988, has been independent of the South African Transport Services which was previously responsible for the operation of railway services. For much of its length between Swakopmund and Rössing, the railway line is located near to the main tarred road. Sidings are located at several points along this line, the nearest being at Arandis. Regular passenger and goods trains travel between Swakopmund, Walvis Bay and Windhoek, providing a vital transport link.

A separate spur line has been laid from Arandis to the Rössing Uranium Mine. Special ore trains bring in pyrite for the Rössing acid plant from the Otjihase Mine near Windhoek. Goods trains also bring in machinery and equipment to the mine and transport sealed containers of the final product (U_3O_8) to Walvis Bay harbour for loading onto cargo container ships and dispatch overseas.

3.7.3.3 *Air transport*

A 2500 metre long all-weather airstrip with a single aircraft hanger and fuel storage facilities has been laid out on the flat area approximately 3 km to the west of the tailings dam (Figure 3.1). This air-strip provides convenient access to the mine for company personnel who commute between the mine and Windhoek on routine flights in company aircraft.

The coastal town of Swakopmund has a 3000 metre long, unsurfaced air-strip, located some 4 km to the north-east of the town. This air-strip is used regularly by commercial, charter and private aircraft, flying between the coastal towns, isolated mining communities and the interior of the country. A regular commercial air service (Namib Air) links Swakopmund with other major centres.

3.7.4 Sewage and Refuse Disposal

All sewage from the exploration and construction camps was treated in septic tanks which drained into

Panner and Dome Gorges, respectively. During the later construction phase, a conventional activated sludge sewage treatment plant with a capacity of 750 m^3 day^{-1} was built to treat the sewage from the construction workforce. This treatment plant, one of four currently operated by Rössing, is located some 600 m east of the main road entering the mine, and is now known as the central sewage plant. All four sewage treatment plants are operated in strict accordance with permit specifications laid down by the Namibian Department of Water Affairs.

The second plant, the Satec Hudamech, with a capacity of 800 m^3 day^{-1}, is located immediately to the west of the mine pond and serves the open pit and geological personnel. The Arandis Orbal plant, situated approximately 1 kilometre south-west of the town and having a capacity of 1230 m^3 day^{-1}, serves the town of Arandis. The final effluent is used to irrigate the vegetable farm, trees, sportsfields and parks in Arandis. Some effluent is, however, sent to the oxidation pond. The fourth plant is situated at the Rössing Country Club. This plant is situated in the nursery area and has a capacity of 110 m^3 day^{-1}. All four of the sewage treatment plants run on the activated sludge principle, with aeration, clarification and final effluent chlorination.

All sludge is dried in drying beds, stockpiled and buried; a small amount being used as a fertilizer in the mine gardens. The final effluent from the treatment plant located on the mine premises is used in dust control on road surfaces and any small amount of excess is drained into Dome Gorge.

Domestic refuse is collected each week and incinerated or dumped in the waste rock dumps.

3.7.5 Industrial Refuse

Refuse generated during the exploration and construction phases consisted of both domestic and industrial refuse. All refuse and waste or disused building materials were removed from the sites by truck or buried under rock and sand as filler material. This practice is still continued, approximately 13 000 m^3 of industrial rubbish are dumped per year at the Rössing Uranium Mine. This rubbish is collected weekly and transported to an active waste rock dump and buried. Old engine oil is purified and re-used on site.

3.7.6 Communications

In a country that is as sparsely populated as Namibia, it is essential that communications systems within the country are of a high standard. The Rössing Uranium Mine is linked to the National telecommunications network, consisting primarily of telephone and telex links to all parts of Namibia as well as over 50 foreign countries.

A regular postal delivery service is also available; where airmail services are not possible, this is provided by road and rail transport. Multilingual radio programmes broadcast by the Namibian Broadcasting Corporation via short-wave and the National FM network, as well as single-channel local television programmes, can be received in Arandis and Swakopmund.

3.7.7 Accommodation

The provision of adequate accommodation and amenities for a large number of employees in a desert environment presented the mine's developers with several difficulties. Nevertheless, Rössing management have successfully faced this challenge in a remarkably short space of time.

