Ecohydrological Assessment of the Wetland Catchment within the Proposed Eskom Kusile Ash Dump Facility

SUMMARY Report

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Reference 689-2011

APPROVAL

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July 2012		

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REVISION

DATE	No.	DESCRIPTION OF REVISION OR AMENDMENT	INITIAL

DOCUMENT SUMMARY DATA

PROJECT: **Ecohydrological assessment of the catchment of the wetland depression within the proposed Ash Dump Facility of the Kusile Power Plant from Eskom and recommendation for the size of appropriate buffer.**

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INDEMNITY AND CONDITIONS RELATING TO THIS REPORT

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1. INTRODUCTION

Wetland Consulting Services (Pty) Ltd. was appointed by Shael Harris from Sebata Institute to undertake an ecohydrological assessment of the wetland's catchment located within the proposed Ash Dump Facility (ADF) of the Eskom Power Station.

The purpose of this study is to assess the surface and subsurface water flows in order to provide guidelines for proposing a buffer zone around the wetland to ensure its protection. The target wetland is the pan and its associated seepage wetlands delineated by Wetland Consulting Services Report 689-2011 contributions.

2. OBJECTIVES

- Identification of the major water fluxes within the catchment contributing water to the wetland.
- Quantification of Lateral Throughflow (LTF) wetland contribution using 2-dimensional transects modelling with HYDRUS (Šimůnek et al., 1999).
- Estimation of the extend of an appropriate buffer around the wetland boundary.

3. LIMITATIONS

- Modelling of hillslope hydrology is a very complex task which requires thorough calibration and detailed information of soil properties which could not be carried out in the scope of this assessment. Soil texture estimates measurements were estimated in the field as well as compared to laboratory results from a geotechnical investigations carried out in the area ("Bravo Ash Dump Report.doc"). However, no soil classification was carried out in the region and soil textural data that was available was not always at the desired depth of location.
- The water balance of the study area needs to be closed and all processes have to be accounted for to achieve reliable results, however the means of this study were limited and assumptions in regard of water balance components were made.
- Meteorological data such as Rainfall and Evaporation was sourced from the Middelburg Farms Weather Station which is approximately 70 km in North-East-Easter direction from the study site. The weather conditions and rainfall amounts at the study site are likely to vary from the data used in this study.

- Not all modelling transects could be analysed in sufficient detail. Auger depth was limited to 1.2 m below surface.
- The number of Saturated Hydraulic Conductivity (K_{sat}) was limited to 6 measurements which were performed at the surface and subsurface up to 0.8 mbgl.
- No measurements of unsaturated hydraulic conductivity or water retention characteristics were taken. Instead values were estimated from soil textural estimates using the neutral network predictions Rosetta (Module included in HYDRUS).
- No actual readings of soil moisture, matrix pressure head or other water related measurements were performed which excludes the comparison between modelled and actual soil moisture values.
- The study is limited to the pan wetland as well as the immediate surrounding hillslope seeps. The contact seepage wetlands within the area are not included in this study.
- Other assumptions made are mentioned in the methods section,chapter 5.

4. STUDY AREA

The study area was described by Allan Bachelor from Wetland Consulting Services in the report “Wetland Verification, Delineation & Impact Assessment for Kusile Ash Dump” (Reference: 689/2011).

Only additional information about the study area is presented in this chapter.

4.1 Catchment

The catchment for the study area is defined as the area where water will potentially drain into the wetlands whereby the delineation was based on surface topography using 1 m elevation contour lines. The approximate extend of the wetland catchment is shown in Figure 1. The total area of the catchment is only 0.31 km^2.

