

GEOLOGICAL AND GEOHYDROLOGICAL REPORT

**Part of the permit application for the development
of a Regional General and Hazardous Waste Disposal Facility
on the farm Grassridge 190 Remainder near Addo, Eastern Cape**

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EXECUTIVE SUMMARY

This report describes the geological and geohydrological conditions of an area some 30 km north of Port Elizabeth that has been identified as a potential site for the development of a new large Regional General and Hazardous Waste Disposal Facility. The study concentrated on the farm Grassridge 190 Remainder, on which the waste site is to be developed, and the immediately surrounding farms.

Based on the geological and geohydrological conditions of the area investigated, the identified site is regarded as suitable for the development of a H:H class waste disposal site for the following reasons:

- The geological conditions of the underlying formations, both in terms of lithology and depth extent are very favourable.
- The static groundwater level in the vicinity of the site is of the order of 70 m below surface.
- Borehole yields are generally very low as illustrated by the four recently drilled boreholes that were all dry on completion of drilling.
- The groundwater quality in the region is generally poor to very poor and as a result very little use is being made of groundwater for domestic, stock watering or irrigation. The poor water quality is a direct result of the marine depositional conditions that existed during the formation of the geological formations hosting the groundwater.
- The underlying formations, the Sundays River and Kirkwood formations, comprise of a very thick succession (estimated to be >300 m) of predominantly siltstone and mudstone, with minor interlayered sandstone layers. These formations have a very low hydraulic conductivity and will prevent the migration of contaminants in the case of liner system failure.
- The deep artesian aquifer associated with the Table Mountain Group sediments, is well protected from any contamination by the thick succession of Uitenhage Group sediments. That the latter sediments form an effective barrier to groundwater flow is illustrated by the artesian nature of the deeper aquifer.
- The site is situated close to a local surface water divide and none of the drainage lines at or upstream of the site represent perennial flow conditions.
- The WASP analysis, which takes into consideration a number of geological, geohydrological, water use and design criteria, also indicated that the site can be classified as “suitable”.
- No geological or geohydrological conditions within the study can be regarded as “fatal flaws” according to the definitions described in the DWAF guideline documents (DWAF, 1998).

Based on the above factors and provided that the site will be designed, constructed and operated according to the DWAF Minimum Requirement Guidelines, from a geohydrological perspective it is concluded that the identified site is suitable for the development of a new Regional General and Hazardous Waste Disposal Facility.

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1 BACKGROUND

The investigations for the establishment of a new regional waste disposal facility for the Greater Port Elizabeth area commenced in 2000. During a Geographic Information System (GIS) based study of a large area to the north of Port Elizabeth, potentially suitable farms on which such a facility could be established were identified (Godfrey *et al*, 2000). These farms were Blaauw Baatjies Vley 189, Grassridge 190, Coega Kammass Kloof 191 and Grassridge 227. A report evaluating four potentially suitable areas on these farms, referred to as Footprints A to D, was issued in 2004 (Meyer, 2004). During 2005 two additional potentially suitable sites and referred to as Footprints E and F on adjacent farms, Grassridge 190 (Remainder) and Grassridge 227 (Remainder) were investigated. In the reports by Meyer (2004, 2005) all potential sites were evaluated and ranked in terms of their suitability for the development of a regional hazardous waste processing facility. This was followed by a report by Meyer in December 2006 providing more detailed geohydrological information collected on the two farms Grassridge 190 and Grassridge 227. That report also described the environmental impacts associated with the three sites (Footprints C, E and F) on these two farms. The report concluded that Footprint F appeared to be the most suitable site of the three. A decision was taken to submit a permit application for Site F on the farm Grassridge 190 and hence some additional geohydrological and associated investigations were required in terms of the DWAF Guidelines "Minimum Requirements for Waste Disposal by Landfill" (DWAF, 1998).

The current report reviews the geological and geohydrological conditions around the farm Grassridge 190 based on previously accumulated information as well as information collected during a recent geophysical survey and exploration drilling programme on the farm.

2 PURPOSE OF THIS PHASE OF THE INVESTIGATION

The two farms Grassridge 190 Remainder and Grassridge 227 are owned by the cement manufacturing company PPC (Pretoria Portland Cement). Their interest in the two farms stems from the large economic deposits of calcrete used in the manufacturing of cement on the farms and which are currently actively mined on the farm Grassridge 227. The further geotechnical and geohydrological investigations were done with the permission of PPC.

The purpose of this phase of the evaluation of the site was to obtain the required information for a permit application and included the following:

- Obtain information on the shallow geotechnical conditions. Geotechnical information of those areas provisionally identified for the development of the waste disposal area, leachate and storm water holding dams, borrow pits and other infrastructure, is to be used in the design of foundation and lining of the facility. This investigation was conducted by the Consulting Engineering firm Jones & Wagener during December 2007 and reported in report No: 15/08/B494. This information will be used

in preliminary design for the site which will form part of the permit application documentation.

- Perform an appropriate geophysical survey of the area to identify potential geological structures that may influence groundwater conditions and to assist in the selection of sites for exploration boreholes.
- Obtain site specific geohydrological information as specified in the DWAF Guideline Document “Minimum Requirements for Waste Disposal by Landfill” (DWAF, 1998) through the drilling of additional exploration boreholes.
- Prepare a geohydrological investigation report to serve as part of the permit application documentation required by the DWAF Guideline document referred to earlier.

Bohlweki Environmental (Pty) Ltd appointed R Meyer, Geohydrological Consultant, to conduct the geohydrological investigation. He has been involved in the selection and development of a new Regional General and Hazardous Waste Disposal Facility since the inception of the project.

3 REPORT LAYOUT

The report describes the information required in terms of the DWAF guideline document “Minimum Requirements for waste disposal by landfill”. As such the report contains the following information:

- Brief description of the position and access routes to the area,
- climate of the region,
- hydrology of the region
- a description of the regional and local geological conditions and other subsurface conditions,
- the results of a hydrocensus of the farm Grassridge 190 and surrounding farms,
- the results of a recently completed geophysical survey,
- the results of the recent exploration drilling,
- the regional and local geohydrological conditions,
- aquifer classification,
- groundwater use and quality, and
- an evaluation of geological and geohydrological conditions in terms of the suitability of the area for the development of the proposed waste disposal facility.

