ADDENDUM

SOIL STRIPPING, STOCKPILING AND PLACEMENT OF SOIL DURING REHABILITATION

(From Botha *et al* 2002)

Soil Stripping

It is recommended that all usable soil is stripped and replaced after final removal of mining infrastructure. As a minimum measure, however, no less than 800mm of soil should be stripped. These estimates take into consideration a possible 10% topsoil loss through compaction, and allow the rehabilitated areas to be returned to the pre mining land capability, i.e. arable land. During the construction phase it is recommended that the topsoil be stripped and stockpiled in advance of construction activities that might contaminate the soil. It is recommended that the cut off depth of stripping be determined by using interception of the underlying geology as criteria.

The stripped soils should be stockpiled upslope of areas of disturbance or mining development to prevent contamination of stockpiled soils by dirty runoff or seepage. All stockpiles should also be protected by a bund wall to prevent erosion of stockpiled material and deflect surface water runoff.

Hutton and Arcadia soils should be stockpiled separately because they have different textures and soil structure. These soils should not be mixed when used for rehabilitation purposes and it is recommended as far as possible to replace the Hutton stockpile to its original position.

Stockpiles can be used as a barrier to screen operational activities. If stockpiles are used as screens, the same preventative measures described above should be implemented to prevent loss or contamination of soil. The stockpiles should not exceed a maximum height of 6m and it is recommended that the side slopes and surface areas be vegetated in order to prevent water and wind erosion. If used to screen mining operations, the surface of the stockpile should not be used as a roadway as this will result in excessive soil compaction.

Wherever possible, the volume of soil stockpiling should be kept to a minimum through the live placement of soils stripped in advance of mining operations onto mined out areas where spoils have been levelled in preparation for rehabilitation.

Rehabilitation and closure

When stockpiled soils have been replaced during rehabilitation, the soil fertility should be assessed to determine the level of fertilisation required to sustain normal plant growth. The topsoil should be uniformly spread onto the rehabilitated areas and care should be taken to minimise compaction that would result in soil loss and poor root penetration.

When returning soil to the rehabilitation site care should be taken to place soil in a manner that will allow for levelling of soil to take place in a single pass. The soil profile should not be built up using a repeated tipping and levelling action to increase the soil depth.

Proper water control measures should be implemented to ensure a free draining rehabilitated landscape. Re-seeding should occur as recommended in the fauna and flora report (Report number: WMB 4940/2761/1/E).

The soil depth at all sites exceeded 600mm resulting in the classification of all areas as having arable land capability. When the sites are rehabilitated a minimum of 700mm of soil should be replaced to return the post-mining land surface to arable potential. A post-mining soil depth of 700mm is recommended in order to buffer against soil depth reductions through settlement or poor soil placement and profiling.

RSA POPULATION CENSUS STATISTICS

Table 1: Age distribution in the Bojanala Platinum District Municipality (BPDM):

Age (yrs)	Total	Percentage
0-6	38 588	12.6
7-13	32 945	10.8
14-18	22 912	7.5
19-22	20 927	6.8
23-64	175 635	57.6
65+	10 486	3.4

(Source: RSA Population Census, Statistics South Africa, 1996)

Table 2: Education and income levels

Level	Numbers	Percentage
Gr. 1 - Std. 5	96 656	31.6
Std. 6 - 10	111 506	36.3
Diploma with Std. 9	4 767	1.6
Diploma with Std. 10	5 939	1.9
Degrees	4 551	1.5
Total	**306 354**	**100.0**

(Source: RSA Population Census, Statistics South Africa, 1996)

Table 3: Language distribution

Language	Formal settlements			
	Boitekong	Mfidike	Photsaneng	Thekwane
IsiNdebele	9	5	-	-
IsiXhosa	991	1285	649	422
IsiZulu	164	84	40	1
Sepedi	148	90	51	65
Sesotho	213	263	149	68
Setswana	5848	1521	1955	1903
Siswati	35	113	20	9
Tshivenda	36	19	-	-
Xitsonga	402	235	66	163
Afrikaans	25	3	-	4
English	7	4	-	-

(Source: RSA Population Census, Statistics South Africa, 1996)

It is alleged that the BPDM's average per capita income is higher than that of the province. In 1996, for example, the average per capita income in the Bafokeng and Rustenburg was R7 172 and R12 333 respectively, while the provincial average was R5 033. This is attributed to the relatively high salaries earned by the mineworkers in the district.

