Goanikontes; these individuals could be at risk in the event that a large flood occurs in the Swakop River below the Khan-Swakop confluence. In such a situation, the floodwaters would likely result in the loss of any equipment or facilities located in the bed of the Swakop River.

Assessments of dam break flow characteristics indicate that, if the dam were to break in the course of passing an unusually large flood of 1,100 m^3/second, the combined flow depth by the time the flood wave reaches Goanikontes will be less than 1.8 metres and the flow depth will be negligible by the time the flood reaches Swakopmund. Damage to Rössing's boreholes and Khan River water reticulation systems will be similar to that experienced during any major flood event without breaching of the dam wall.

Research and monitoring needs
A careful check should be maintained on the integrity of the KARS Dam wall during and after all flood events.

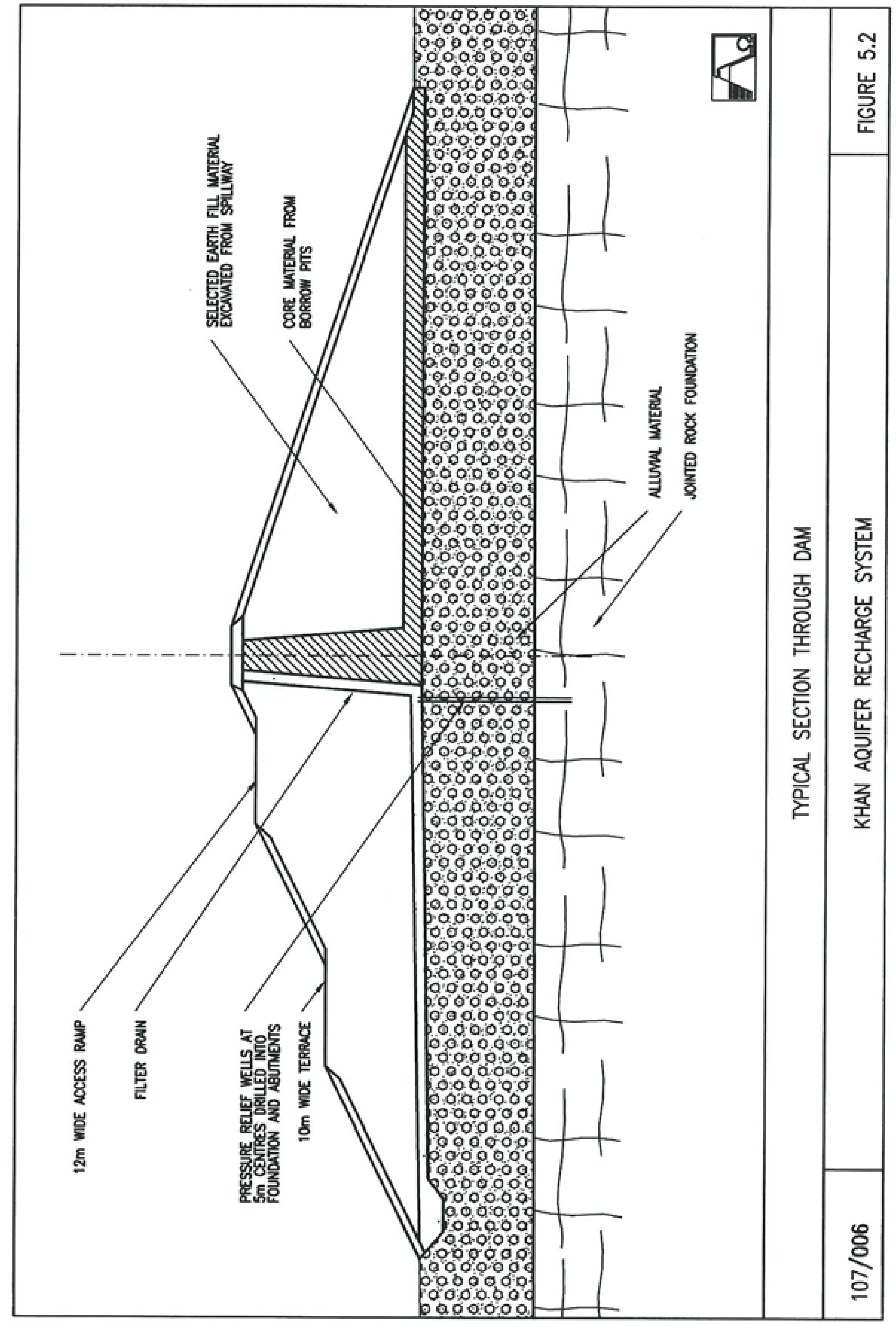
5.2.2.5 Choice of dam wall design

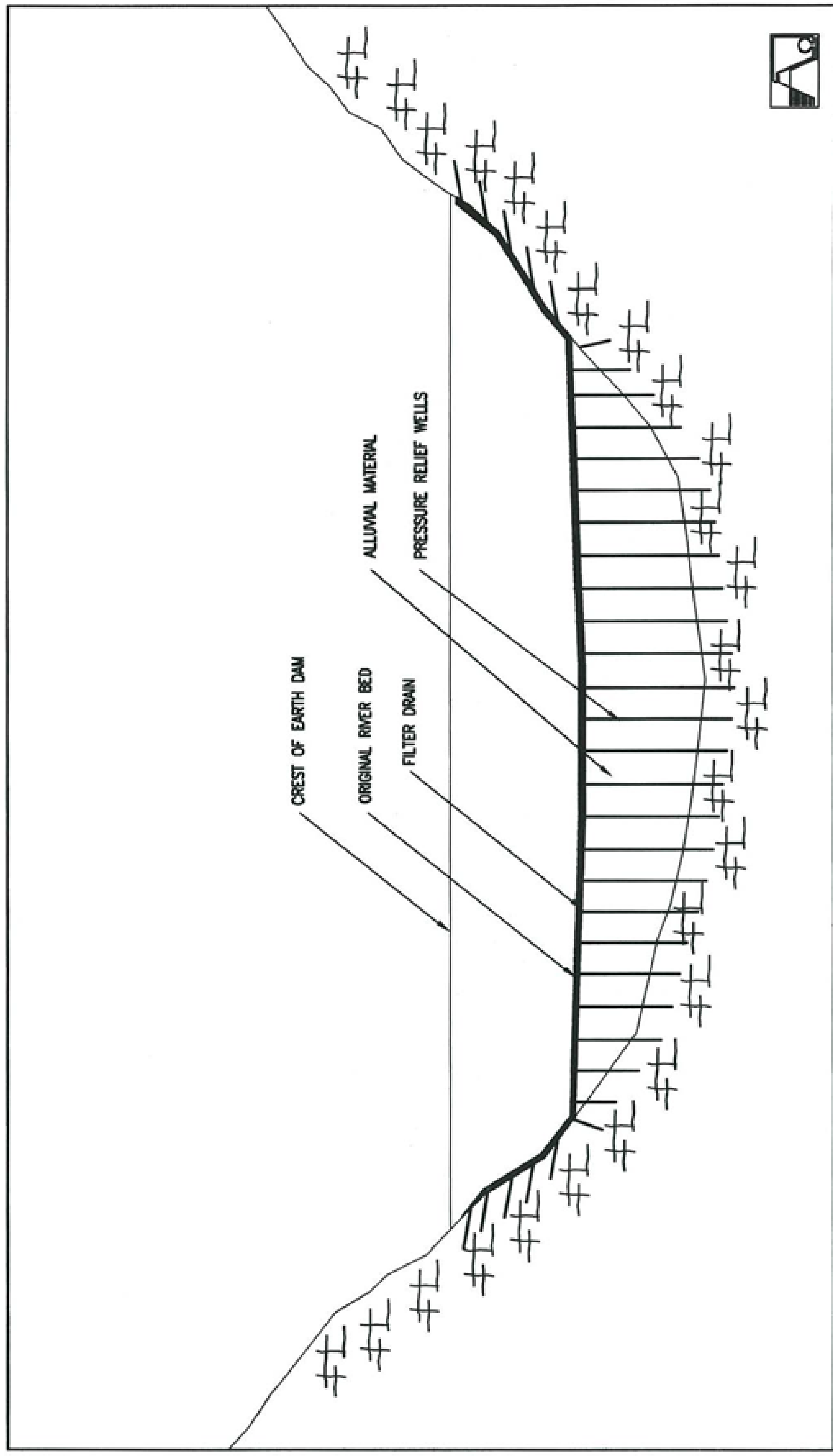
Impact statement
Several people perceive that alluvium is an unsuitable material from which to construct a dam wall to hold back seasonal floods in the Khan River.

Impact description
Alternative materials should be evaluated and appropriate sources identified for use instead of alluvium.

Impact significance
Use of alternative materials (e.g. waste rock, concrete) will significantly increase the costs associated with the proposed KARS Dam and could also lead to additional adverse impacts on other areas where different materials have to be borrowed. This impact is considered to have the potential for major significance. In addition, a different suite of options would be required when such a dam wall was decommissioned at the end of the life of the Rössing Mine.

Impact mitigation