3.7.7.1 *Construction workforce*

The initial exploration teams stayed in tents in Panner Gorge to the south-west of the ore body for the first six months, after which the exploration camp was built. This consisted of prefabricated rooms on concrete floors, together with an ablution block, kitchen, dining room, lounge, laundry and snooker room. This was occupied by single people whilst married staff were transported between Swakopmund and the site by bus. Construction workers, as well as the mining and drilling crews, all stayed on their respective work sites.

In 1974, the construction campsite was built to the north of the present-day tailings impoundment to house construction workers from the various companies involved in the construction of the uranium plant and the acid plant. Initially, three camps, (A, B and C) were constructed; these were followed by two more (Camps D and E) and a private camp (Cementation), situated to the west of the tailings impoundment. The first three camps and Cementation were later demolished and D and E camps were re-named Rossec and Namib Lodges; both of these are still in existence (information supplied by W.A. Woxholt).

3.7.7.2 *Permanent workforce*

One of Rössing's objectives has been to offer every permanent employee the chance to bring his family to live in one of the comfortable residential areas provided by the mine. At the end of 1984, the mine had provided houses for 1546 families and single quarters for 573 people. Rössing has three housing areas in which homes are allocated according to the grade of the employee, namely: Arandis, Tamariskia and Vineta.

The town of Arandis was built some 10 km to the north west of the mine (Figure 3.1; Plate 8) to accommodate Rössing's less skilled workers. Construction started from scratch in 1975 and by 1989 the town covered an area of 135 hectares, comprising 900 family units and 9 quarters for single employees, with a total population of 6500. Houses in Arandis are of a high standard, provided with solar hot water systems, electricity and water-borne sewage. Each family unit is equipped with 2-3 bedrooms, a bathroom complex, kitchen and a central living room with dining area. Several of the newer houses have garages. Single-quarter units consist of 24 to 30 single rooms with a communal lounge. Employees are transported to and from the mine each day by bus.

In Swakopmund, Rössing built 500 company houses in the suburb of Vineta and a further 246 houses in the suburb of Tamariskia. Both suburbs are located in the northern part of town, close to all the amenities, and house employees in the higher semi-skilled, skilled, professional and managerial grades. These company houses are provided at a nominal rental to employees. Further housing construction is planned to accommodate those employees who have not yet taken advantage of the company's housing scheme.

Most of the higher grade single employees live in the sociable, college-type accommodation of Single Quarters, while a few have opted to rent their own accommodation in Swakopmund and even in Walvis Bay. In the early stages of development at Rössing, many employees were housed in caravans at Mile 4 to the north of Swakopmund, or in mobile Park Homes at the newly developed Country Club some 15 km outside Swakopmund on the Usakos road. All mine employees housed in Swakopmund are transported to and from the mine by bus, or commute in private transport.

3.7.7.3 *Contractors*

Contractors who undertake short- to medium-term projects at Rössing Mine are housed in well-equipped single quarters at Rossec Lodge or Namib Lodge. These two sets of accommodation are located approximately 2 km to the north of the main mine buildings (Figure 3.1). Both lodges have full mess facilities and some recreational amenities.

3.7.8 Social Amenities and Recreational Facilities

3.7.8.1 *Arandis*

After the initial construction of houses in Arandis, a community development programme was started. This was aimed mainly at the housewives of mineworkers and consisted of sewing and craft classes, general health and hygiene programmes, and child-care courses. After the first year, the best class members were then trained "on-site" to run these classes and activities themselves, ensuring a greater degree of community involvement. Today, all classes and committees are run by Arandis residents.

The Arandis Community Centre and the Arandis Club have developed as the social hub of the town. Central community services include a library, a community centre, social club, swimming pool, a community hall, children's play area, amphitheatre and a non-denominational church building. A variety of privately owned businesses are operated within Arandis and the town presently houses approximately half of the mine's employees.

Sports facilities include an athletic track, soccer fields, a swimming pool and floodlit tennis courts. Boxing and karate are popular indoor sports, with tournaments staged at the open-air cinema.