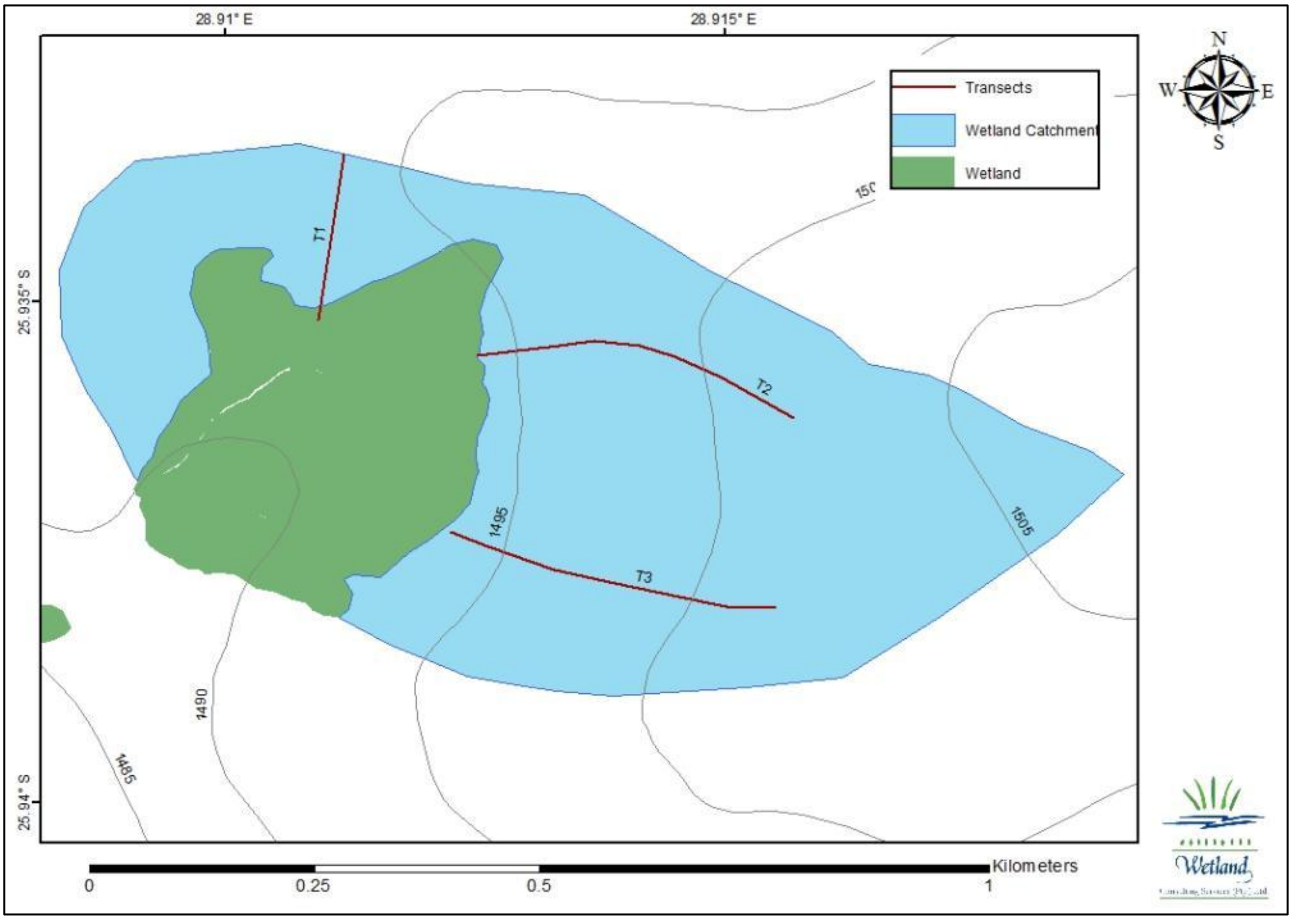

Figure 1: Wetland's catchment and modelling transects. Elevation contour lines are in 5 m intervals.

4.2 Hydrology of the Soils

Subsurface flow processes potentially have a large contribution to the wetland. It is important to assess whether flow paths actually contribute to wetland soils or drain to depths where plants do not have access. In this sense the following definitions shall distinguish between contribution to wetland soils and water moving away from the wetlands such as groundwater recharge.

Definitions:

Lateral Throughflow (LTF) is water that flows laterally within the active soil profile where soil forming processes take place and roots are abundant or where water flows within the boundary between the soil profile and bedrock such as saprolite or weathering fronts. LTF typically occurs lower in the soil profile in E-horizons or within saprolite when the parent material is less permeable than the material of the soil.

Groundwater in this study is defined as saturated conditions that occurs below the active soil profile and where roots only occur sporadically.

The soils at the upper positions of the hill slopes showed signs of temporary saturation at the bottom of the soil profiles at about 1 to 1.2 mbgl, however the thickness and storability of the soil is unlikely to cause LTF as all rainfall can be captured by the soil profile. Further downslope the soil profile becomes shallower and hence the capacity to store water is less. During summer this causes saturation in the lower part of the profile where water accumulates and hence causes LTF which is then driven by gravity (soil matrix pressure head approaches zero).

4.3 Landuse

The entire area of the catchment is covered by fallow lands and natural grassland. Clumps of Black Wattle trees occur close to the dirt road in the north of the catchment. It is assumed that the few exceptions do not have a large impact on the modelling results and hence the entire catchment was treated as grassland only.

5. APPROACH

The approach followed in this study was to attempt to determine the key hydrological processes supporting the wetland in question. This was based on a catchment basis, with the intention of defining the probability of rainfall falling within the catchment actually reaching and contributing to maintaining the wetland.

Typical factors that need to be considered in the approach include infiltration of rainfall, surface runoff, evaporation, transpiration (by vegetation), groundwater percolation, Lateral Throughflow (LTF), seepage, ponding and water storage in the soil matrix. Furthermore the seasonal and annual variation in rainfall needs to be considered.

In this study the model HYDRUS (Šimůnek et al., 1999) was used which is most capable to capture all hillslope processes. A graphical illustration of the flow components used in the modelling is shown in Figure 2.

In order to account for seasonal and inter-seasonal variation a period of 10 years was modelled. Within this period there was at least one dry, mean and wet year.

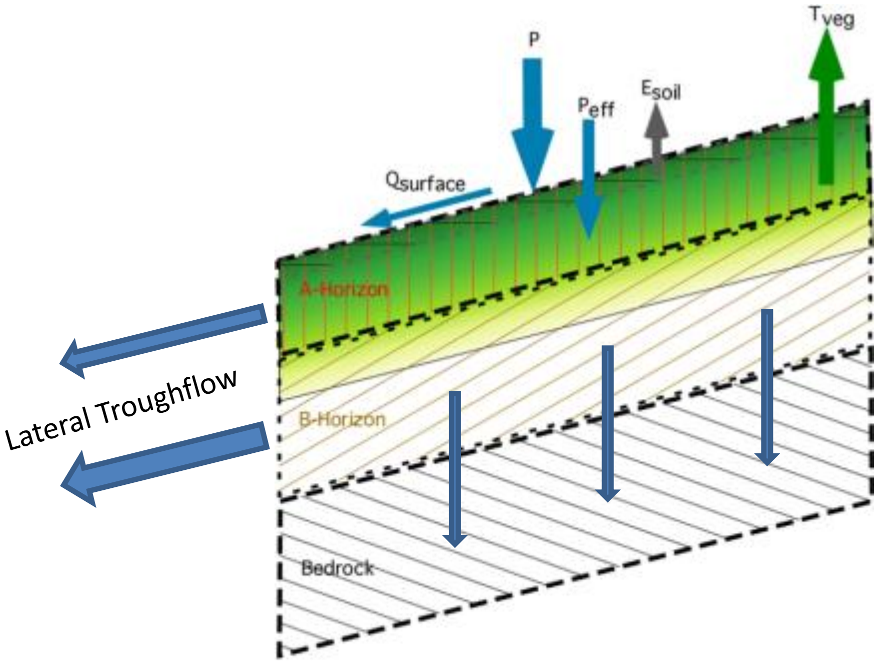

Figure 2: Conceptual flow pathways in 2-dimensional modelling of the vadose or unsaturated soil zone.