Following evaluation of a range of alternatives and an extensive investigation of earth and roll-fill material suitable for dam construction, it is proposed to construct a zoned earth fill embankment comprising alluvial fill (excavated from the river bed within the dam basin) which will be compacted into the upstream and downstream zones. A core of compacted decomposed gneiss which is of low to medium plasticity and low permeability is to be provided. A suitable source for the core material has been identified some 6.5 kilometres from the dam site, just off the desert plains (**Appendix** 7). A cross-section through the dam is indicated in **Figure 5.2**. Seepage pressures under the dam and through the abutments will be controlled by means of pressure relief wells as illustrated in **Figure 5.3**.





TYPICAL SECTION THROUGH KHAN RIVER AT THE PROPOSED DAM SITE

KHAN AQUIFER RECHARGE SYSTEM

107/006

FIGURE 5.3

Water from the pressure relief structures will discharge into drainage media constructed at the downstream toe of the dam as well as at the downstream interface between the dam wall core and the riverbed alluvium.

The core material is to be extended upstream along the base of the embankment to form a blanket over the base of the dam at the embankment - alluvium contact. With time it is anticipated that fine silt will accumulate in the basin and that this silt, together with the core blanket, will act as a partial seal to the base of the dam and serve to reduce seepage underflow and seepage pressures. It is important to note that there is no permanent cut-off under the dam. This alternative (a permanent cut-off of sub-surface flows) was eliminated due to potential decommissioning difficulties and also due to difficulty in ensuring a complete seal without which the cut-off would be ineffective.

Research and monitoring needs
Only required during the period when the dam has trapped flood waters. During decanting operations, a close check should be kept on the degree to which water is able to percolate through the alluvium dam wall.