3.7.8.2 *Rössing Country Club*

The Rössing Country Club (RCC) is situated 15 km outside Swakopmund, between the main Swakopmund - Usakos road and the Swakop River. The RCC was opened officially in 1977, to provide a forum for cohesive social activities for all Rössing personnel. The Country Club has its own 18 hole golf course and additional facilities for cricket, squash, bowls, tennis and swimming, as well as general recreation areas and landscaped gardens. Most of the individual sports teams constructed their own club houses, while Rössing contributed the sports facilities. The RCC gardens are irrigated with water drawn from the lower Swakop River whilst the golf course is irrigated with purified sewage effluent obtained from the Swakopmund Municipal Sewage Works.

3.7.9 Security

The Metallurgical, Engineering, Personnel and Administration areas are encompassed by a 7.5 km security fence. The fence has a number of gates leading to outside working areas, which are locked during back shifts and at weekends. Access to the mine for all employees and visitors is by one entrance; entry is controlled by identity cards for employees and contractors and by written permits for visitors. Three gates control access into gorges leading from the Open Pit to the Khan River and a game fence which encompasses the tailings dam controls vehicle access. There is a random search procedure for all vehicles and persons leaving the mine through the main gate. The Protection Services section now includes the operational side of the fire brigade and is responsible for the operation of fire fighting equipment as well as ambulance and rescue services. The Chief Fire Officer

is also responsible for all fire prevention methods on site.

3.7.10 Borrow Areas

Borrow pits totalling some 50 hectares in extent have been dug during the current mining operations at Rössing. The majority have been sited in the bottoms of Dome, Pinnacle and Panner Gorges, the sand and rock being used for the construction of road surfaces, seepage dam walls and the first (basal) portions of the tailings dam. With continued developments at Rössing, most of the borrow pits in Dome and Pinnacle Gorges have been covered by waste rock dumps and are no longer visible. Other borrow pits near the original tailings dam wall have also been covered by tailings. Active borrow pits are still maintained in Pinnacle Gorge and in the area to the west of the tailings dam.

3.8 Workforce

The numbers and types of employees making up the Rössing workforce have undergone several changes during the short time that the mine has been in operation. Three basic groups of activities defined the manpower needs of the mine. These were: the early pilot plant and construction phase, the operations workforce for day-to-day operation of the mine, and the contractors that are brought in to undertake special construction or engineering projects.

3.8.1 Construction Workforce

The pilot plant was constructed during 1970 by Fraser & Chalmers using a relatively small workforce. The actual construction of the Rössing Mine was done by a consortium known as Western Knapp - Power Gas and the first concrete was poured on 26.7.1974. The project was completed at the end of 1976. The number of construction personnel involved during this period reached a peak of some 2095 people during October 1975, supplied by approximately 27 contractors.

3.8.2 Operations Workforce

Since the start of mining operations in 1976, the workforce at Rössing has undergone several changes. Staff numbers rose rapidly at first, reaching a maximum of 3251 in May 1982. This was followed by a gradual decline in numbers to 2454 in 1988. During the same period, labour turnover has dropped from 40 % in 1977 to 6.2 % in 1987, with a slight rise to 8.1 % in 1988 (Figure 3.14). The reduction in staff numbers can be ascribed to a process of natural attrition associated with improved mechanization and automation of process and plant facilities.

The Rössing Uranium Mine operates three 8-hour shifts per day, 365 days per year. All Rössing employees have the same conditions of employment and the mine's labour practice is entirely non-discriminatory. All jobs are graded on the internationally recognized Paterson job evaluation system and promotion is based on an employee's competence and ability. Each employee receives housing at a nominal rental, membership of a comprehensive medical aid scheme and pension fund, permanent health insurance and life insurance. Approximately 60 % of the total workforce are unskilled or semi-skilled workers (Paterson A and B Bands), while the remainder occupy skilled, professional or managerial posts (Paterson C Band and above). Over 49 % of Rössing's employees have remained with the company for longer than 10 years, indicating that long- service goes hand-in-hand with employee job satisfaction.