6. RESULTS

The objective of this study was to attempt to define the area outside of the wetland boundary where activities in the wetland catchment were not expected to significantly affect the hydrology of the wetland (depression).

6.1 Conceptual Outline of Flow Paths into the Wetland

Test pits/boreholes within the wetland catchment have shown the evidence of lateral throughflow (LTF) mainly at the interface between soil and weathered dwyka tillite. The otherwise relatively impermeable tillite material has weathered to a large extend within shallow depths below the soil profile and hence form a seasonal shallow phreatic aquifer which is most likely in contact with the wetland. However, a hard plintic horizon in form of ferricrete is subject to another impermeable shallower layer. This ferricrete layer only exists within close range of the wetland in depths between about 0.4 and 0.8 mbgl and most likely caused the formation of a leached shallow E-horizon, in the same area.

Based on these observations it is suggested that are therefore two main pathways of water from the catchment into the wetland. First the shallow LTF mainly within the E-horizon just above the ferricrete and second preferential flow paths at the soil-tillite-interface flowing below the ferricrete and probably influencing the pan basin directly due to the lack of any detectable ferricrete layer within the pan itself. The schematic below is an interpretation, based on the test pits and borehole logs of a cross section through the catchment and the pan/depressional wetland. Modelling of flows was only performed to the upslope edge of the depression along the transects indicated in Figure 1 and does not assess the possible pathways within or below the wetland soils.

The possible contribution of shallow seasonal groundwater within the weathered tillite material potentially contributes to the wetland but could not be addressed quantitatively in this study. However the recharge of the seasonal shallow aquifer was assessed and is presented as groundwater recharge and quantified in section 6.2.

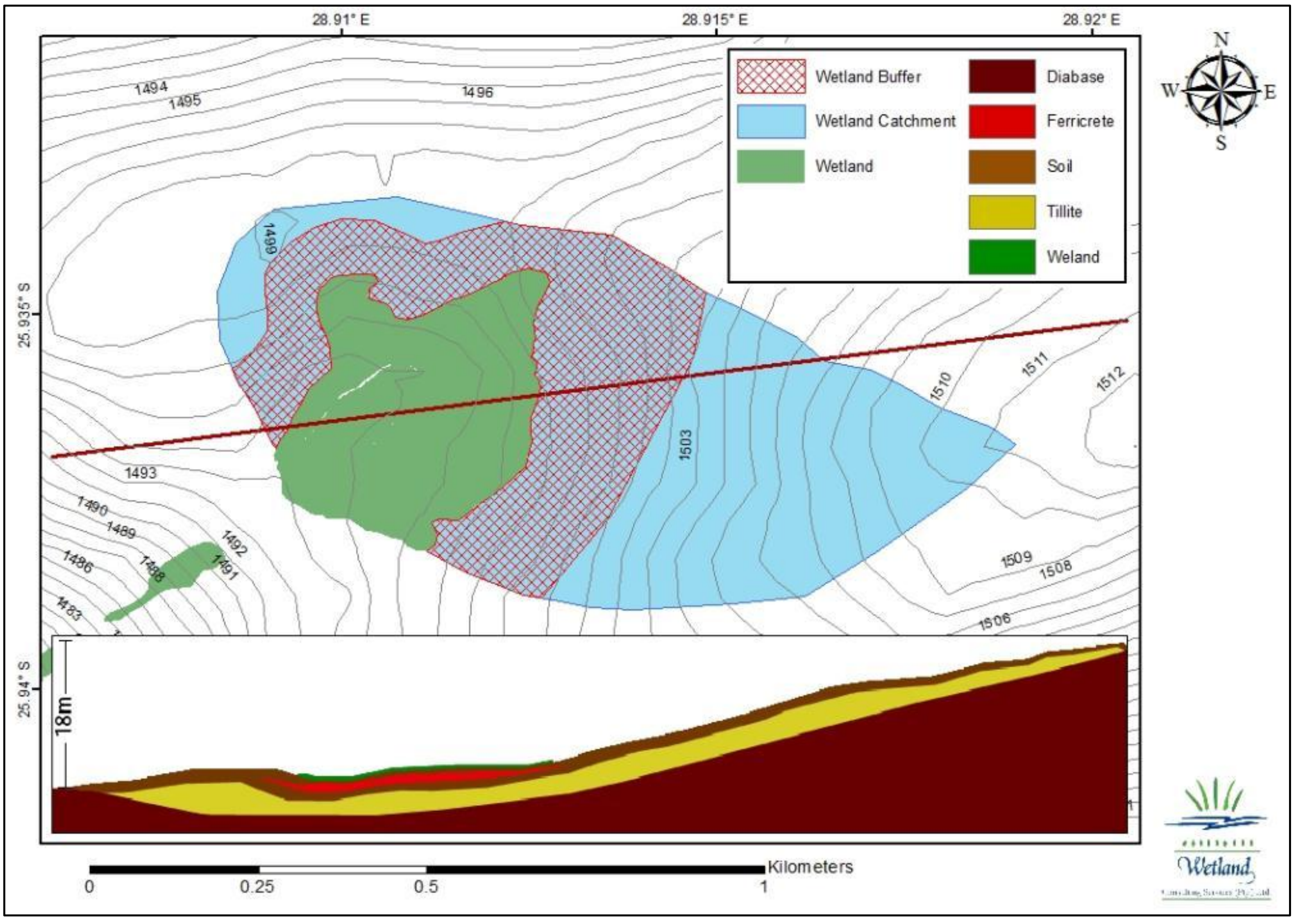

Figure 3: Transect along the study area showing the relationship between soil, geology, wetland and wetland buffer.