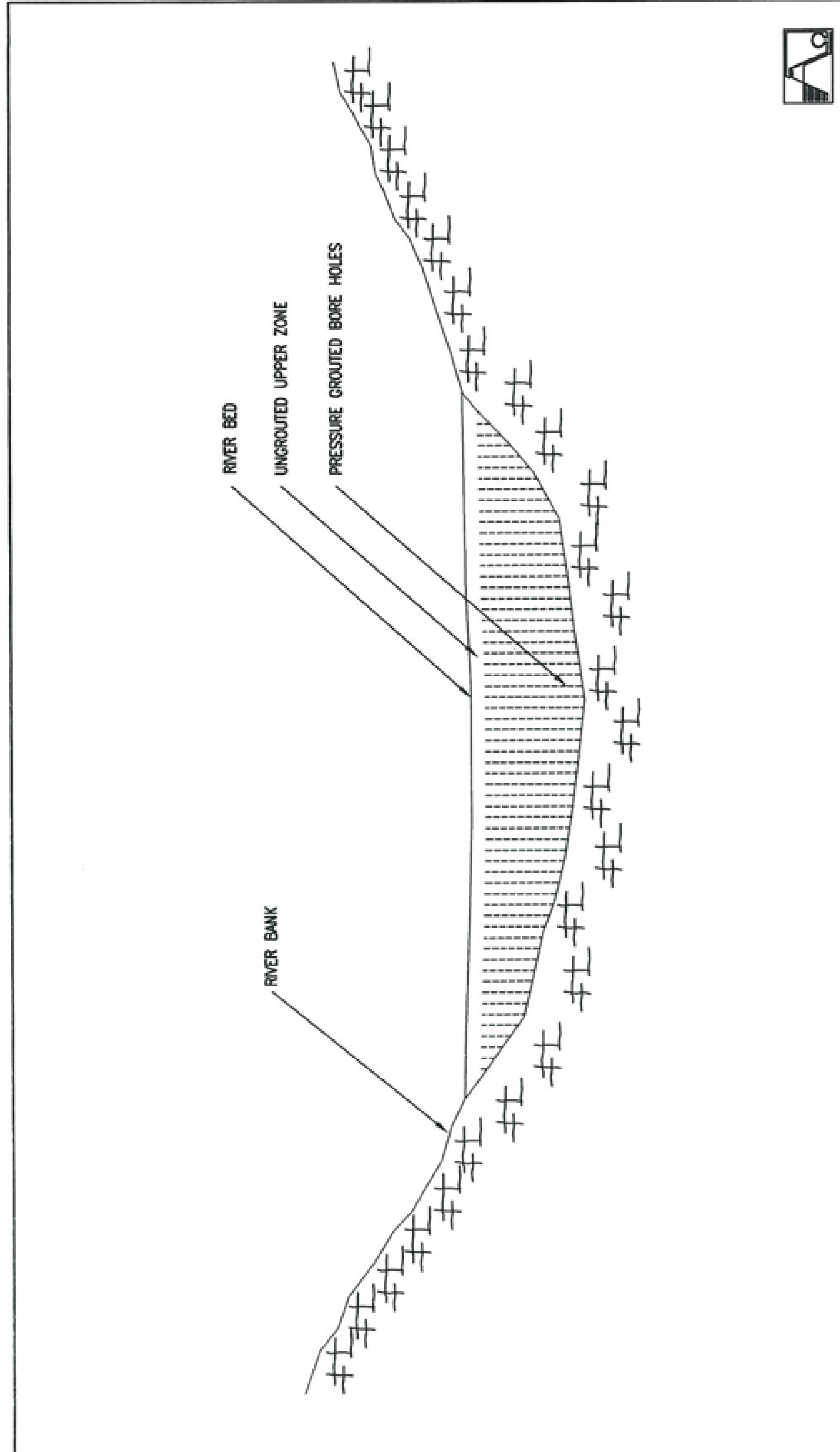
5.2.2.6 Decanting water and infiltration management

Impact statement
Decanting clarified water from the KARS Dam and allowing it to flow over the surface of the river bed is perceived to be inefficient and wasteful.

Impact description
High evaporation rates will lead to large losses of water decanted from the KARS Dam. In addition, this evaporation loss will also lead to a decrease in water quality through an increase in total dissolved salts.

Impact significance
Floodwaters in the Khan River are typically of a relatively good quality, with low concentrations of total dissolved salts. If the quality of this water is allowed to deteriorate it will reduce its usefulness to other users. This impact is considered to be of minor significance.

Impact mitigation
The primary objective of the KARS Project is to capture surface run-off and effect controlled infiltration of the water into the alluvial sands forming the base of the river. Since the longer the water is kept at surface the greater will be the evaporative losses, as soon as the water captured in the dam has had an opportunity to clarify water will be decanted from the dam via a decant system and outlet pipe. This water, together with seepage water, will be routed down the river via a system of cross-bunds orientated so as to detain the water and enhance infiltration (**Figure 5.4**).



TYPICAL SECTION THROUGH KHAN RIVER AT THE PROPOSED RIVER BARRIERS

KHAN AQUIFER RECHARGE SYSTEM

FIGURE 5.4

107/006

The bunds are simple-to-construct, low-technology structures built of riverbed alluvium and designed to lengthen the flow path of surface flows (**Figure 5.5**). They can be breached and re-located with standard earth-moving equipment as management of infiltration dictates. Silt which is likely to accumulate in the basins formed by the bunds will be excavated and disturbed from time to time to maintain infiltration rates.

It is intended that the length of the river between the KARS Dam site and the downstream limit of the mine concession area will be managed in a series of compartments. Two natural geological structures in this river reach act as sub-surface flow retarders. It would be possible to enhance the retardation efficiency of these natural structures by introducing an impervious grouting material to raise their level slightly, though still well below the surface of the river bed. Alternatively, a full-depth grout-curtain could be introduced to replace a natural retarder.

At this time, the design of the flow retarders is still in the conceptual stage. Flow retarders would only be considered once the efficiency of the proposed infiltration and recharge process has evaluated. Such flow retardation structures would not be introduced without a thorough evaluation of their potential impacts. If used, the flow retarders will be located and sized to ensure that base flow passes over or through the structures without the ground water surfacing.

Recharge and abstraction from the compartments will be managed so as to store as much water as the aquifer will accommodate. Water will be abstracted from the alluvial aquifer by means of boreholes located in the two lower-most compartments which are located within the mine concession area.

Research and monitoring needs

Different recharge and infiltration mechanisms and management strategies need to be evaluated in order to maximize recharge efficiency. If flow retarders are constructed, their effects should be monitored closely during the operational and decommissioning phases of the project.