Design guidelines

1. Exterior berm construction
   - The purpose is to regulate and contain water within specific flow paths
   - Keep berms as small as possible for aesthetic reasons
   - Provide a freeboard sufficient to prevent overtopping during a rain event with a frequency of 25 years or more
   - Consider berm soil consolidation and subsidence as well as gradual wetland fill with vegetation and sedimentation thus reducing capacity
   - Berm height = maximum desired normal operation level + return storm rainfall amount + (lifetime loss of freeboard due to sedimentation, plant accumulation and sediment).
   - Provide clay lining to reduce permeability of mother berm material is too pervious or install external seepage collection channels
   - 3m wide at top for vehicle access, 1m wide for pedestrian access
   - Water containment berms are subject to local dam safety regulations
2. Flow diversion banks
   - The purpose is to divert water through the wetland thus creating a longer flow path to improve efficiency via increased hydraulic residence time
   - The top may be above of below water level
3. Detention time and pollution removal
   - Between 5 and 14 days for soluble pollutants removal (Reed et al. 1988; Watson et al. 1989; Watson & Hobson 1989; Hammer 1989; Crites 1994; Kadlec & Knight 1996)
   - Between 0.5 and 3 days for suspended pollutants removal (Ibid)
   - Pollution removal efficiency reduces as temperature drops
4. Hydro-period and water regime
   - Hydro-period: "…the number of days per year of surface water at a given wetland location." (Kadlec & Knight 1996)
   - Water regime: "…the hydro-period as well as the combination of water depth and flooding duration."
   - Duration and depth of flooding affects plant physiology because of soil oxygen concentration, soil pH, nutrients and toxic chemical concentrations.
   - Suggested hydro-periods:
     - Channel zones - 360days per year
     - Reed bed area - 300 days per year
     - Shrubs and trees - 0-60 days per year
5. Hydraulic preferential ways
   - A sinuous pattern of open flow channels are recommended to avoid hydraulic short circuiting
   - To minimise short circuiting a uniform longitudinal bottom slope from inlet to outlet should range from 0%-5% (Hammer 1989)
6. Length to width ratio
   - A high length to width ratio is recommended in order to minimise short circuiting and maximise the contact with bio film substrate for biological removal of pollutants
   - Minimum length to width ratio for an economical design (i.e. to reduce berm construction cost) is in the order of 2:1 (Knight 1978)
   - The optimum length to width ratio is in the order of 10:1 (Hammer 1989)
   - Effective flow distribution can also be achieved by providing:
     - Adequate inlets
     - Deep zones
     - Islands
     - Flow diversion banks, etc.
   - The aspect ratio of the macrophyte zone should range from 4:1(length : width) to10:1 (DLWC - New South Wales 1998)

7. Drainage
   - Draining of a constructed wetland can be beneficial for the following reasons:
     - It allows supplementary planting if initial results was poor
     - The control of weeds are possible
     - It aids in mosquito and fish management
     - It facilitates control over potential erosion
     - It allows repair of the wetland
   - Design deep zones to provide a refuge for fish and amphibians during dry periods
8. Inlet zone
   - The inlet should provide a controlled entry of water to the wetland
   - An effective flow distribution is a requirement from the inlet in order to minimise short-circuiting and dead zones as well as to increase the frictional resistance
   - Water velocities less than 10cm/s are recommended for unprotected bottoms (Marble 1992)
   - Peak water velocities should not exceed 45cm/s through the wetland (Jones 1995)
   - Energy dissipation may be required to counteract erosion
   - To reduce the possibility of a potential algae bloom in the inlet zone, it is necessary to minimise direct sunlight contact with the water
   - In the case of poor oxygen saturation of incoming water it may be necessary to allow oxygenation to enhance nitrification before the macrophyte zone
   - The slope of the bottom in the inlet zone should be practically zero to ensure an equal water distribution
9. Islands
   - Islands enhance hydraulic efficiency by diverting the flow and increasing the contact area as well as providing visual and habitat variety
   - The size and shape are determined by the following (DLWC-New South Wales 1998):
     - Flow conditions and wetland characteristics
     - Visual impact
     - According to the function of the wetland (flow diversion, energy dissipater, etc.)
   - An island should be greater than 25m² and separated from the wetland's shoreline with permanent deep water (Marble 1992)
   - The island's surface should be 30cm or higher then the normal water level
   - To minimise erosion of the island banks, it is necessary to establish vegetative cover right to the water's edge
   - Provide walk access for water fowl
10. Littoral zone
    - The littoral zone is the interface between terrestrial and aquatic habitats
    - Gentle slopes provide excellent littoral habitat for most fauna and flora associated with this zone
    - Littoral vegetation provide bank protection against erosion
    - Habitat opportunities can be maximised by:
      - Constructing gentle slopes
      - Vegetating with diverse littoral species
      - Incorporating sinuous edge conditions to maximise the littoral habitat
11. Fetch and resuspention
    - Fetch: "…the maximum length of exposed water surface, in the direction of the wind, over which wind can blow unimpeded to generate waves."
    - To prevent the effect of fetch the wetland open water zones should be located perpendicular to the prevailing wind direction
    - Resuspension: "…the process that takes a particle from the sediment and moves it in the water body."
    - Minimal fetch and exposure to wind will discourage the resuspention and transportation of sediment
    - If the selected site is exposed to long fetch and a risk of bank scouring and resuspention exists, sufficient protection from the adjacent topographic relief or vegetation should be provided
12. Vegetation
    - It is necessary to provide access to vegetation to facilitate the required maintenance
    - The ratio of open water surface to reed bed area depends on the following objectives and their priority to each other:
      - Water quality
      - Habitat diversity
      - Aesthetics/recreation
    - A ratio of 1 to 3 (open water area : reed bed area) is suggested for a multi-objective design
    - If water quality is the highest objective a ratio of 1:5 should be considered
    - Habitat diversity suggest a ratio of 1:1