The LTF contribution to the wetland soils is limited to the above ferricrete layer only as the ferricrete layer is the boundary between soil (above) and shallow aquifer (below) and acts as a near impermeable layer.

6.2 Water Balance

A water balance equates all fluxes over a specified period and defined domain. The modelling period started on the 01/06/2002 and ended on the 21/05/2012.

The water balance summarized in Table 1 shows the dominance of ET.

Table 1: Water balance components for the period between July 2004 to May 2012 for all modelled transects (T1-T4). GWR is the calculated Groundwater Recharge, LTF is Lateral Throughflow at the end of the transect, Q_{sur} is the surface runoff, P is Precipitation, ET is actual Evapotranspiration and dS is the change of water content in the soil.

Site	GWR (mm)	GWR (% of P)	LTF (mm)	LTF (% of P)	Qsur (mm)	P (mm)	INF (mm)	ET (mm)	dS (mm)
T1	132.6	1.9	44.3	0.6	3.2	7029.7	7026.6	8105.3	-125.6
T2	114.7	1.6	19.1	0.3	1.1	7029.7	7028.6	8632.1	-173.3
T3	35.6	0.5	32.0	0.5	2.4	7029.7	7027.3	8369.5	-140.8
AVG	**75.1**	**1.1**	**25.6**	**0.4**	**1.7**	**7029.7**	**7028.0**	**8500.8**	**-157.1**

6.3 Lateral Throughflow

LTF mainly occurs when water is ponding due to a lower permeable layer in the matrix and then starts moving downslope driven by gravity. Based on the modelled results, rainfall vs. LTF, for the three transects yielded similar results**Error! Reference source not found.**. This was due to the imilar soils within the study area but more importantly due to the same location within the hillslope catena. Soils in the study area are thicker at the hillslope crests and shallower towards the valley bottom, typically 0.5 m thick at the wetlands. Furthermore slopes within the transects were all in the same magnitude whereby slope controls LTF to a large extend.

From these results it is evident that LTF was nearly absent during dry years as when the soil profile is relatively dry then it has the capacity to attenuate large rainfall. Hence LTF is largely dependent of the antecedent soil water conditions as well as rainfall intensity.

On average LTF was 0.4 % of rainfall, based on the entire catchment, but if only the lower part of the transect is included in the calculation then LTF has a much larger percentage of the water balance. Looking at seasonal LTF it can have either a very large contribution or no contribution as it only occurs during summer.

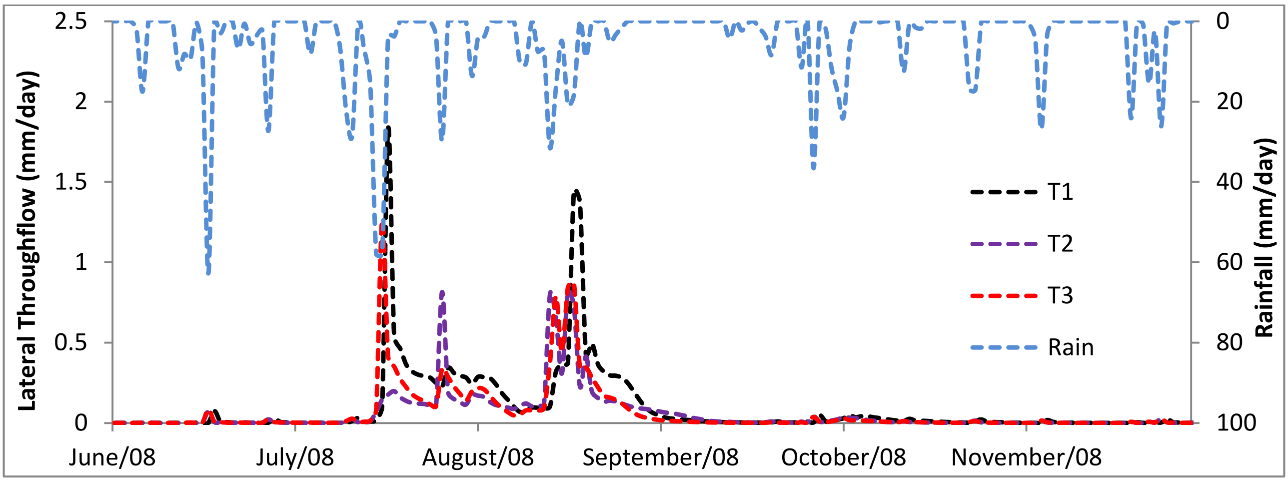

Figure 4: Rainfall and lateral throughflow for all transects during summer 2008/2009.

As shown in Figure 4 a continuous supply of water from the catchment to the wetland during the wet season. Even when rainfall stops LTF still continues to seep into the wetland supplying water to the shallow soils.

6.4 Assessment Effective Wetland Catchment

The effective catchment of the wetland is defined as the area where LTF from the hillslopes contributes to the wetland soils measured from water movement during the wettest conditions within the 10 years modelling period.

The modelling results were analysed for water movement within the transects using graphical display of velocity vectors for the largest rainfall event with wet antecedent soil moisture conditions. The highest LTF contribution period was chosen from Figure 5 which shows the total volume (expressed in mm of water) of water within the modelling domain during the modelling period. It is assumed that most LTF will occur during the wettest conditions. Analysis of the data in Figure 5 shows that the largest contribution was at the day 2660 which was the same for all transects and translates to the date 09/09/2008.