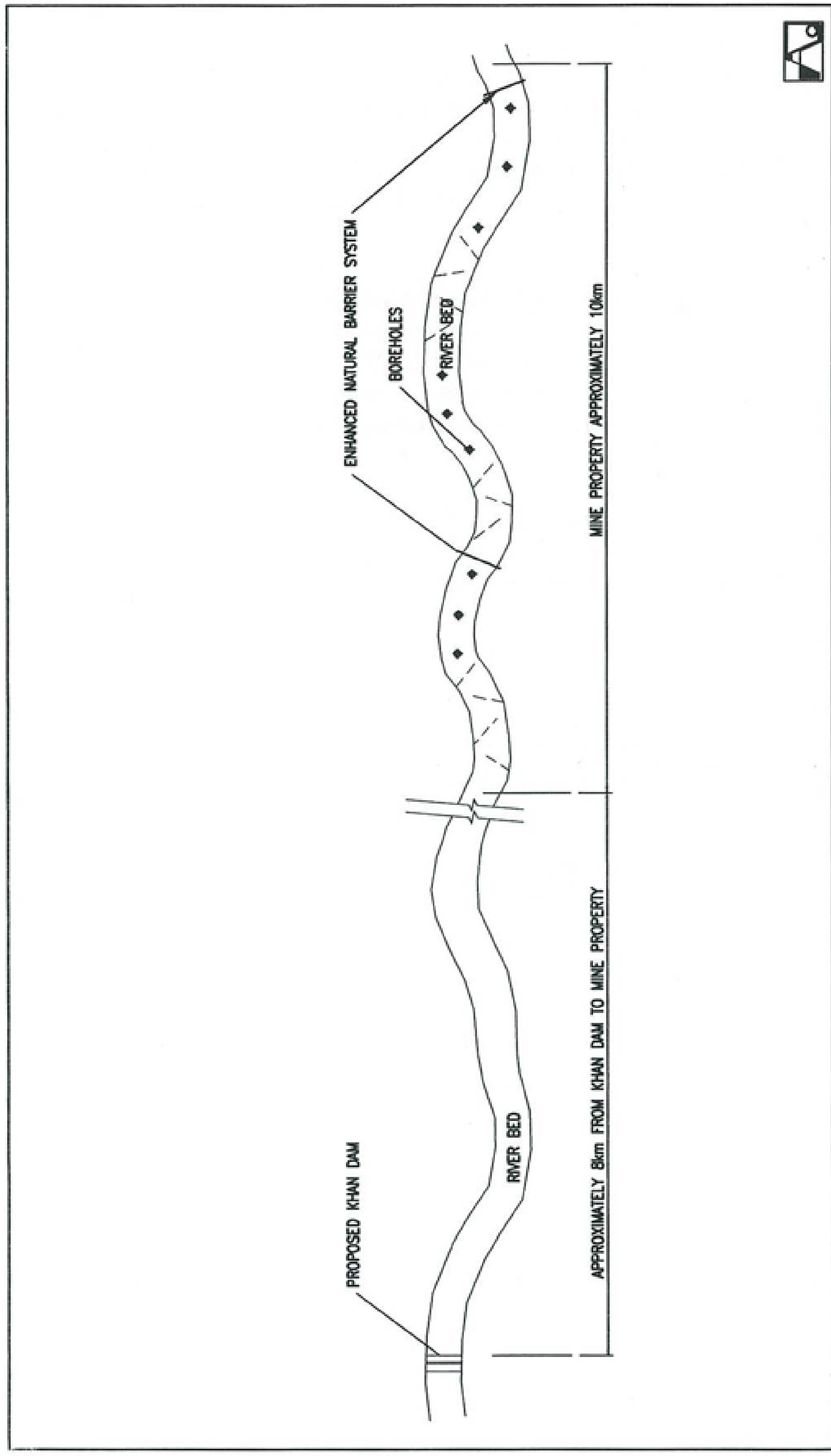
5.2.2.7 Decommissioning options

Impact statement

Several problems are associated with the decommissioning of a dam wall and associated structures built in the Khan River. The scale of these problems is determined largely by the type of material used in construction of the dam wall.

Impact description

The alluvium dam wall will have to be decommissioned once the KARS Project has reached the end of its useful life and the dam capacity has been lost through the accumulation of trapped silt and alluvium. Decommissioning would cause an increase in the load of sediment which is transported downstream to the lower Swakop River. Sub-surface flow retarder structures would form permanent flow barriers which would force sub-surface flow to surface, causing evaporation loss and salinization.



SCHEMATIC PLAN ON RIVER SHOWING BARRIERS, MINE BOUNDARIES etc.

KHAN AQUIFER RECHARGE SYSTEM

FIGURE 5.5

107/006

ENVIRONMENTAL IMPACT ASSESSMENT OF THE PROPOSED KHAN AQUIFER RECHARGE SCHEME

Impact significance

Because the original dam wall material will be excavated from sites in or near to the bed of the Khan River, it would be possible merely to breach the wall vertically in the centre and allow successive floods to erode away the accumulated silt and alluvium. Whilst the low frequency of floods indicates that it could take a considerable time to remove the wall completely, it would eventually restore the Khan River to its original gradient.

For an alluvium dam wall, it would be necessary to remove any material (such as waste rock) which was placed to reduce wind and storm erosion. This could be buried in a waste dump designed for rehabilitation. It would be difficult to decommission any concrete inlet or spillway structures; the most feasible option would be to remove the material to a waste dump on the Rössing Mine property for rehabilitation.

If installed, the impact of the sub-surface flow retarder structures is likely to be minor since these will have been constructed so as to operate without allowing sub-surface water to reach the surface of the river bed.

Impact mitigation

It is envisaged that on decommissioning the dam will be breached to allow floods to pass through the basin. For some years following breaching there will be gradual erosion of silts, sand and gravel which will have accumulated within the basin. This silt will be dispersed along the Khan River to the Swakop River and along the lower Swakop River.

Concrete structures in the outlet works and the main spillway will be blasted, removed from the river section and transported to Rössing Mine for disposal together with similar materials.

In respect of the artificial sub-surface flow retarders it is proposed that these are blasted and excavated to an extent required to reinstate flow conditions typical of the river section immediately upstream or downstream.

Research and monitoring needs

Decommissioning of the dam will be the responsibility of Rössing who will make adequate provision for this event within the ambit of their current policy of making provision for mine closure. Ground water monitoring should be continued after the KARS Dam has been decommissioned so as to evaluate any residual effects on water levels, evaporation rates and the accumulation of salts.