4 LOCALITY AND ACCESS

The farms Grassridge 190 and 227 are located approximately 35 km directly north of Port Elizabeth and 15 km southwest of Addo and are located within the Nelson Mandela Metropolitan Municipality's area of jurisdiction. The main access route from Port Elizabeth is

along the R335 towards Addo, while from Uitenhage following the R75 towards Kirkwood, and taking the gravel road turnoff towards Addo, provides access to the farms (**Figure 1**).

The farm Grassridge 190 is near the crest of a local topographically high area (~290 mamsl) on land sloping gently to the south. The site is located in a broad valley sloping to the southeast near the boundary between the farms Grassridge 190 Remainder and 227.

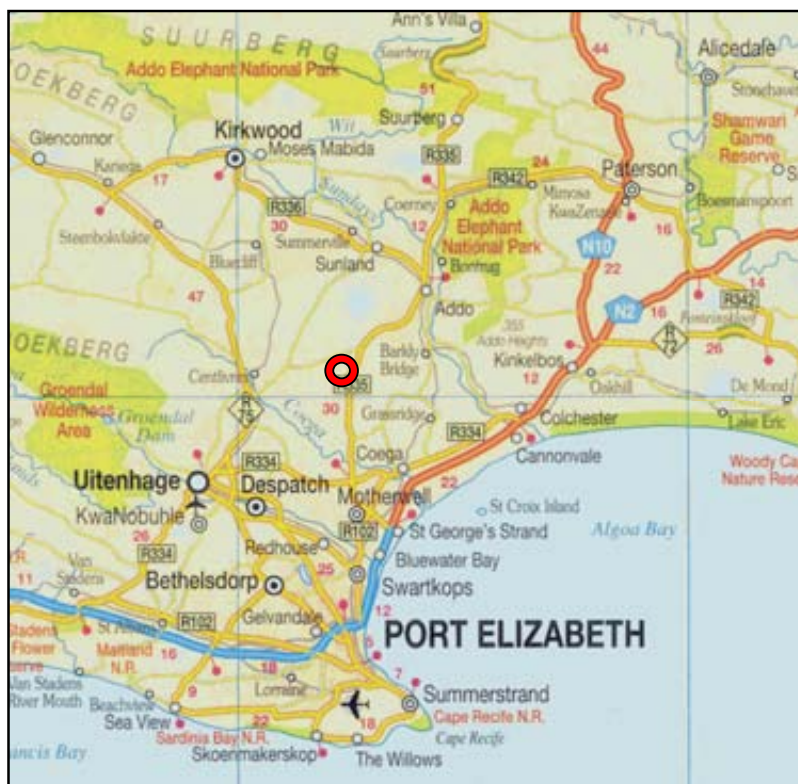


Figure 1: Map of the Port Elizabeth area showing the approximate position of the proposed site (red circle).

5 HYDROLOGY OF THE REGION

The position of the selected site in relation to surface water catchment boundaries is shown in **Figure 2**. This shows that the site is almost on the surface water divide between the drainage areas of the Sundays and Coega Rivers. It is located within the quaternary surface water sub-catchment M30A draining towards the Coega River in the south and close to the junction of three Quaternary sub-catchments M30A and M30B (Coega River) and N40F. Quaternary sub-catchment N40F is part of the larger Secondary catchment of the Sundays River basin, while drainage from the Quaternary sub-catchments M30A and M30B is towards the ephemeral Coega River to the south.

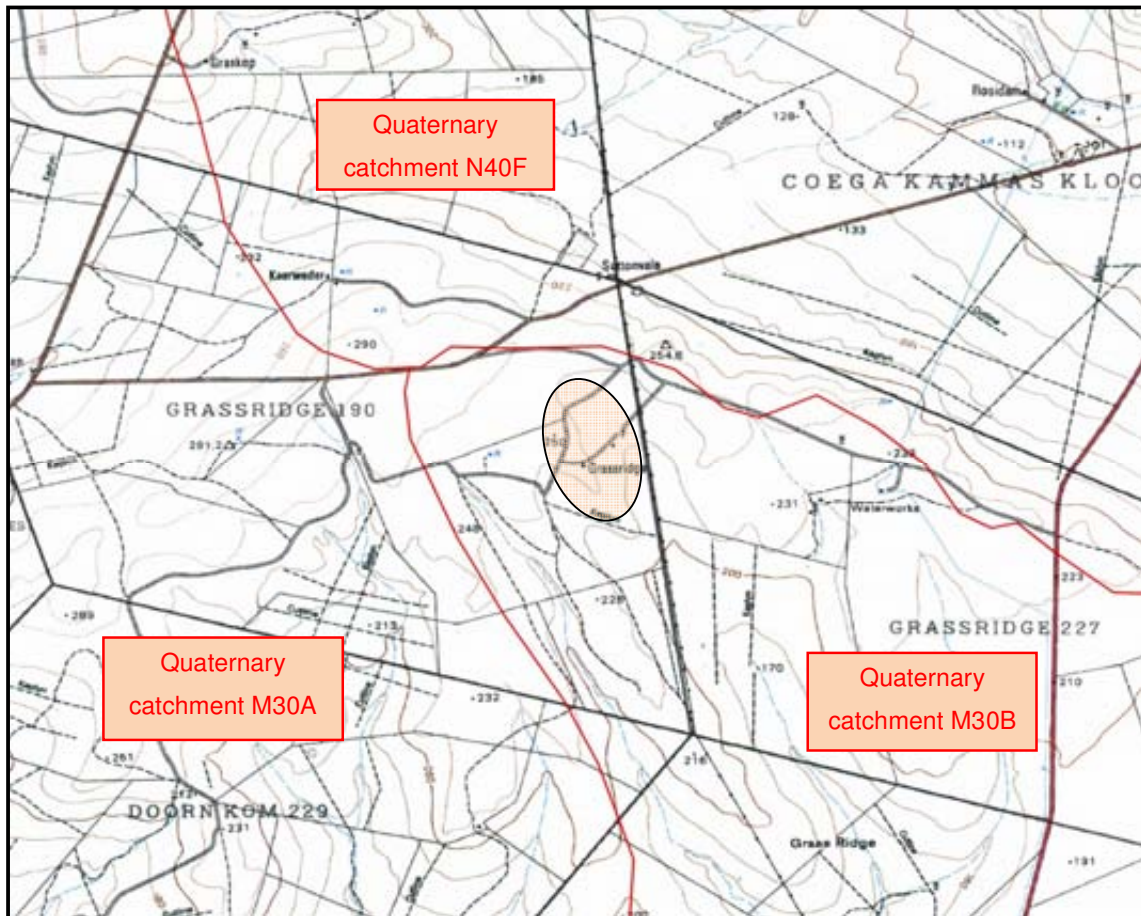


Figure 2: Approximate area selected for the development of a waste disposal facility (oval shape) in relation to the three Quaternary catchments. The red line indicates the catchment boundaries of Quaternary catchments N40F draining towards the Sundays River and M30A and M30B draining into the Coega River (Map reference: 1:50 000 scale 3325DA Addo).