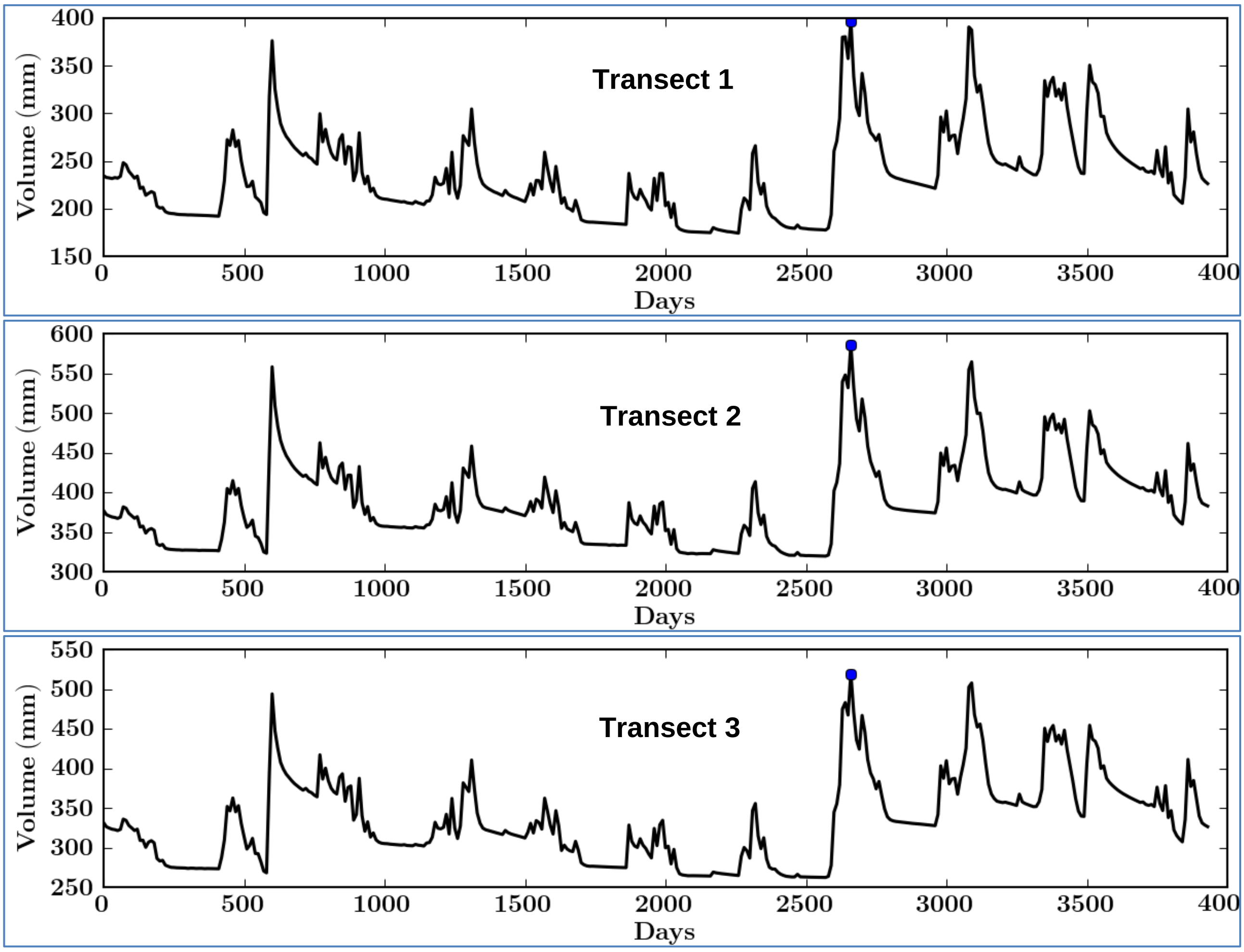

Figure 5: Volume of water expressed in mm for the transets 1-3. Time start was 01/06/2001 and end was on 21/05/2012. The blue dots indicate the maximum volume (09/09/2008).

6.5 Conceptual Wetland Buffer

The wetter the soil profile the more LTF was observed hence this approach to estimate the distance of contribution measured from the wetland boundary upslope. Velocity vectors of all 4 transects are shown in Figure 6 whereby only the lower parts of the transects are shown where LTF occurred. Table 2 shows the distances of maximal length within the transect contributing to the wetland. According to these findings soils are recommended to keep in their current state for at least the distance of the Conceptual Wetland Buffer in order to maintain wetland health. The LTF results of the various transects have shown that the presence of low permeable material such as tillite bedrock forces saturated water to flow laterally mainly as preferential flow between the soil profile and the tillite material. The modelling transects have shown a different length contribution of LTF it is therefore important to design a conceptual buffer rather than a constant-distance-to-wetland-buffer in order to guarantee wetland health. A conceptual buffer was designed according to the criteria soil form, slope and modelling results. A map of the recommended conceptual buffer is shown in Figure 7.