5.2.2.8 Silt accumulation reduces project lifespan

Impact statement

The rapid accumulation of silt within the reservoir basin will reduce the lifespan of the project and reduce its effectiveness as a solution to recharging the Khan River aquifer. The removal or dredging of accumulated silt would be technically difficult and would also increase the costs of the water.

Impact description
Silt accumulation in the dam will be determined by flood size and flood frequency (Hydrology Division, 1988; Department of Water Affairs, 1991a). Floods occurring near the beginning of the rainy season tend to carry larger quantities of silt than floods which occur later in the rainy season. Measurements of the silt content of Khan River flood waters show that silt content varies between about 2 % and 23 %. An average silt content of 5 % is accepted as a fair estimate (Hawkins, Hawkins & Osborn, 1991). If the long-term mean annual inflow of 3.41 Mm^3 is accepted, this will bring in approximately 170,000 m^3 of silt per year. A 9 Mm^3 capacity reservoir could have a theoretical lifespan which could possibly be greater than the estimated remaining lifespan of the Rössing Mine.

Silt-laden waters entering an empty reservoir basin will have their velocity reduced and thus a reduced silt carrying capacity. Silt will be deposited mainly in the deeper areas of the dam and both the maximum and average depth of the reservoir will rapidly decrease. There is also a possibility that a major flood (> 100 Mm^3) carrying 5 % by volume of silt might reach the dam and reduce its capacity by 50 % in one season. Nothing can be done about this possibility.

The progressive shallowing of the reservoir basin will promote higher water temperatures and thus greater evaporative losses. Undisturbed layers of accumulated silt within the reservoir basin will retard infiltration into the aquifer from within the reservoir and will increase the quantity of silt in waters discharged over the spillway. This silt-laden water will reduce the infiltration rates in downstream spreading grounds and require frequent maintenance of the surface to remove silt layers. Any reduction in anticipated infiltration rates in the spreading grounds will increase the length of time which standing water remains in these basins. This will lead to increased algal growth in the water and increased evaporative losses.

The flood trapping efficiency of the dam will decrease at an increasing rate over time as its capacity is decreased by accumulated silt loads within the reservoir basin. There is therefore an unavoidable element of risk in terms of the long-term viability of the project. However, Rössing Management have indicated that their best current estimates of the remaining economic life of the Rössing Mine suggests a time-frame of twenty years. Therefore, since the projected lifespan of the dam is approximately equal to the lifespan of the mine, a dam on the Khan River would still provide a "long-term" solution to some of the water supply problems of the Rössing Mine.

Impact significance
The impact is considered to be of moderate significance, since alternative, more expensive options may have to be considered. The removal and disposal of silt could result in significant increases in costs and cause additional environmental impacts at whichever site is chosen for silt disposal.

Impact mitigation
Ideally, the largest dam feasible should be constructed in order to maximize the flood retention capacity and prolong the lifespan of the project. This will reduce the significance of this impact to minor levels. However, whilst the topography of the dam site would allow the construction of a very large dam, the negative environmental impacts of a dam at this site would increase accordingly.

Research and monitoring needs
Monitor the volumes of floods and their silt loads reaching the dam and conduct a regular silt survey of the reservoir basin.

Establish a photographic record using fixed-point photographs to monitor changes in vegetation and general effects of silt accumulation on the dam.

Monitor the dam operation and efficiency on an ongoing basis.

5.2.3 Ecological issues

5.2.3.1 Impact on fauna and flora immediately above and below the dam wall

Impact statement
The existing perennial riparian vegetation in the bed of the Khan River at the KARS Dam site will be lost during dam construction. Above the project site, inundation will also reduce the extent of this very important habitat. The riparian vegetation forms an important refuge and food source for many species of Namib fauna; the intense disturbance at the project site, followed by inundation of upstream vegetation by trapped floods, will eliminate sections of this habitat.

Impact description
The construction of an alluvial dam in the bed of the Khan River will cover an estimated basal area of between 2.5 and 3 hectares. An estimated additional area of 2 hectares upstream of the dam site will be affected by the excavation of borrow materials. In addition, construction of a spillway will affect an additional area of approximately 1 hectare. As soon as the dam fills, the additional area inundated would depend on the size of the dam wall that is constructed. If a 25 metre high alluvium dam wall is built, the maximum area inundated would be approximately 70 hectares. At full supply capacity, a 25 metre high wall would inundate some 3-4 kilometres of riverbed.

The area most likely to be immediately affected by inundation following dam construction is obviously the portion of riverbed immediately upstream of the dam wall, since it is probable that smaller floods rather than larger floods will occur. Certain types of habitats could be covered during dam construction or inundated when either dam starts to fill. A plan view of the area inundated at full supply level (for the 25 metre high wall option) is shown in **Figure 5.1**.

Stands of perennial riparian vegetation, predominantly *Acacia erioloba* and *Faidherbia albida* are confined to scattered groups on alluvial terraces on the inward sides of meanders in the river. These are interspersed with scattered groups of shrubs and small trees, predominantly a few *Prosopis* sp., and numerous *Tamarix usneoides*. A few *Salvadora persica* bushes are scattered over the lower rocky slopes of the river banks. Annual plants also occur on the flood terraces and in the lowest flood channels of the river bed of the Khan River.

Approximately 20 kilometres upstream of the Khan Dam site, the lower extremity of another aquifer compartment reaches the surface of the river bed as the water passes over an impermeable band crossing the river. The numerous game tracks in the area indicate that this site is an important watering point for game animals.

Impact significance
Construction of a 25 metre high dam wall will result in the loss of a small area of riparian habitat. This is considered to be a minor impact in view of the presence of additional riparian habitat along the Khan River, both above and below the proposed dam site. However, it is likely that the impacts from the dam could be partially off-set by the development over time of some form of replacement riparian vegetation. However, whilst this replacement vegetation is likely to contain a number of different species, it is unlikely to possess the same characteristics as the original habitat.

Impact mitigation
(See research and monitoring requirements).

