Sediment removal and management

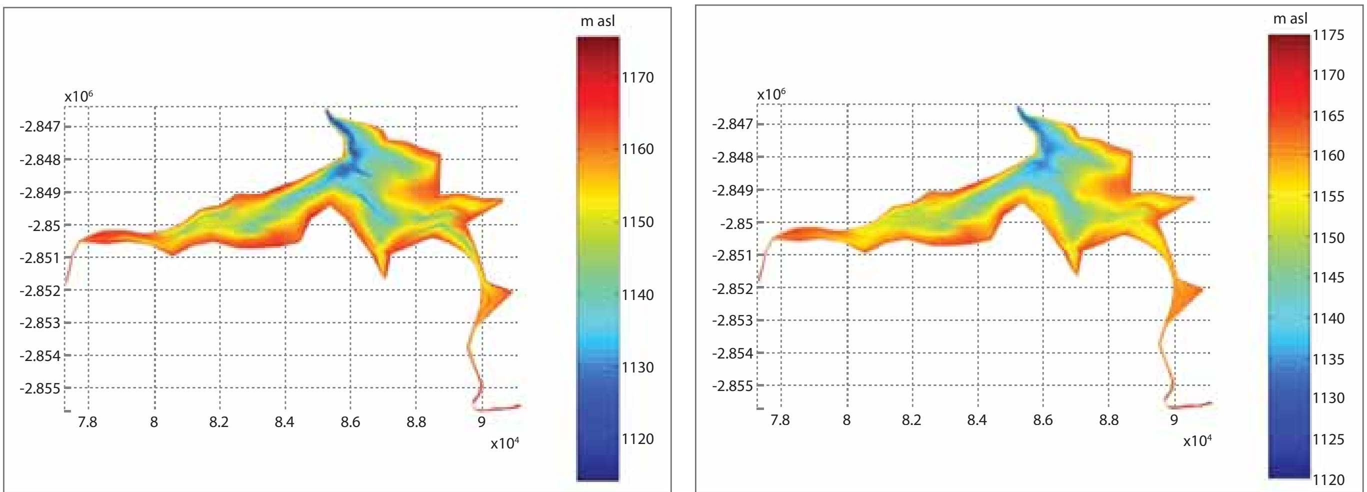
THE SEDIMENT REMOVAL and Management Project deals with nutrient-rich sediments that contribute to severe eutrophication in the Hartbeespoort Dam (HBPD), as well as with sediments that should be retained and removed in future to protect the dam from sediment influx and associated build-up of nutrients.

About 40–45 X 10^6 m^3 of sediments associated with nutrients (phosphorus, nitrogen, carbon) have accumulated in the HBPD for the more than 85 years of its operation (Figure 1).

The consequences of sediment build-up in the HBPD are the loss of 21% of the dam's initial storage capacity and the continuous release of nutrients (termed the Internal Nutrient load) associated with the top layer sediments, and especially phosphorous as the pivotal nutrient in eutrophication abatement.

The top layer of dam sediments (volume ~ 5.5 X 106 m^3) that interacts with the overlaying water contains ~ 2 000 tons of phosphorous that are trapped in particles, attached to the surfaces of particles, or contained in interstitial water. It is conservatively estimated that 10–15% of this phosphorous mass trapped in the dam top layer sediments is annually released/recycled to the bigger water body. This is termed the Internal Phosphorous load. The internal P load, coupled to the external nutrient influx via tributaries, results in severe eutrophication of the HBPD and excessive biomass growth.

In the context of internal loading a small (but very active in nutrient recycling) part of the dam's sediments is a buoyant, gelatinous layer (generally termed the "jelly" layer) that is located in the dam wall zone (shaded green in Figure 2). This layer is composed of dead biomass (detritus) and fine clay particles rich in nitrogen and phosphorous, and particularly in organic carbon that provides energy for the fast decomposition of detritus and the release of trapped nutrients back to the bigger water body.