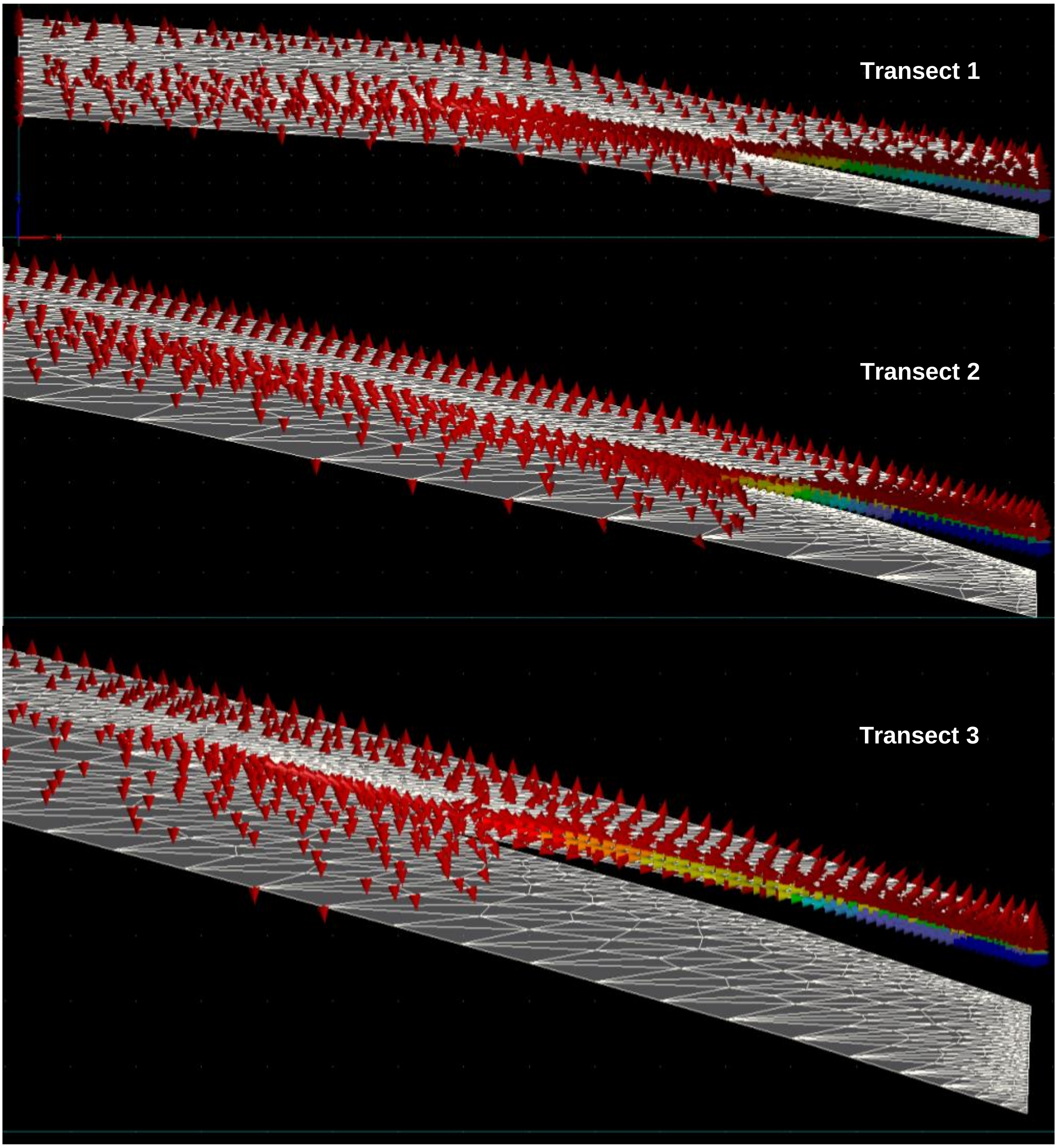

Figure 6: Velocity vectors of the lowest parts of the transects during day 2660 (wettest conditions). The distance of lateral throughflow contribution from the wetland boundary was determined from these plots. Units are in m/day. Only Transect 1 is displayed in full length, graphs 10 times stretched in z-direction.

Table 2: Total modelling transect length and Maximal Length Contribution which is the distance from the lower transect end upwards which contributed lateral throughflow to the wetland during the wettest condition of the modelling period. The Conceptual Wetland Buffer is the distance from the wetland to the maximal length of contribution along the transect.

Transect	Length (m)	Length Contribution (m)	Conceptual Wetland Buffer (m)
T1	1139	117	128.7
T2	458	205	225.5
T3	640	121	133.1