Research and monitoring needs
All construction activities should be carefully controlled and supervised in order to minimize damage or disturbance to the local fauna and flora. The species diversity and vigour of the riparian vegetation immediately upstream of the dam site should continue to be monitored at least on an annual basis. Fixed-point photographs should be taken annually to allow a record to be kept of the demise of the original flooded vegetation and the colonization by replacement species.

5.2.3.2 Impact on fauna and flora along the lower Khan and Swakop rivers

Impact statement and description
The riparian vegetation downstream of the Khan Dam site may be damaged due to a variety of factors and activities. These include drying out due to excessive water abstraction, collection of firewood by construction crews, trampling effects caused by large numbers of people and machinery, and removal to facilitate the movement of construction machinery.

The loss of this vegetation could also have several secondary effects such as the loss or interruption of a plant and animal dispersion or migration corridor (**Section 5.3.3.5**) and an increase in downstream erosion rates (**Section 5.3.3.7**).

Impact significance
Whilst the sub-region is not in a pristine condition, the linear oasis formed by the lower Khan and Swakop rivers is one of very few such systems in the Namib Desert (Ashton *et al.*, 1991). Its significance in the overall ecological functioning of the Namib Desert system therefore increases in importance. The vegetation of the lower Khan and Swakop rivers has the potential to provide habitat for a wide variety of animals, reptiles, amphibians, birds and insects. All game in the area are protected in terms of the Nature Conservation Ordinance of 1975.

Damage to the riparian habitat would also affect its associated fauna. The area most at risk is the Khan River reach between the mine frontage and the junction with the Swakop River. If the vegetation in this reach is lost, the impact will be moderate to highly negative. Effective implementation of mitigatory actions will reduce the significance of these impacts to moderate levels. Impacts in the lower Swakop River are expected to be low to moderate.

Impact mitigation
Strict control should be maintained over the construction activities to reduce the area of impacts in the vicinity of the dam wall. All work zones, storage areas and borrow areas, as well as routes followed by construction vehicles and teams should be clearly demarcated.

No collection of firewood from the riparian vegetation should be allowed. Construction workers should be supplied with fuel (e.g. firewood or gas).

All borrow sites and vehicle routes downstream of the Khan Dam site should be rehabilitated as far as possible by levelling and back-filling. Preferably, no borrow pits should be located outside the reservoir basin.

As far as is possible, strict control must be exercised over rates of water abstraction in order to minimize the risk of excessive abstraction.

Research and monitoring needs
The species diversity and vigour of the riparian vegetation downstream of the Khan Dam site should continue to be monitored at least every six months. All monitoring boreholes should be regularly checked to note the depth of the ground water. Careful predictive modelling is also required to determine the optimum sustainable abstraction rate which will not damage the integrity of the downstream riparian vegetation.

5.2.3.3 Loss of rare or endangered species

Impact statement
Damage to, and alteration or loss of, habitat may threaten the existence of rare or endangered species occurring in the sensitive ecosystems of the sub-region. Intense disturbance due to construction activities may discourage or prevent the local fauna from utilizing the site area.

Impact description
At present, ten species of rare and protected plants occur in the sub-region. However, all of these species have been recorded from the open stony flats and washes; no protected plant species have been recorded from the bed of the Khan River.

In contrast, a number of sensitive animal, bird and reptile species occur along the bed of the Khan River. These could be adversely affected by construction activities. However, any floods trapped by a dam will create a new, if temporary, source of surface water; this could well attract additional bird and animal species to the vicinity of the dam.

If the construction site is well managed and restored after completion of the dam, the improvement in habitat could result in some re-colonization of the area.

Impact significance
In the absence of rare or protected plant species in the areas where construction or inundation could occur, the potential impact on plant species is likely to be minor at most. The impact on bird, animal and reptile species is also likely to be minor.

Impact mitigation
All construction activities should be controlled to limit the extent of physical disturbance along the bed of the Khan River. All disturbed areas, such as borrow pits, etc., should be restored on completion of the dam wall and spillway.

Research and monitoring needs
None required.

5.2.3.4 Increased spread of alien vegetation

Impact statement
Alien invasive plants are usually pioneering species which thrive on areas of disturbed ground. Construction activities and the movement of numbers of people around the dam site will lead to high levels of localized habitat disturbance. This is likely to facilitate the spread of existing populations of alien invasive plants with the gradual displacement of indigenous species.

Impact description
At present, the only information available on the distribution of alien invasive plants around Rössing is listed in Craven (1986) and Ashton (1988). Additional information for other rivers in the Namib Desert is contained in Robinson (1976), Tarr and Loutit (1985), Boyer and Boyer (1988), Boyer (1989) and Department of Water Affairs (1991a). The seeds of all of these invasive species are transported by water. The construction of the Khan Dam will create additional moist habitat that will favour the development of invasive plant populations.

The common reed (*Phragmites australis*) is likely to extend its distribution. The temporary nature of the water body created by a dam will prevent the development of permanent populations of annual invasive species, though these will develop rapidly after water levels recede and remain for periods of up to a few months. Perennial species will colonize the areas which retain moisture longest. Populations of invasive alien plants which develop in the Khan Dam basin will provide a continual source of seeds for the spread of infestations further down the Khan and Swakop Rivers.

Impact significance
The present levels of invasive vegetation in the bed of the Khan River are low to moderate, with the exception of the moist area at Vergenoeg, some 20 kilometres upstream of the Khan Dam site. Here, stands of *Phragmites australis* are common.

Increased numbers of alien invasive plants could have a minor to moderate negative impact on the indigenous vegetation of the Khan River. The potential significance of this impact is dependent on the efficacy of any control measures which may be used. The use of any chemical control technique should be very carefully evaluated since this could have far greater adverse effects than the target invasive plants. In the case of *Prosopis* sp., the seed pods and foliage provide a useful food source for game animals; an increased abundance of this tree species could have a minor beneficial impact, though it would also have a moderate negative effect through increased loss of water by evapotranspiration.