Dam bottom contours (1923) **Dam bottom contours (2008)**

Figure 1: HBPD sediment build-up as determined through bottom contours measurement and modelling

> Any serious approach to the remediation of the HBPD should – *inter alia* – attend to a reduction of the excessive Internal Phosphorous load.

The above-mentioned 40–45 X 10^6 m^3 of sediments are distributed (Figure 1) over 25% of the dam's area (full supply level). The sediments are mostly settled in natural valleys that existed in the area before the damming of the river.

An additional 1.25–1.5 X 10^6 m^3 of sediments are accumulated in the Crocodile River's inlet zone (shaded red in Figure 3). Thereby the settling efficiency and retention capacity of the incoming sediments are considerably decreased.

The recovery of lost settling efficiency and retention capacity in this zone is of considerable importance within an overall strategy for sediment removal and management – now and in the future.

As estimated in the 1990s (Rooseboom 1993), about 300–500 x 10^3 m^3 of sediments – associated with nutrients – enter the HBPD each year, depending on precipitation and runoff. Such data should be updated through monitoring of the Crocodile River at DWAF's Hydro Station A2H012 (Kalkheuwel) within the *Harties metsi a me* programme. Currently available monitoring data indicate that the Crocodile River sediments contain a considerable mass of loosely-bound nutrients that should be removed before entering the dam.

Contrary to previous initiatives and plans for the HBPD remediation, the *Harties metsi a me* programme has recognised the importance of the dam's Internal P load, and has developed a present and future strategy to deal with it. Data on the composition of top layer sediments (as derived from a comprehensive research study of HBPD sediments, Cukic 2008) indicates that such sediments should be regarded as a resource and not a waste. They could be processed for reuse (land conditioning, tailings dam rehabilitation, composting, etc), thereby serving environmental restoration and protection, compensating for the environmental disturbances of the catchment from which they originally derived.

> The Sediment Removal and Management Project will focus on: the removal of top-layer dam sediments rich in nutrients, including the "jelly" layer; the removal of sediments currently accumulated in the Crocodile River inlet zone and river mouth; the future interception of incoming sediments with associated nutrients; and the processing of removed materials for beneficial uses.

GOALS

Several goals have been set for the project:

- Reduction of historical Internal Nutrient load (i.e. recycling), aiming to reduce the dam's trophic levels.
- Reduction of the current influx of sediments and associated nutrients, by the improvement of settling efficiency and sediment retention capacity at the inlet zone and mouth of the Crocodile River.
- Reduction of future influx of sediment and associated nutrients to the dam, by an in-stream intervention (conditionally foreseen as the pre-impoundment).
- Processing of extracted materials for beneficial uses (such as soil amendments, compost, tailings dams rehabilitation) and manufacturing of marketable products (such as bricks, blocks, etc), thereby creating new jobs and recovering a portion of the costs associated with sediment dredging and processing.

APPROACH

The approach to sediment removal and management could be summarised as follows:

- Remove nutrient-laden top sediments from the aquatic environment – where they produce harmful effects – to terrestrial environments where they can be put to benefit.
- Carry out all operations in an environmentally safe, technically feasible, financially reasonable, and socially acceptable manner.
- Use a part of the coarser sediments for the manufacture of construction materials, thereby achieving more efficient cost recovery.
- Motivate and mobilise entrepreneurship (dredging operations, processing of dredged materials, power plant construction, extension of railway activity, etc).
- Stimulate job creation based on the activities as envisaged.

OBJECTIVES

Among the many objectives set within the project, the most important ones are the following:

- Dredging of the dam's nutrient-laden top sediment layers (dam wall zone, dam main basin, Magalies River mouth) for the reduction of Internal Nutrient load.
- Dredging of sediments accumulated in the Crocodile River's inlet zone for recovery of its settling efficiency / retention capacity.
- Partial dredging of the Crocodile River mouth for the improvement of its settling efficiency / retention capacity.
- Processing of dredged materials for the separation of solid and liquid phases.