13. Outlet zone
    - The design of the outlet zone should consider
        - Avoiding dead zones
        - Controlling water level
        - Avoid blocking
        - Facilitate monitoring of flow and water quality
    - A deep water zone is suggested to collect and route flows to an outlet weir
    - This terminal deep zone must be kept small to discourage long residence time and subsequent algae bloom
    - Outlet structures are often sensitive to accumulation of debris and subsequent blocking
    - A final filtering of biomass is desirable to reduce biomass export
    - A rock filter or mesh debris fence can alleviate this problem but need to be cleared form time to time
    - It is desirable to control the water level of the wetland at the outlet zone. The choice of structure used should be dependent on the condition and the objective
14. Gradient of water-land interface
    - Reed beds should slope very gentle ranging between 1:6 and 1:8 to provide shallow water for wetland processes (DLWC-New South Wales 1998). These slopes are also conducive to public safety
    - A gradual slope between 1:4 and 1:6 permits free movement for many waterfowl species (Green & Salter 1987; Proctor et al 1983; Bartoldus et al 1994)
    - Recommended minimum water to land slope is 1:6 to 1:10
15. Variety of substrate
    - A variety of substrates along the shoreline is desirable in providing a diversity of habitats for fauna and flora
16. Macrophyte zone
    - The depth of the reed beds or macrophyte zones may vary from a minimum depth of 0.1 to a maximum of 0.5m with 0.4m as the optimum depth (DLWC-New South Wales 1998)
    - An aspect ratio from 4:1 (length : width) to 10:1 should be considered to discourage short circuiting and to increase the hydraulic efficiency
17. Water flow and depth control
    - Water depth and flow velocity are important factors influencing the dissolved oxygen concentration of wetlands
    - Higher flow rates in shallow water tend to increase the dissolved oxygen concentrations caused by atmospheric aeration
    - A higher dissolved oxygen concentration directly correlates with higher aquatic invertebrates and vertebrate presence and activity
    - Water depth is the main factor affecting wetland plant growth. Each zone as an optimum operational level and should stay constant to minimise stress for vegetation
18. Deep open water zones
    - The depth of open water can vary between 1.3m and 2.5m (DLWC-New South Wales 1998)
    - The slopes for open water areas can be relatively steep, i.e. 1:3 to 1:5 (DLWC-New South Wales 1998), however if an island is present then slopes of 1:5 - 1:8 should be considered
19. Water level fluctuation
    - Severe fluctuations will have severe negative effects on the ecological balance of a wetland
    - Maximum daily water level fluctuations of 300mm is acceptable without any negative results (Smith et al 1981)
    - Fluctuations greater than 900mm have adverse effects (Fisher & Lavoy 1972)
20. Wetland morphology
    - In order to maximise macrophyte growth the wetland should be shallow, sheltered, soft-bottomed and unshaded
21. Wetland soils
    - Soils with a high humus and sand component are suitable with regard to vegetation establishment