Because of the proximity to catchment boundaries and the local topographic conditions, no perennial rivers or streams occur in close proximity to the site and therefore 1:50 year flood lines are not really applicable. Nevertheless an assessment of the 1:50 year flood conditions for the stream flowing through the broad valley in which the site is located, has been done. Two assumed catchment areas (100 ha and 200 ha) and existing rainfall records for the area (Rain gauge 0034762, Uitenhage district) were used in the simulation. Calculations show that a peak 24 hour rainfall event of 149 mm would result in a 50-year peak flow of 7.7 m/s and 11.1 m/s for a 100 ha and 200 ha catchment size respectively. This flow would result in a water depth of 0.7 m and 0.8 m in a 30 m wide channel of concave shape for the 100 ha and 200 ha catchment areas respectively. Should the area be approved for further development, these calculations have to be revised once the geometry of the channel has been established more accurately. Preliminary designs for the waste disposal site have taken these predicted flow rates and water depths into account.

6 CLIMATE AND CLIMATIC WATER BALANCE OF THE REGION

As detailed records of climatic conditions of the site are not available, the temperature, rainfall and evaporation information from two recording stations in the vicinity, Port Elizabeth and Addo are presented here (**Table 1**).

The evaporation data for the two stations, Port Elizabeth and Addo are listed in **Table 2**. The somewhat lower evaporation in the interior compared to that at the coast is probably due to slightly lower maximum temperatures inland and differences in the wind conditions.

As the planned facility will accommodate hazardous waste, it will be classified as a H:H type site. No climatic water balance calculations are required for H:H type sites as provision is made in the liner design to capture, control and treat any leachate generated on site.

7 REGIONAL AND LOCAL GEOLOGICAL CONDITIONS

7.1 Regional geology

The geological stratigraphic sequence of the larger study area (i.e. the Uitenhage - Port Elizabeth – Addo area) is summarized in **Table 3**, with the youngest sequence being of Quaternary age and the oldest being Cape Supergroup (information taken from the 1:250 000 geological map 3324 Port Elizabeth Geological Survey, 1989) and the 1:50 000 scale geological maps 3325CB Uitenhage Noord and 3325DA Addo (Council for Geoscience, 2000).

A prominent feature of the area is a large basin structure, known as the Algoa Basin formed during the breakup of Gondwanaland between outcrops of the older and intensely folded Cape Supergroup rocks to the south, west and north. (Le Roux, 2000; Hattingh and Goedhart, 1997). The Algoa Basin is bounded in the north and east by the Zuurberg fault, while the Coega fault occurs close to the southern boundary of the basin. Younger sediments of the Uitenhage Group fill this basin and are buckled into open SE plunging folds along NW-SE trending axes. This structural pattern is illustrated by the anticlinal fold on the farm Blaauw Baatjies Vley 189, also described by Winter (1973). During the late-Jurassic period (160 to 145 Ma) pebble and boulder alluvial deposits accumulated in the basin being washed from the surrounding mountains under a high energy environment to form the Enon Conglomerate Formation, the basal formation of the Uitenhage Group. A thick succession of clays was then deposited unconformably onto the Enon Formation forming the mudstones and siltstones of the Kirkwood formation. Subsequently marine and estuarine clays were deposited in the basin during a transgression period to form the Sundays River formation. During the Tertiary (65 to 2 Ma) numerous transgressions periods occurred to form terraces in the Cretaceous sediments while calcareous sandstones were deposited during these times.

Table 1: Average maximum and minimum temperatures and rainfall as recorded at Port Elizabeth, Addo and Uitenhage weather stations.

Month	Monthly Minimum/Maximum/Average Temperature (°C)									Average Rainfall (mm)		
	Port Elizabeth			Addo			Uitenhage			Port Elizabeth	Addo	Uitenhage
	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave			
Jan	17.9	25.4	21.7	16.6	29.2	22.9	17.3	27.8	22.6	36	28	33
Feb	17.9	25.4	21.6	16.6	29.3	22.9	17.5	27.9	22.7	40	40	35
Mar	16.9	24.6	20.7	15.4	28.1	21.8	16.1	27.0	21.5	54	43	44
Apr	14.3	23.0	18.7	12.1	26.2	19.1	13.0	25.8	19.4	58	37	41
May	11.5	21.7	16.6	8.7	24.0	16.3	9.6	24.0	16.8	59	31	30
Jun	9.2	20.3	14.7	6.0	21.9	14.0	6.9	22.3	14.6	62	24	23
Jul	8.8	19.7	14.3	5.2	21.9	13.6	6.4	21.8	14.1	47	26	29
Aug	9.8	19.6	14.7	6.4	22.6	14.5	7.9	22.0	14.9	64	33	36
Sep	11.4	20.0	15.7	8.8	23.6	16.2	10.2	22.7	16.4	62	27	28
Oct	13.1	20.8	17.0	11.0	24.6	17.8	12.3	24.3	17.8	59	41	42
Nov	14.6	22.3	18.5	12.9	26.3	19.6	14.3	24.8	19.6	49	39	46
Dec	16.4	24.3	20.3	14.7	28.1	21.4	15.9	26.8	21.4	34	27	30
Average total annual rainfall (mm)										624	396	417

Source: SA Weather Services, Port Elizabeth

Table 2: Evaporation data for the region

Station name & number	Coordinates		Mean Annual Evaporation		Recording Period
	Latitude	Longitude	S-pan (mm)	A-Pan (mm)	
Port Elizabeth M2E001	33° 59'	25° 36'	1528	1792	1957-1979
Addo N4E001	33° 34'	25° 42'	1401	1742	1960-1979

Source: Midgley *et al* (1994). Surface Water Resources of South Africa.