Figure 2: Spatial distribution of sediments within the HBPD

Figure 3: Spatial distribution of sediments in the Crocodile River inlet zone and river mouth

- Processing of separated solids for the production of top-soil for agricultural use and tailings dam rehabilitation, while providing new jobs and partial cost recovery.
- Processing of separated sand and part of the coarser materials for the manufacture of marketable products (sand, bricks, blocks, aggregate, etc) for the construction industry, while providing new jobs and substantial cost recovery.
- Collection and treatment (if needed) of separated water for discharge back into the dam or for reuse in agriculture and industry.
- Carrying out all operations in an environmentally safe manner, without disturbance of neighbouring interests.
- Job creation and establishment of small community projects (SMMEs), based on the dredging and processing of dredged materials.

STRATEGY

Several interconnected operations/activities will be involved in the removal and management of sediments. They should be synchronised, optimised and completed within planned time frames. These operations include:

- Dredging/extraction of sediments – present and future
- Primary transport of dredged/extracted materials
- Processing of dredged/extracted materials including:
  - separation of liquid and solid phases
  - dewatering of solids
  - collection and treatment (if needed) of separated liquid phases for reuse or safe discharge
  - processing of solids for the manufacture of environmentally valuable and marketable products.
- Establishment of small community projects (SMMEs) and creating new jobs.

Dredging/extraction of sediments

The dredging/extraction operation will include the extraction of ~ 5.5 x 10^6 m^3 top layer nutrient-rich sediments within the dam's main basin – including the "jelly" layer and the Magalies River mouth sediments as necessary steps for the reduction of the dam's internal nutrient load to a desired level. This will require the extraction of deep-water top sediments.

An additional volume of ~ 2–2.25 x 10^6 m^3 of sediments from the Crocodile River inlet zone and river mouth should be dredged in order to remove the nutrient-rich sediments, as well as to recover sediment retention capacity and to improve settling efficiency in this zone. Combined deep-water sediment

The purchase of contemporary multi-purpose dredging equipment is intended. The establishment of a dredging team within the Harties metsi a me programme is envisaged to assist with shallow water dredging, as well as with shoreline/wetlands remediation and the harvesting and removal of biomass

Figure 4: Mobile, multi-purpose, shallow-water dredging equipment (to be purchased)

Table 1 Volumes of sediments to be dredged/extracted

Area	Type	Volume 000 m^3
Dam wall zone & northern dam basin	Jelly layer	300 – 500
	Top layer	1 000 – 1 500
Central / southern dam basin	Top layer	2 000 – 2 500
Crocodile River inlet zone	Top layer and part of consolidated sediment	1 000 – 1 250
Crocodile River mouth	All sediment	1 250 – 1 500
Magalies River mouth	Top layer	300 – 500
TOTAL		**5 850 – 7 750**

extraction and shallow-water dredging (Figure 4) would be applied in this operation.

The purchase of contemporary multi-purpose dredging equipment, similar to those depicted in Figure 4, is intended. The establishment of a dredging team within the *Harties metsi a me* programme is envisaged to assist with shallow water dredging, as well as with shoreline/wetlands remediation and the harvesting and removal of biomass.

The volumes of sediments to be dredged/extracted from the indicated zones are presented in Table 1.

Dredging of the "jelly" layer from the dam wall zone (Figure 2) and of sediments from the Crocodile River inlet zone and river mouth (Figure 3) is considered a priority. Both schemes will be examined through so-called bulk sampling and pilot runs before actual operations will be finally designed and implemented.

> About 5.85–7.75 x 10^6 m^3 of sediments should be dredged/extracted once-off in order to reduce the historical sediment and internal nutrient load to target levels. Both deep-water dredging/extraction and shallow-water dredging techniques should be applied.