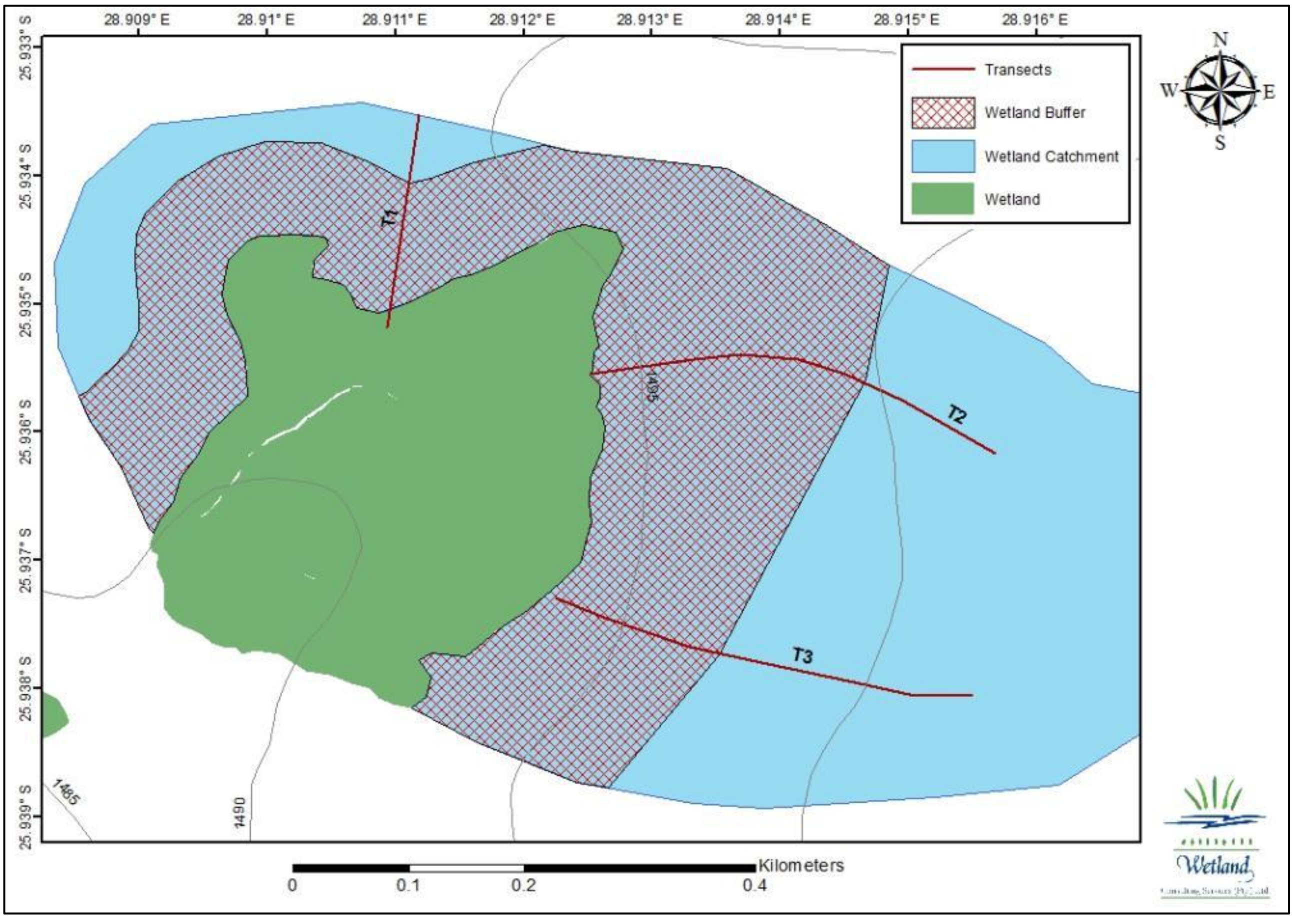

Figure 7: Recommended conceptual wetland buffer around the wetland boundary.

6.6 Wetland and its Buffer within the Original and the Revised Ash Dump Footprint

The footprint of the ADF was revised in order to protect the pan wetland and its surrounding seepage wetland. The original layout of the ADF, the wetlands and the wetland depression buffer are shown in Figure 8 and overlays the entire wetland as well as its buffer and catchment.

Figure 9 shows the revised layout of the ADF which was designed to mitigate the impact of the pan and associated seepage wetland. The revised layout is not interfering with the wetland; however the wetland buffer and catchment are partly intersected by the proposed ADF.

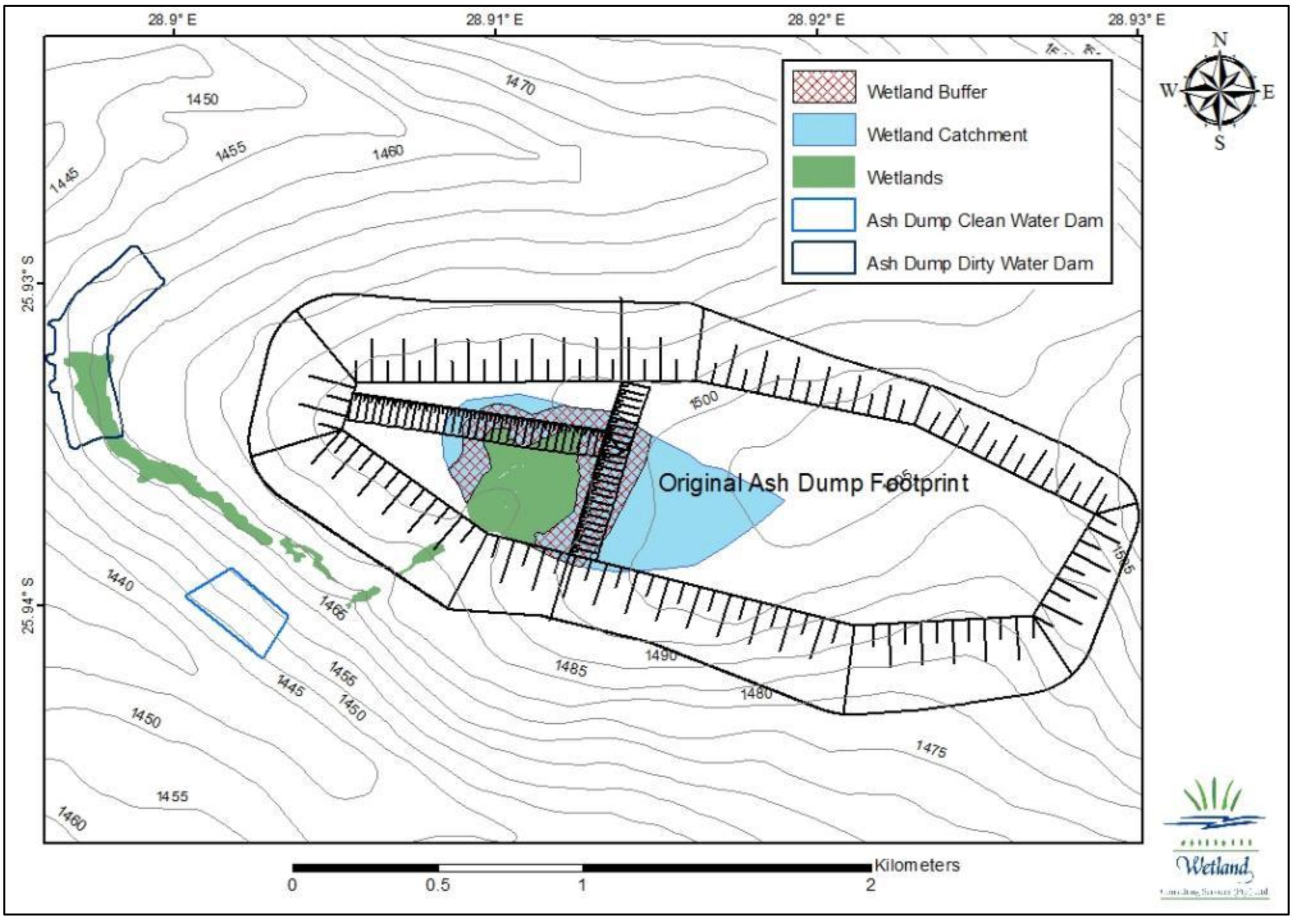

Figure 8: Wetlands, wetland buffer, wetland catchment and original layout of the proposed ash dump facility.