Intense east-southeast trending folding characterises the Cape Supergroup rocks to form the Elands River Syncline towards the south and the Swartkops River anticline in the north (Toerien and Hill, 1989). Apart from the dominant folding, the other major structural feature is the normal tensional Coega fault traceable eastwards from the Groendal Dam to the coast. Vertical southward displacement along this fault is substantial. Maclear (2001) cites a value of 1 800 m, while Marais and Snyman (1965) report the average displacement to be of the order of 550 m.

Table 3: The geological sequence in the Port Elizabeth/Uitenhage/Addo area

Period and age range (Ma)	Group	Sub-Group	Formation	Lithology
Holocene				Alluvium, calcrete and dune fields
Quaternary (1.65-0.1 Ma)	Algoa			Fluvial terrace gravel
			Bluewater Bay	Alluvial sheet gravel and sand
			Nanaga	Aeolianite
Tertiary (67-1.65 Ma)			Alexandria	Calcareous sandstone, shelly limestone, conglomerate
Cretaceous/Jura (210-67 Ma)	Uitenhage		Sundays River	Greenish-grey mudstone, sandstone
			Kirkwood	Reddish, greenish mudstone, sandstone
			Enon	Conglomerate
Devonian (410-360 Ma)	Witteberg		Witpoort	White quartzitic sandstone
	Bokkeveld	Traka	Adolphspoort	Shale and siltstone with sandstone at base.
			Karies	Shale, discontinuous sandstone
		Ceres	Gamka	Feldspathic sandstone, fossiliferous
	Table Mountain	Nardouw	Baviaanskloof/Skurweberg/Goudini	Arenite, quartz sandstone
			Peninsula	Quartzite, quartz sandstone
			Graafwater	Arenite, quartz sandstone, quartzite

Note:

	Outcrops present near the investigated area on Grassridge 190
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As part of an oil exploration drilling programme, deep drilling north of Addo indicated a thickness of 1863 m for the Sundays River formation. The combined thickness of the Sundays River and Kirkwood formations over large parts of the area, is in excess of 1000 m. Due to intense folding and the presence of an anticlinal structure underlying the specific farms investigated during this phase, the combined thickness of these two formations is however significantly less in the area under investigation. No definite thickness can be given

as no boreholes that penetrated the entire succession are present close to the area under investigation. It is however estimated that the combined thickness of the Sundays River and Kirkwood formations is at least of the order of 300 m in the vicinity of the farms Grassridge 190 and Grassridge 227.

Apart from the anticlinal structure described above, there are no other significant structural features mapped within the study area. The geophysical exploration programme of the late 1960s also did not reveal any deep structural features in this area (Winter, 1973).

Hattingh and Goedhart (1997) reported on structural evidence of Neogene to Quaternary period (23 - 2 Ma) tectonic activity in the Algoa Basin. Observations of displacement in Neogene age strata near the Coega fault in the south suggest that some older faults in the Algoa Basin may have been rejuvenated. They also propose that the Eastern Cape area experienced renewed tectonic activity as recent as the Holocene triggered by tectonic activity along the offshore Agulhas Fracture Zone.

Although seismic events are recorded from time to time along the south-eastern African continental margin, the epicentres are located far northeast of the Algoa Basin and are according to Hartnady (1990), linked to extension of the East African Rift system. Hattingh and Goedhart (1997) report that no modern seismic activity has been recorded in the southern part of the Eastern Cape by either of the two seismic stations located at Grahamstown and Port Elizabeth.

7.2 Local geological conditions

The geological conditions underlying the present study area comprising of the farms Grassridge 190 Remainder and Grassridge 227 is discussed in this section. A portion of the 1:50 000 scale geological map 3325DA Addo (CGS, 2000) showing the surface geological conditions in the study area is presented as **Figure 3**. The legend for the map is presented in **Table 4**.

Table 4: Geological legend for the geological map shown in Figure 3

Symbol	Colour	Formation name	Lithology
T-Qn	Brown	Nanaga	Aeolianite/Calcareous sandstone/sand
Ta	Pink	Alexandria	Calcareous marine/ estuarine/lagoonal sandstone, conglomerate, coquinite
Ks	Red	Sundays River	Grey mudstone, siltstone, sandstone
J-Kk	Yellow	Kirkwood	Reddish and greenish mudstone, sandstone and conglomerate