The dredging operation and hydraulic transportation of dredged materials require energy. The construction of a small hydro-power plant (~0.5 MW) in the dam wall zone is strongly recommended, in order to provide energy for the dredging and 'primary transport' of sediments, and for use by other consumers after the completion of dredging operations.

Transportation of dredged/extracted materials

The transportation of dredged materials (termed 'primary transport') will be performed hydraulically in order to avoid environmental risk, traffic pressure, and social disturbance. The general strategy is to transport dredged/extracted materials from the dam wall zone and northern part of the dam basin, to mines and farms situated northeast and northwest of the dam. However, materials from the southern part of the dam basin should be transported to the Oberon area.

Materials extracted from the Magalies River mouth would be transported to Kommandonek. Materials dredged from the lower part of the Crocodile inlet zone and river mouth would be transported to the Oberon area, but materials dredged/extracted from the upper part of the Crocodile inlet zone would be transported to the *Roos se Oord* area (refer to map on page 17 for orientation).

Dredged materials from the dam wall zone (~ 0.5 x 10^6 m^3 of "jelly" layer) and northern part of the dam's main basin (~ 10^6 m^3 of top layer sediments) would be transported towards farming/mining areas north, northeast and northwest of the dam.

Three options for the hydraulic transportation of sediments from the dam wall zone and northern part of the dam basin are considered viable:

Option A: Transportation towards the Crocodile River Mine, with possible (Option B) to the east (towards the Eland Platinum Mine) and/or to the west (towards mines in the Rustenburg area that are in need of water supplies).

Option C: Transportation towards the Eland Platinum Mine with possible extensions to the west towards the Crocodile River Mine and/or towards mines in the Rustenburg area that are in need of water supplies.

The processing of dredged/extracted materials

As mentioned above, sediments from the dam, as well as water separated from them, are to be considered a resource. Accordingly, strategies to process them and to establish schemes for their beneficial uses have been considered and developed. Several operations are required for the processing of dredged/extracted materials, including;

- Separation of liquid and solid phases
- Collection of separated liquid phases for reuse/safe discharge
- Dewatering of solids
- Processing of solids for the manufacture of environmentally valuable and marketable products.

In Figure 5 the general scheme is presented for the processing of dredged/extracted materials to produce environmentally valuable and marketable products (such as compost, soil conditioners, material for tailings dam rehabilitation, etc); construction materials (such as blocks, bricks, poles, agglomerates, etc); and water for reuse and/or safe return to the dam.

All these products are marketable and could provide recovery of costs associated with dredging/processing. It could also generate 80–100 new jobs over the next ten years. There would be a multiplier effect of 2–3, taking into account transportation, distribution and application of final products. It is roughly estimated that a recovery of 50–150% could be achieved, depending on the scheme applied, investments made and the market response.

The scheme as presented in Figure 5 would be modified depending on local-specific conditions and requirements as envisaged for the areas where large portions of land are available. Such a modification will be made for the processing of dredged materials from the dam wall zone and northern part of the dam's main basin that would be transported towards farming/mining areas north, northeast and northwest of the dam. Parts of the Eland Platinum Mine property and the HADECO flower farm are primarily intended for processing of these dredged materials. The irrigation scheme (refer to Figure 6) with reused water would be developed to accomplish this operation.