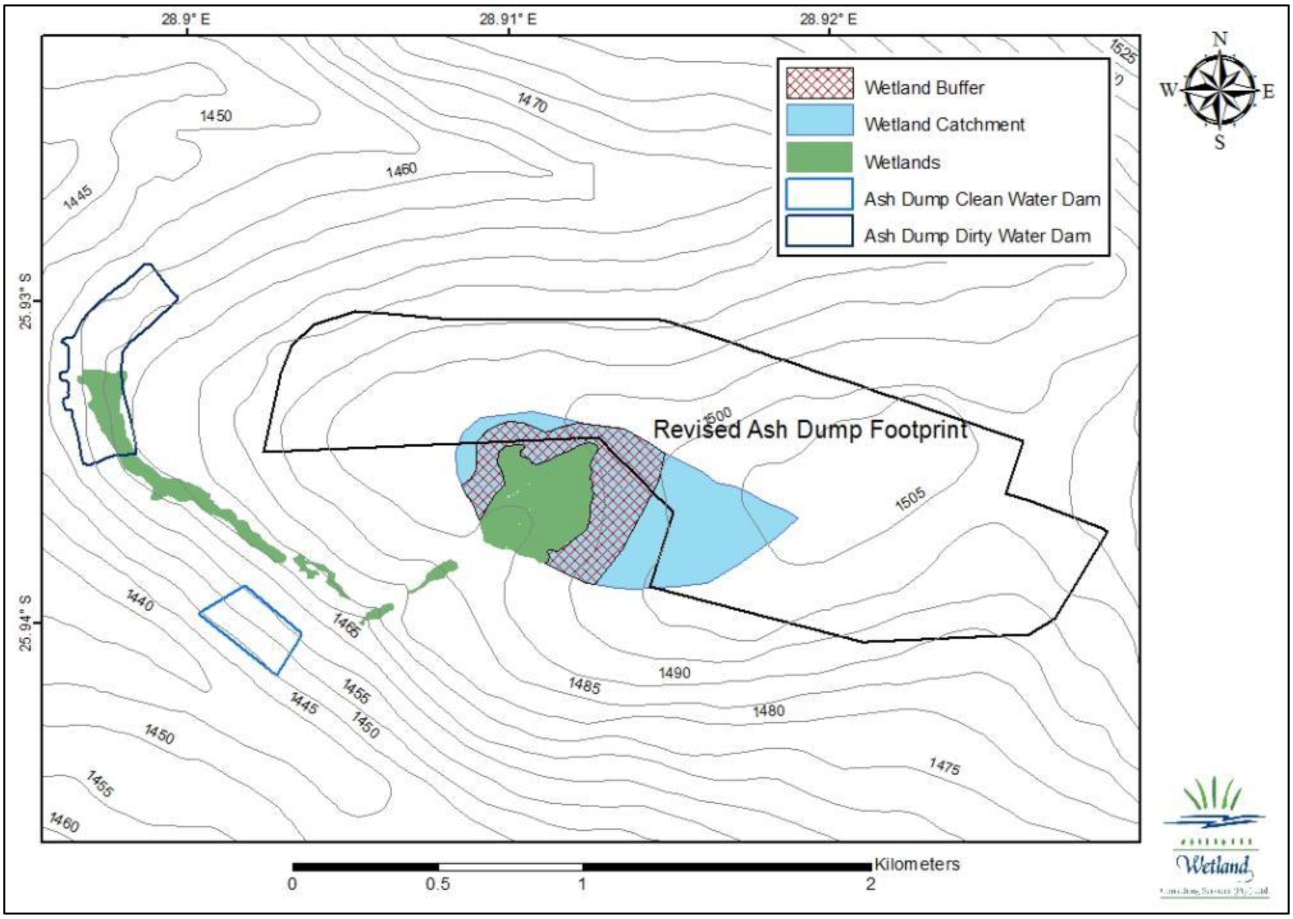

Figure 9: Wetlands, wetland buffer, wetland catchment and revised layout of the proposed ash dump facility.

6.7 Confidence of Results

A number of assumptions were applied in this study which had a limited temporal and monetary scope. However, the approach taken in this study aimed to reduce the amount of assumptions and utilized methods which are conceptually traceable in the sense that water movements within transects could be monitored and studied. Rather than using statistical lumped models a detailed physical based model with graphical interface was applied where all processes are visible and traceable in high temporal resolution.

The overall confidence of this study is rated to be 2 out of 5 since no calibration of the modelling results was possible.

7. SUMMARY OF RESULTS

- Three water contribution pathways from the catchment to the wetland were identified in this study which are Lateral Throughflow (LTF), possible groundwater link as well as surface runoff.
- Over a period of nearly 10 years which captured dry, average and wet years the LTF from the catchment into the wetland was found to be 0.4 % of rainfall. However seasonal LTF from smaller periods made a far larger component in the water balance.
- A buffer of a constant distance from the wetland boundary was found to be inappropriate. Instead a conceptual buffer which depends on modelling results which varies from location to location is recommended and shown in Figure 7. The buffer's distance from the wetland ranged from 133 to 225 m.
- The original layout of the Ash Dump Facility (ADF) superimposes the wetland as well as its recommended buffer and its catchment as shown in Figure 8.
- The revised layout of the ADF does not superimpose the wetland however it partly does for its catchment and its recommended buffer as shown in Figure 9.

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