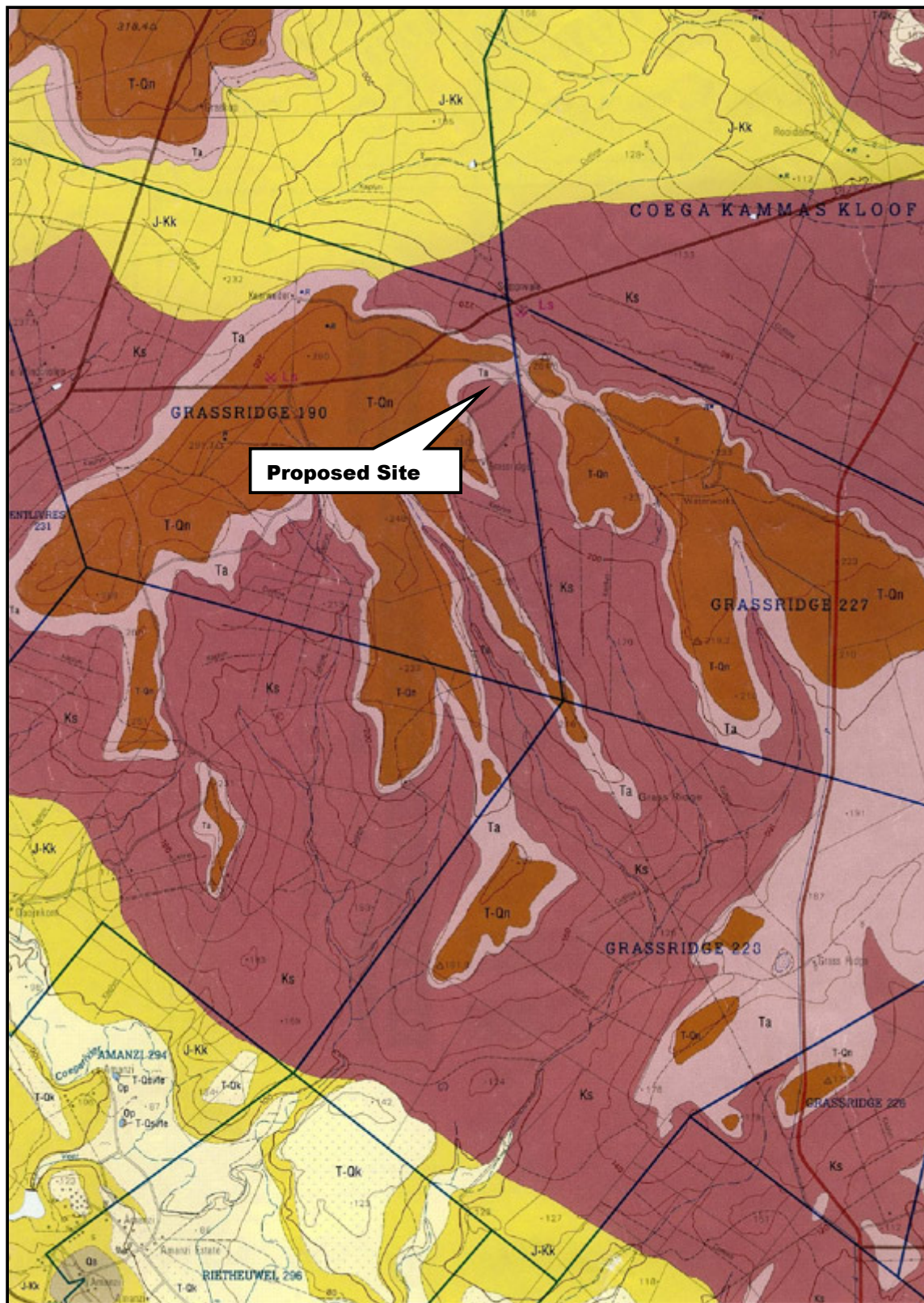


Figure 3: Portion of the 1:50 000 Geological map 3325DA Addo showing the geology on the farms Grassridge 190, Grassridge 227 and Grassridge 228 and the approximate area identified for the development of the waste disposal facility.

A prominent E-SE plunging anticlinal structure (generally referred to as the Addo Ridge) is shown on isopach maps of the Sundays River and Kirkwood formations prepared by Winter (1973). The associated synclinal structure to the south is referred to as the Coega Embayment by Winter (1973). The farms Grassridge 190 and 227 are located along the axis of this syncline where prominent aeolianite outcrops of the Nanaga formation, flanked by calcareous marine and estuarine sandstones of the Alexandria formation, occur. These two formations are underlain by thick sedimentary successions of Sundays River and Kirkwood formations. Both these formations consist predominantly of mudstone and siltstone, with minor sequences of sandstone and conglomerate. From a deep oil exploration borehole (Borehole CK1/68 - approximately 4 km north of Addo), it is known that the Sundays River formation has a thickness of 1863 m (le Roux, 2000). However, from the isopach maps prepared by Winter (1973) the thickness of the Sundays River formation is interpolated to be approximately 300 m on the farm Grassridge 190. At another deep oil exploration borehole (AD1/68) some 7 km east-north-east of the farm Grassridge 190, and on the north-eastern flank of the Addo Ridge anticline only 203m of Sundays River Formation was intersected. Based on the isopach maps prepared by Winter (1973) and the synclinal structure (Coega Embayment), it is concluded that the Sundays River formation should be at least 300 m thick at these locations on the farms Grassridge 190 and 227. Isopach maps for the underlying Kirkwood formation (Winter, 1973) indicate that this formation is at least 200m thick. It is therefore concluded that surface calcrete and calcareous sandstones outcrops at Grassridge 190 are underlain by at least 500 m of mudstone, siltstone and minor sandstone layers of the Sundays River and Kirkwood formations.

The Kirkwood formation is again underlain by another thick sedimentary succession of shale and sandstone formations deposited in a moderately shallow marine environment to form what is known as the Bokkeveld Group. From these thickness estimates it is clear that the Table Mountain Group rocks hosting the strategically important artesian aquifer, and occurring stratigraphically below the Bokkeveld Group, is overlain by at least 1 000 m of low permeability sedimentary rocks largely deposited in a marine environment.

Within the boundaries of the preferred site located on Grassridge 190 Remainder, outcrops of three geological formations are present (**Figure 3**). These formations, with a short description of the lithology, are listed in the table below, in order of increasing age (**Table 5**). Based on the 1:50 000 geological map of the area it appears that the Sundays River formation is often exposed in the topographically lower lying areas where the overlying Nanaga and Alexandria formation have been removed by erosion. Outcrops of Alexandria formation are found along the valley slopes, while the Nanaga formation often occupies the local higher topographic features. No linear structural features have been mapped in the area. It also appears that the densely vegetated areas are mostly associated with outcrops of the Sundays River formation, while the open grasslands developed on outcrop areas of the Nanaga formation.

Table 5: Geological formations present on the farm Grassridge 190

Age period	Formation	Lithology	Estimated thickness (m)
Pliocene to Early Pleistocene (~ 5 to ~1 Ma)	Nanaga Formation	Calcareous sandstone/sandy limestone, aeolianite,	<25
Miocene to Pliocene (~22 to ~2 Ma)	Alexandria Formation	Calcareous marine/estuarine/ lagoonal sandstone, conglomerate, coquinite	<20
Late Cretaceous (~145 to ~110 Ma)	Sundays River Formation	Grey mudstone, siltstone, sandstone	>300

8 RESULTS OF GEOPHYSICAL SURVEY

According to the DWAF Minimum Requirements for Site Investigations (DWAF, 1998) of a H:H type landfill it is a requirement to drill a minimum of three exploration boreholes as part of the site investigation. It is a further requirement that an appropriate geophysical survey be conducted to determine whether geological structures that may influence geohydrological conditions are present and to guide the selection of drilling sites. Accordingly a geophysical services company, Engineering and Exploration Geophysical Services cc (E&EGS), was appointed to conduct a ground magnetic and electromagnetic survey of the proposed site. Ground magnetic surveying was used to determine whether magnetic geological structural features such as dykes traverse the area, while the electromagnetic method is sensitive to changes in weathering depth, conductive strata, faults and lithological contacts. These techniques were considered the most appropriate given the local geological conditions. The geophysical report is attached as **Appendix A**.

The magnetic and EM measurements were done at station spacing of 20 m along profile lines covering the area selected for the development of the facility. The magnetic profiling revealed a very constant magnetic field across the entire area with no anomalous regions that could be associated with linear structures. This was in agreement with expectations.