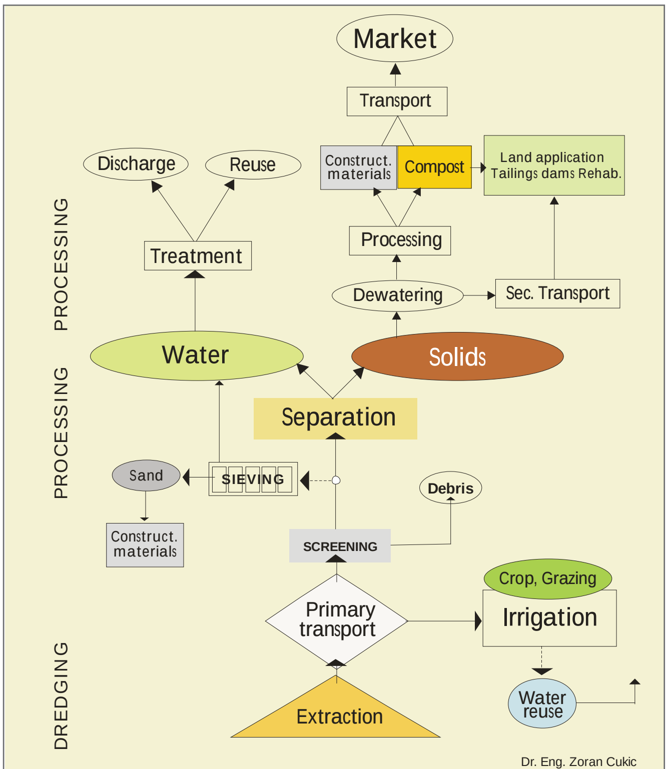


Figure 5: The layout of a general scheme for the processing of dredged/extracted materials