Impact mitigation
Ideally, alien invasive vegetation should be manually or mechanically removed, preferably before seed has been set, to limit further spread. The applicability of any chemical control techniques to the situation that develops following dam construction will have to be assessed after the dam has filled for the first time. It is important to note that the effectiveness of any eradication programme depends on the thoroughness with which it is conducted.

Research and monitoring needs
Assess current distribution and species diversity of alien invasive plant species growing in the bed of the Khan River. Monitor changes at annual intervals over the different stages of the project. Consult the Department of Water Affairs, and the Ministry of Environment & Tourism as to the necessity of implementing any control strategies.

5.2.3.5 Loss of dispersion/migration corridor

Impact statement and description
Construction of a dam wall across the Khan River will reduce the extent to which the river functions as a dispersion route and migratory pathway for small mammals, amphibians, some large mammals and riparian vegetation.

Impact significance

The Khan River is an important linear oasis in the Namib Desert. The river system is the only suitable continuous habitat within a large area which allows the dispersion and migratory movement of small mammals and amphibians, in particular. The river bed also forms a migratory route for certain large mammals and allows the downstream spread and replacement of indigenous and alien riparian vegetation. Loss of this vital function will disrupt the local and possibly even the sub-regional functioning of this system. These impacts could have a moderate significance for the functioning of the ecosystem.

Impact mitigation

It is unlikely that management actions can effectively restore the loss of a direct migratory route such as the Khan River, unless alternative nearby pathways exist. Given the locally hilly terrain and absence of surface water in the sub-region, alternate migratory pathways around the Khan Dam site are unknown. However, after the dam has been built, re-colonization of the reservoir basin and downstream riparian vegetation will limit the extent of the "blockage" to a few hundred metres. If the area remains largely undisturbed, at least some elements of the fauna will be able to cross over the spillway or gently-sloping dam wall.

Whilst the construction of some form of "pathway" over the dam wall will facilitate this movement, it must be remembered that such a "pathway" could also be used by off-road vehicles with concomitant damage to the dam wall structure. Inevitably, game animals are expected to find their own bypass route around the new dam wall.

Research and monitoring needs

None required.

5.2.3.6 Loss of sediments and nutrients to downstream ecosystems

Impact statement and description

A dam on the Khan River will trap sediments and their associated nutrients from flood waters. This will change the geomorphological processes presently operating in the bed of the river and will reduce the supply of nutrients and alluvial material to downstream ecosystems. The larger the dam that is built, the greater will be this impact on downstream ecosystems.

Impact significance

The passage of sediment-laden water down the normally dry rivers of the Namib Desert during flood events represents probably the major mechanism whereby downstream ecosystems receive nutrient inputs. Interception of flood-borne sediments by a dam wall will limit the potential for nutrient recharge to the ground water, surface sediments and downstream riparian vegetation. However, it is likely that this impact will extend down the Khan River and below its junction with the Swakop River. This could have a moderate impact if the ground water nutrient supply is insufficient to meet the nutrient requirements of downstream ecosystems.

Impact mitigation

See research and monitoring requirements.

Research and monitoring needs

The lack of quantitative information on the relative quantities of nutrients transported by surface floods and ground water in the Khan River prevents proper evaluation of the potential significance of this impact. Clearly, the relative quantities of nutrients transported by surface floods and ground water is dependent on the size of particular floods. It is recommended that this impact should be accepted as inevitable.

5.2.3.7 Elevated erosion rates below dam wall

Impact statement

Any water passing over the spillway of a dam on the Khan River will have an elevated capacity to pick up and suspend downstream sediments because its original sediment load will have been depleted by deposition in the reservoir basin.

Impact description

The enhanced sediment-carrying capacity of water discharged from a dam results in increased erosion of riverbed sediments from the river reach below the dam wall, until an equilibrium between aggradation and degradation is reached. The quantitative assessment of this impact is extremely difficult but it can be described in qualitative terms. Basically, the "sediment hungry" water scours away accumulated sediments downstream of the dam wall or spillway until the depth and rate of flow is insufficient to lift and transport sediment particles.

Impact significance

This impact is potentially of moderate significance in the area immediately downstream of the dam wall where water flows are highest and sediment loads lowest. The sediment load carried by the Khan River during floods varies between 3 % and 22 %; a fair estimate of the average sediment carrying capacity of flood water is 5 % (HH&O, 1991). This value can be used to estimate the approximate volume of sediment likely to be eroded by water discharged via the spillway.

As the Khan River flow equilibrates and sediment-carrying capacity is restored with increasing distance from the dam wall, the significance of elevated erosion rates will decline to become minor. The nutrients associated with these re-mobilized sediments would help to recharge nutrient levels in the ground water as well as in downstream surface sediments.

Impact mitigation

At the dam site, dissipation of the energy of waters spilling over the spillway would require localized riverbed protection. The walls of downstream spreading grounds will also retard the flow of water discharged over the spillway. However, if the flow is sufficiently high, the spreading ground walls can be allowed to wash away, increasing the sediment load carried by the water and decreasing its erosion potential.

Research and monitoring needs
The sediment-carrying capacity of sediment-poor water should be estimated for different possible discharge flow scenarios.

5.2.3.8 Disturbance due to elevated noise and dust levels

Impact statement and description
Increased levels of dust and noise can be expected to occur during the construction of the dam wall, spillway, outlet structures and the walls of downstream spreading grounds. Noise levels will be particularly high when blasting of rock formations is required to properly shape the spillway. These impacts will disturb small and large mammals and, possibly, birdlife.

Impact significance
Since this impact is expected to be confined mainly to the construction period, its significance is expected to be minor. High levels of airborne dust can be expected after construction if the exposed alluvium material of the dam wall is not covered with a protective layer to reduce wind erosion.

Impact mitigation
Construction activities should be completed as soon as possible to reduce the length of time that the disturbance occurs. Where possible, exposed areas of alluvium (e.g. the faces of the dam wall) should be covered to reduce wind erosion. Rain falling on the construction site will form a thin crust on the soil surface which will limit the extent of wind erosion in borrow areas. However, given the scarcity and localized nature of rainfall at Rössing, it may be necessary to provide some form of cover for those borrow areas located away from the riverbed. Floodwaters carry sufficient quantities of silt to cover any borrow areas located in the bed of the Khan River.