The electromagnetic profiling showed large variations in electrical conductivity of the subsoil, from ~30 mS/m to 120 mS/m (Figure 5). Interpretation of these results suggested the following correlation between electrical conductivity and surface mapped geology:

High conductivity	Sundays River formation
Intermediate conductivity	Alexandra formation
Low conductivity	Nanaga formation

A prominent feature on the conductivity contour plan (**Figure 4**) is the low conductivity zone extending across the site towards the south-eastern corner of the survey area flanked by ridges of very high conductivity. Based on the initial interpretation of the geophysical survey results, and taking cognisance of the local geological conditions and the preliminary design of the disposal cells (Jones & Wagener, 2008), four drilling targets were identified for the drilling of the exploration boreholes. These positions are marked on **Figure 4**.

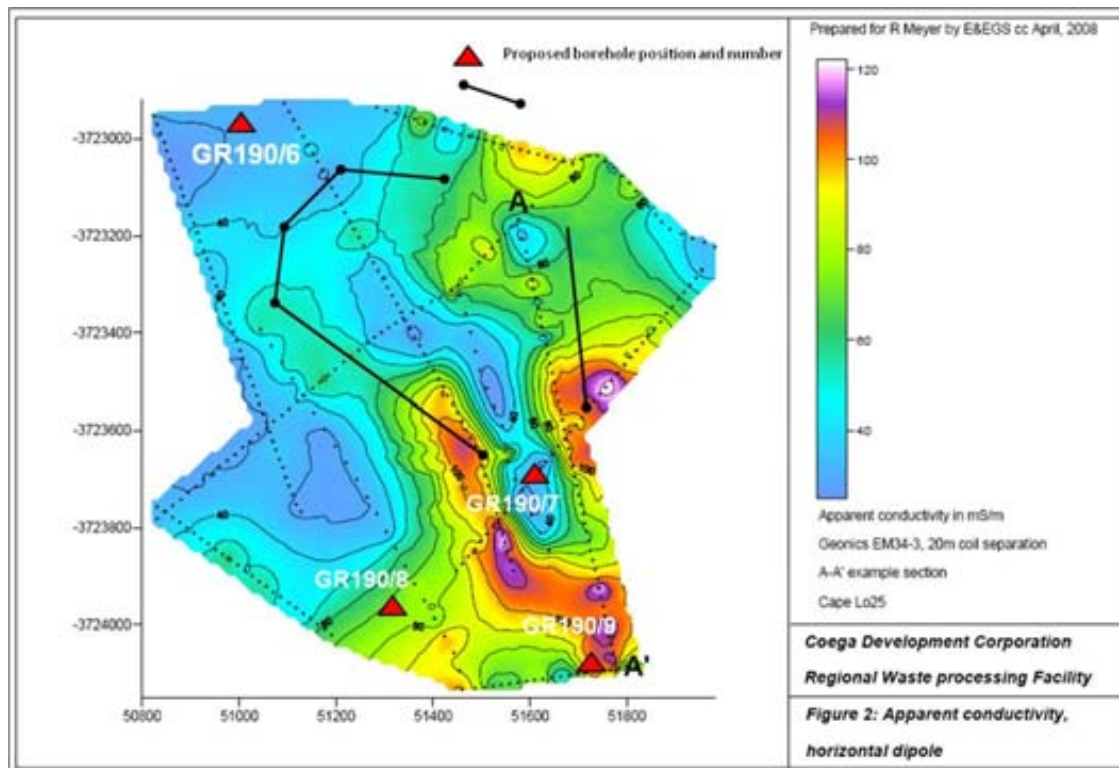


Figure 4: Contour map of apparent electrical conductivity around the proposed site on Grassridge 190 (from E&EGS, 2008) showing provisionally selected positions of exploration boreholes.

9 RESULTS OF ADDITIONAL EXPLORATION DRILLING

Boreholes were drilled during the period 14-19 May 2008 close to the four selected positions based on the geophysical survey results to depths ranging between 69 m and 93 m. The geological descriptions of these boreholes are presented in **Appendix B** and boreholes were allocated the reference numbers GR190/6 to GR190/9. It is important to note that in none of these boreholes water was encountered during drilling, although some water did accumulate in three of the boreholes and water levels could be measured in these a few days after completion of the drilling.

The dominant lithology in all boreholes was mudstone with interlayered thinner sandstone layers. The upper sections (0-15 m) are often calcareous. The maximum thickness of sandstone layers observed within the Sundays River formation was about 20 m and occurred in boreholes GR190/7, GR190/8 and GR190/9. A provisional stratigraphic interpretation of the geological succession in each borehole is given in **Table 6**.

Although the 1:50 000 geological map indicates outcrops of the Nanaga Formation at borehole GR190/6, it is proposed that the surface calcrete layer is directly underlain by the older Alexandra Formation. Similarly, at borehole GR190/8 where according to the map, Alexandra Formation rocks should outcrop, the 20 m thick sandstone layer underlying the

3 m thick clay layer, is interpreted to be part of the upper Sundays River formation and not the Alexandria formation. Borehole GR190/9 in the south and in the valley floor only intersected the Sundays River formation. The calcareous nature of the upper 14 m may suggest that this material has been transported and deposited into lower lying areas of a deeply eroded palaeo-topography.

Table 6: Stratigraphic correlation between boreholes

Bh #	GR190/6		GR190/7		GR190/8		GR190/9	
	Depth interval	Formation	Depth interval	Formation	Depth interval	Formation	Depth interval	Formation
Stratigraphic Sequence	0-3 m	Surface calcrete	0-5 m	Surface calcrete	0-5 m	Weathered Sundays River formation	0-3 m	Soil
	3-13 m	Alexandria formation	5-75 m	Sundays River formation	5-75 m	Sundays River formation	3-14 m	Transported (valley fill?) material or weathered Sundays River formation
	13-69 m	Sundays River formation					14-93m	Sundays River formation

Slightly moist conditions were encountered in boreholes GR190/6, GR190/7 and GR190/9, while much dryer conditions were observed, especially in the upper sections, during the drilling of GR190/8. This is believed to be a contributing reason for the low electrical conductivity reflected in the geophysical results.