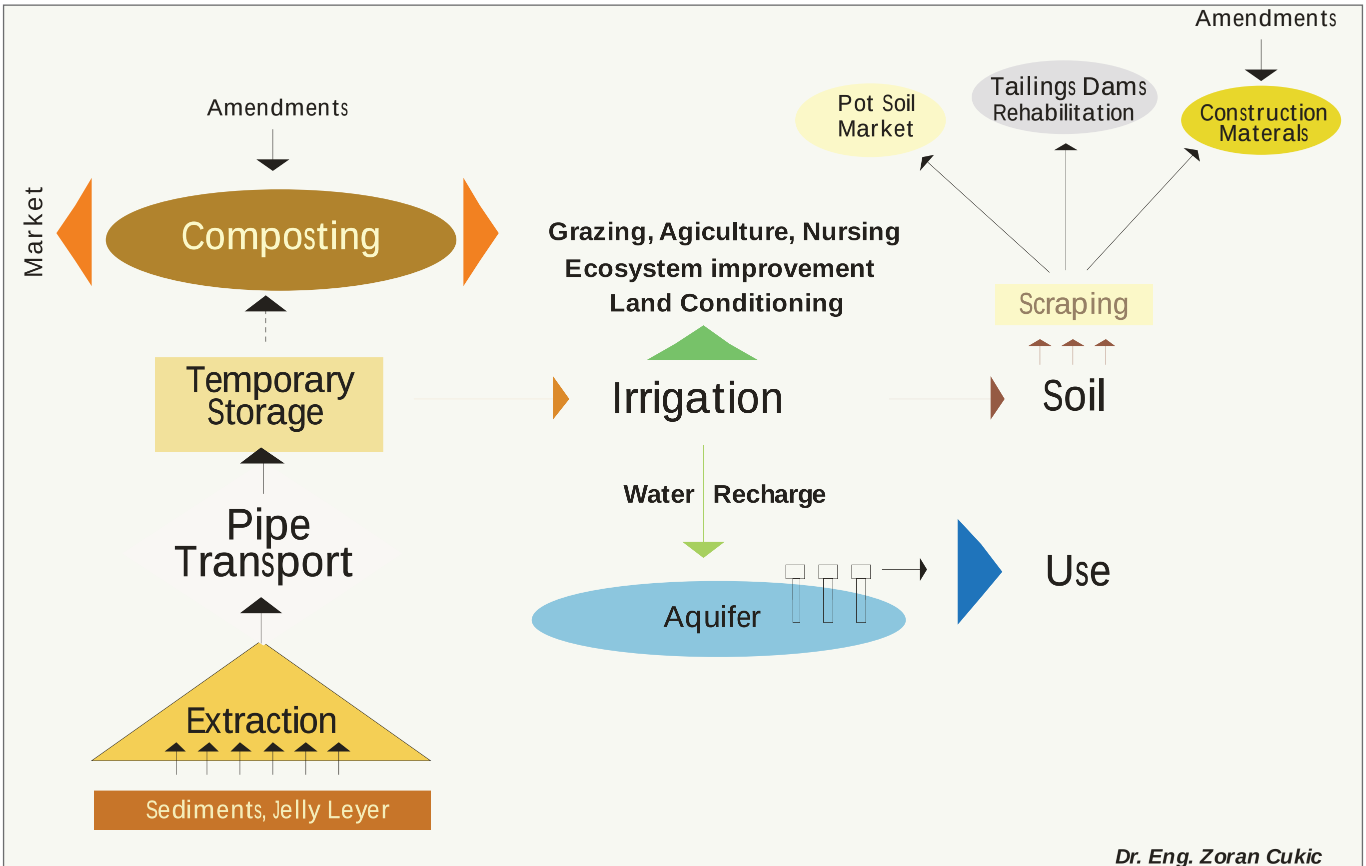


Figure 6: The layout of the envisaged irrigation scheme for the processing of "jelly" layer and top-layer sediments from the dam wall zone and northern part of the dam's main basin

Following a step-by-step approach for the design and implementation of the processing scheme, a pilot study to identify elements for the design and to assess the environmental impact will be carried out at the Eland Platinum Mine and HADECO flower farm. This would be done by materials provided through the bulk sampling (extraction of a limited volume) of "jelly" layer and top layer sediments from the dam wall zone.

The irrigation scheme (Figure 6), with site-specific modifications, will be applied at Kommandonek for ultimate disposal of dredged materials from the Magalies River mouth and for processing of separated water up to the levels required for discharge back into the dam.

The top-layer sediments from the central and southern part of the dam's main basin, sediments from the Crocodile River mouth, as well as sediments from the lower part of the Crocodile River inlet zone will be processed for beneficial uses in the Oberon area, from where the final products will be transported to end users. Separated water will be processed to the levels required for safe return to the dam, with possible use for agriculture and various other water features.

> Oberon is considered a key area for the processing of dredged materials from the central and southern part of the dam's main basin, the Crocodile River mouth and lower part of the Crocodile River inlet zone. The Crocodile River sediments that should be retained and extracted in the future could also be processed in the Oberon area, depending on the option implemented. Revival of the railway line between Pretoria and Magaliesburg to assist with the transportation of final products from the Oberon area is highly recommended.

The dredged materials from the upper part of the Crocodile River inlet zone will be processed in the nearby *Roos se Oord* area. The final products will be transported to end users and separated/processed water returned to the Dam, or potentially reused in agriculture if land would be made available.

Incoming sediments (~ 0.25-0.3 x 10^6 m^3/y) that will be retained in the envisaged pre-impoundment (yet to be considered), will also be transported to the *Roos se Oord* area where they will be processed for beneficial uses. The final products will be transported to end users and separated/processed water returned to the dam for agricultural reuse.

> The Roos se Oord/Pelindaba area is considered the key location for the removal and processing of sediments from the upper part of the Crocodile River inlet zone and, depending on the options implemented, this would also be the area of choice for the future handling of sediments that would be extracted from the envisaged pre-impoundment.

A part of the Pelindaba property, next to the *Roos se Oord* area, would potentially be used for the temporary disposal and processing of sediments from the upper part of the Crocodile River inlet zone and for the retention of incoming sediments. A considerable portion of land available in this area holds positive potential for irrigation as the most suitable scheme for the processing of dredged materials and water reuse.

Dr Eng Zoran Cukic, Petrus Venter

Source:
http://www.saice.org.za/downloads/monthly_publications/2012/2012-Civil-Engineering-August/#/0