Research and monitoring needs
Careful attention will have to be paid to ensuring that all construction workers comply with occupational hygiene and safety requirements in the dusty desert environment.

5.2.3.9 Development of new riparian habitats along shoreline

Impact statement and description
New riparian habitat could be created along the shoreline of the reservoir created by a dam at the Khan Dam site. Fast-growing indigenous and alien tree species, as well as a variety of reeds and sedges, could proliferate in response to the higher water table and nutrient-rich silt deposited upstream of the dam wall.

Impact significance
This benefit has the potential for moderate significance to the fauna and flora of the Khan River ecosystem. The benefit may, however, be reduced if alien invasive

species such as *Prosopis* sp. predominate and prevent the development of indigenous tree species such as *Faidherbia albida*.

Impact optimization
Where possible, the development of alien invasive species of vegetation should be prevented.

Research and monitoring needs
Regular annual checks of the vegetation that develops around the shoreline of the reservoir basin should be conducted. A control programme should be considered if large numbers of alien invasive species are encountered.

5.2.4 Health and safety issues

5.2.4.1 Contamination of ground water by radionuclides

Impact statement
There is continued public concern that ground water emanating from, or flowing past, the Rössing Uranium Mine could be contaminated by radionuclides. The concern centres on the perception that such contamination will render the water unfit for use by downstream water users, including the natural ecosystems, and also have adverse effects on the health or survival of these users.

Impact description
If ground water is contaminated by excessively high levels of radionuclides it is unfit for human use and could cause damage to elements of the natural fauna and flora, such as riparian vegetation, which make use of ground water. The natural background radiation levels in the area around the Rössing Uranium Mine are considered to be relatively high, due to the presence of localized radiation anomalies in the area around the Rössing orebody.

Impact significance
The radionuclide concentrations in monitoring boreholes reflect the variability of the natural background levels of radionuclides derived from the regional geological formations. In comparison with other rivers in southern Africa, the levels of radionuclides in the ground water around Rössing Mine are high. Additional studies carried out by the CSIR indicate clearly that the natural background concentrations of uranium isotopes have not been increased by seepage of effluent from the Rössing Mine property. Nevertheless, these levels are consistent with the local geology of the area. Therefore, given the existing contamination control processes and procedures which are in place, the potential for contamination from mine-related uranium wastes is considered to be very low.

Impact mitigation
The use of riverbed alluvium from the Khan River is unlikely to increase radionuclide levels in ground water and the impact would therefore be insignificant.

Nevertheless, routine monitoring of radionuclide levels in the monitoring boreholes should continue. Any additional boreholes drilled in the bed of the Khan River downstream of a dam should be regularly sampled and checked for their radionuclide content.

Research and monitoring needs
See details of recommended mitigatory actions.

5.2.4.2 Contamination of ground water

Impact statement
Contamination of the Khan River ground water by nitrate derived from any of a number of activities at the Rössing Mine could reduce the ground water's fitness for use by downstream users.

Impact description
Medical evidence indicates that high concentrations (greater than 10 mg/ℓ) of nitrate and nitrite in water used continually for drinking purposes can cause methylhaemoglobinaemia in infants under the age of 6-12 months (DWAF, 1996). There is no such effect on adult humans.

Impact significance
The natural background levels of nitrate in ground water around the Rössing Uranium Mine are very variable, ranging from zero (i.e. non-detectable) to 312 mg/ℓ, with a mean value of 20.8 mg/ℓ. In addition, high background levels of fluoride, sulphate and chloride raise the total salt content of the ground water and render it brackish and unfit for human consumption. Therefore, since it is highly unlikely that humans would drink ground water from the Khan River, the significance of high natural nitrate levels is minimal.

Impact mitigation
The most suitable means of eliminating the potential for this impact to occur is through the continued use of the existing cut-off trenches which intercept any seepage from the mine site.

Research and monitoring needs
No special measures required. The routine monitoring of ground water chemistry should continue.

5.2.5 Socio-economic issues

5.2.5.1 Aesthetic impacts of borrow areas etc.

Impact statement
If borrow areas and waste rock piles located near the dam site are not adequately

rehabilitated after construction, there will be an adverse impact on the aesthetic appearance of the KARS Dam site. Similarly, the aesthetic appearance of borrow areas located away from the dam site could be adversely impacted if they are not properly rehabilitated.

Impact description
The aesthetic appearance of the Khan River could be adversely affected by the presence of large areas of open-cast alluvium diggings during construction. This will detract from the present beauty of the area.

Impact significance
This impact has a potentially minor to moderate significance. Location of borrow areas within the reservoir basin will lead to a minor increase in reservoir capacity; implementation of this and other appropriate rehabilitation measures will reduce this significance to minor levels. Where construction materials are sourced from outside the reservoir basin, these should be rehabilitated after construction is complete.

Impact mitigation
All borrow areas should either be located within the reservoir basin or rehabilitated by in-filling and landscaping.

Research and monitoring needs
Maintain a routine check of rehabilitated areas to ensure that the layer of covering material remains in place. Add additional cover material if the fill is exposed by wind or water action.

5.2.5.2 Increased litter and waste around construction site

Impact statement and description
The increased numbers of people in the area and the construction activities could result in the accumulation and dispersion of litter and other garbage in the site area and the work force camp area. This could cause damage to the flora and fauna as well as a decrease in the aesthetic appeal of the area. The greatest damage is caused by waste oil and plastics, as well as flammable materials.

Impact significance
This impact will be of minor significance provided that the mitigatory measures are applied.

Impact mitigation
Plan and implement an efficient waste collection and disposal system, as well as a clean-up campaign after construction is completed. Ensure that all waste materials are disposed of in appropriate systems. Prevent the risk of fires spreading from incineration systems.

Transport any waste oil to the Rössing Uranium Mine workshops for recycling.