Despite drilling the new boreholes to depths between 69 m and 93 m, all were dry on completion, the slight moist conditions encountered during drilling is believed to have been responsible for some water seepage into the borehole to eventually establish a water level a few metres above the base of the borehole. It is suspected that the slight seepage originates mainly from the thinner sandstone horizons and not the mudstone. Except in the case of borehole GR190/6, which remained completely dry four days after drilling was completed, seepage along the borehole sides resulted in the formation of a tight clay making it very difficult to lower any probes into the boreholes for the measurement of water levels or to collect water samples. This is an indication that the monitoring boreholes to be installed should the permit application be successful and the site be developed into an operating waste disposal facility, will have to be constructed very carefully to prevent formation collapse and clogging of screened sections. This will probably involve the drilling of a larger diameter borehole (208 to 260 mm) to accommodate the installation of a suitable gravel pack and uPVC screened sections.

10 HYDROCENSUS OF GRASSRIDGE 190 AND SURROUNDING FARMS

A borehole census of the farms Grassridge 190 (including Grassridge 190 Portion 3), Grassridge 227, Grassridge 228, Coega Kammas Kloof 191 and a part of Blaauw Baatjies Vley 189, with a minimum radius of 3 km around the proposed site, was done during the different stages leading up to the permit application. All this information is captured in **Table 7** including information on the four new drilled boreholes (highlighted in yellow).

Table 7: Borehole census information of the farms Grassridge 190, 227 and 228

Farm name	Bh number	Coordinates GPS (WGS84 datum)						Approx. Elevation (mamsl)	Depth (m) and date drilled	Static wl (mbc) and elevation (mamsl)	Yield (l/s) and use	Equipped	Water quality available	Additional comments
		Latitude			Longitude									
		D	m	s	D	m	S							
Blaauw Baatjies Vley 189 Portion 2	BBV189/2/1	33	37	16.0	25	31	45.1	202	na ~1974	n.a.	0.2 l/s; Domestic (Suttonvale)	Solar powered pump	Table	No access possible
	BBV189/2/2	33	37	16.7	25	31	49.1	197	na	No access	Yield n.a.; not used.	No	No	No access possible
Blaauw Baatjies Vley 189 Portion 3	BBV189/3/1	33	36	28.8	25	31	10.7	299	na	No access	Yield n.a.; Stock watering	Solar powered pump	Table	
	BBV189/3/2	33	36	33.5	25	31	28.6	257		>50 m	Yield n.a.; stock watering	Solar powered pump	Table	
Grassridge 190 Portion 3	GR190/3/1	33	37	17.4	25	31	44.8	203	n.a.	~30 (pumping); 173	Low yield; not used	Wind pump	Table	Domestic and stock watering on farm Blauw Baatjies Vley 189/2
	GR190/3/2	33	31	45.5	25	31	45.5	203	103	>50; <153	Very low yield; not used	No	No	Drilled in 2003
	GR190/3/3	33	37	17.4	25	31	45.1	202		36.3; 166	Yield n.a.; not used	Previously engine and Mono pump	No	Due to low yield equipment removed; now abandoned.
Grassridge 190 Remainder	GR190/1	33	38	33.1	25	32	44.8	255	120 m	Dry <135	Was ~0.5 l/s (J Erasmus), now dry.	Previously submersible pump installed	No	According to J Erasmus of PPC, wl previously at ~60m; PPC intention was to use as emergency supply. Drilled 11/08/1976?
	GR190/2	33	38	45.0	25	32	43.7	245	125 m	75.45; 169	~0.8 l/s (J Erasmus), not used	Submersible pump installed, but not currently operational	No	Drilled 31/10/1976 by C Potgieter; not possible to sample due to pumping equipment in bh.
	GR190/3	33	38	32.4	25	32	03.8	268	n.a.	Blocked at 3m	Yield n.a.; not used.	Not equipped	No	Next to reservoir.
	GR190/4	33	38	20.8	25	30	21.3	203 m	n.a.	Blocked at 1 m	Yield n.a.; not used.	Not equipped	No	According to J Erasmus, PPC, bh backfilled and dry.
	GR190/5	33	38	29.3	25	33	22.3	220 m	300 ft?	80.45; 139	Yield n.a.; not used.	Not equipped	Table	Drilled 1954?
	GR190/6	33	38	03.3	25	32	53.3	251	69	Dry; <182	Dry	Exploration bh	No	Drilled May 2008
	GR190/7	33	38	28.8	25	33	21.7	215	75	73; 142	<0.1	Exploration bh	Table	Drilled May 2008
	GR190/8	33	38	33.0	25	33	10.7	238	93	72; 166	<0.1	Exploration bh	Table	Drilled May 2008
	GR190/9	33	38	40.2	25	33	27.4	204	75	69; 135	<0.1	Exploration bh	Table	Drilled May 2008

Table 7 (cont.): Borehole census information of the farms Grassridge 190, 227 and 228

Farm name	Bh number	Coordinates GPS (WGS84 datum)						Approx. Elevation (mamsl)	Depth (m) and date drilled	Static wl (mbc) and elevation (mamsl)	Yield (l/s) and use	Equipped	Water quality available	Additional comments
		Latitude			Longitude									
		D	m	s	D	m	S							
Coega Kammas Kloof 191 Portions 2, 3, 4, 5 and 6	CKK191/1	33	36	50.5	25	35	46.6	75	n.a.	No access	Yield n.a.; not used.	Wind pump	Table 8	Unknown
	CKK191/2	33	37	04.5	25	35	36.5	97	n.a	Blocked	Yield n.a.; not used.	Wind pump but broken	No	Borehole abandoned
	CKK191/3	33	36	10.5	25	34	42.0	96	n.a	No access	Na	Wind pump	Table 8	
	CKK191/4	33	36	06.0	25	34	27.2	91	n.a	Blocked	Yield n.a.; not used.	Not equipped		Borehole abandoned
	CKK191/5	33	35	59.3	25	33	52.3	134	n.a	Blocked at 26 m depth	Yield n.a.; not used.	Previously equipped with wind pump		
	CKK191/6	33	36	14.6	25	34	21.5	90	n.a	17.6	Yield n.a.; not used.	Not equipped	Table 8	
	CKK191/7	33	36	38.7	25	34	19.4	106	n.a	No access	Yield n.a.; not used.	Wind pump		Wind pump, not operational
	CKK191/8	33	36	45.1	25	35	29.8	80	n.a	~3.5 m	Yield n.a.; not used.	Wind pump	Table 8	Wind pump not operational
	CKK191/9	33	36	42.0	25	36	31.4	70	n.a	5	Yield n.a.; not used.	Not equipped	Table 8	
	CKK191/10	33	36	41.3	25	35	32.2	72	n.a	4	Yield n.a.; not used.	Not equipped	Table 8	
	CKK191/11	33	36	53.4	25	35	38.7	75	n.a	Blocked	Yield n.a.; not used.	Not equipped		
	CKK191/12	33	36	53.7	25	35	41.3	82	n.a.	Blocked	Yield n.a.; not used.	Not equipped		
	CKK191/13	33	36	52.0	25	33	41.4	162	n.a.		Yield n.a.; not used.	Not equipped	Dry	Very brackish water
	CKK119/14	33	36	55.2	25	34	59.8	98	n.a.	n.a.	Yield n.a.; not used.	Wind pump		
	CKK119/15	33	36	53.7	25	35	7.6	101	n.a	n.a.	Yield n.a.; not used.	Not equipped	Dry	
	CKK119/16	33	36	39.6	25	35	07.1	83	n.a.	Blocked	Yield n.a.; not used.	Not equipped	Dry	
	CKK119/17	33	36	38.3	25	35	12.1	91		Blocked	Yield n.a.; not used.	Not equipped	Dry	
	CKK119/18	33	36	46.8	25	35	57.2	75	n.a.		Yield n.a.; not used.	Not equipped	No	Very brackish water

Table 7(cont.): Borehole census information of the farms Grassridge 190, 227 and 228

Farm name	Bh number	Coordinates GPS (WGS84 datum)						Approx. Elevation (mamsl)	Depth (m) and date drilled	Static wl (mbc) and elevation (mamsl)	Yield (l/s) and use	Equipped	Water quality available	Additional comments
		Latitude			Longitude									
		D	m	s	D	m	S							
Grassridge 227	GR227/1	33	39	14.9	25	36	38.4	208	80	Bh blocked	Yield n.a.; not used.	Previously w/pump, now destroyed	No	Borehole collapsed between 40-50 m and is now blocked at ~1 m depth. Previously equipped with wind pump.
	GR227/2	33	38	47.3	25	34	18.9	218	135	74.22 143	~2 l/s; not used	Equipped with 100 mm sub- mersible pump	No	Drilled in 1998 by PPC, but not used for the last 3 years. Water struck at 75m. Intended as standby bh. Electricity supply to pump currently faulty and bh could not be sampled.
	GR227/3	33	38	38.0	25	34	38.7	233	135	34.53 198	Dry when drilled; not used	Not equipped	Table 8	Drilled in 1998 by PPC, dry when drilled. Bh closed and not used.
	GR227/4	33	38	31.2	25	34	28.8	235	Dry, >100m	>100m; <135	Yield n.a.; Never used by PPC	Not equipped	No	Apparently had some water, but was never used by PPC
Grassridge 228	GR228/1	33	42	29.6	25	33	20.9	92	130	4.12;(Nov'07); 88	6.7 l/s, not used	Not equipped	Table 8	Locally known as "Sout gat", not used due to poor quality.
	GR228/2	33	40	44.6	25	34	55.2	152	n.a.	22.92; (Nov'07); 129	Yield n.a.; not used.	Previously w/pump, destroyed	Table 8	
	GR228/3	33	41	22.9	25	35	33	184	n.a.	n.a.	Yield n.a.; not used.	Destroyed	No	Bh destroyed, coordinates approximate only.
	GR228/4	33	41	11.4	25	35	34.4	190	n.a.	n.a.	Yield n.a.; not used.	Destroyed	No	Bh destroyed, coordinates approximate only

Notes:

	Exploration boreholes drill during May 2008
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Table 8: Groundwater quality of selected boreholes around the proposed waste disposal facility

Farm or Standard	Bh no. or Reference Standard	pH	Elect cond.	Approx. TDS (Calc)	Alk	NH4	Ca	Cl	F	Fe	Mg	Mn	NO3 + NO2 (N)	PO4	K	Si	Na	SO4	Zn
	Units		mS/m	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
SABS 241:2006 Edition 6.1	Class I	5-9.5	<150	<1000		<1	<150	<200	<1		<70		<10		<50		<200	<400	<5
	Class II	4-10	150-370	1000-2400		1-2	150-300	200-600	1.0-1.5		70-100		10-20		50-100		200-400	400-600	5-10
	Class II max. water consumption period	No limit	7 yrs	7 yrs		No limit	7 yrs	7 yrs	1 yr		7 yrs		7 yrs		7 yrs		7 yrs	7 yrs	1 yr
	Sundays River Pipeline	8.1	74.8	486	151	<0.1	32	79			19		0.2	<0.2	3	1.7	93	52	
Grassridge 190 Portion 3	GR190/3/1	8.3	576	3744															
Grassridge 190	GR190/5	7.5	273	1775	429	2.5	38	835			42		6.1	<0.2	17	<0.6	432	3	
	GR190/7	8.0	308	2002	234	<0.1	74	693	0.49	7.9	64	0.08	<0.2	<0.2	32	5	444	118	<0.06
	GR190/8	8.1	176	1144	252	<0.1	47	302	0.57	28	39	0.09	0.78	0.93	32	10	274	63	<0.06
	GR190/9	8.0	197	1281	266	<0.1	75	670	0.51	9.2	66	0.09	<0.2	<0.2	30	5.9	441	107	0.18
Grassridge 227	GR227/3	7.4	99.1	644	208	0.12	115	259			15		0.85	<0.2	4	6.1	55	22	
Grassridge 228	GR228/1	7.2	523	3400	212	2	58	1640			81		<0.2	0.93	14	1.2	871	261	
	GR228/2	7.2	804	5226	116	<0.1	259	2710			200		3.9	<0.2	19	12	1070	302	
Blaauw Baatjies Vley 189 Portion 2	BBV189/2/1	7.9	325	2113															
Blaauw Baatjies Vley 189 Portion 3	BBV189/3/1	8.6	272	1768															
	BBV189/3/2	8.1	471	3062															
Coegakammaskloof 191	CKK/191/1	7.9	719	4674															
	CKK/191/3	7.8	502	3263															
	CKK/191/6	8.1	78.1	508															
	CKK/191/9	7.7	843	5480															
	CKK/191/10	9.8	994	6461															
	CKK/191/11	9.1	671	4362															

Notes

	Concentration exceeds SABS 241:2006 Class I water guideline
	Concentration exceeds SABS 241:2006 Class II water guidelines

Water quality information is captured separately in **Table 8**. The positions of all boreholes are marked on **Figures 5 to 9**.

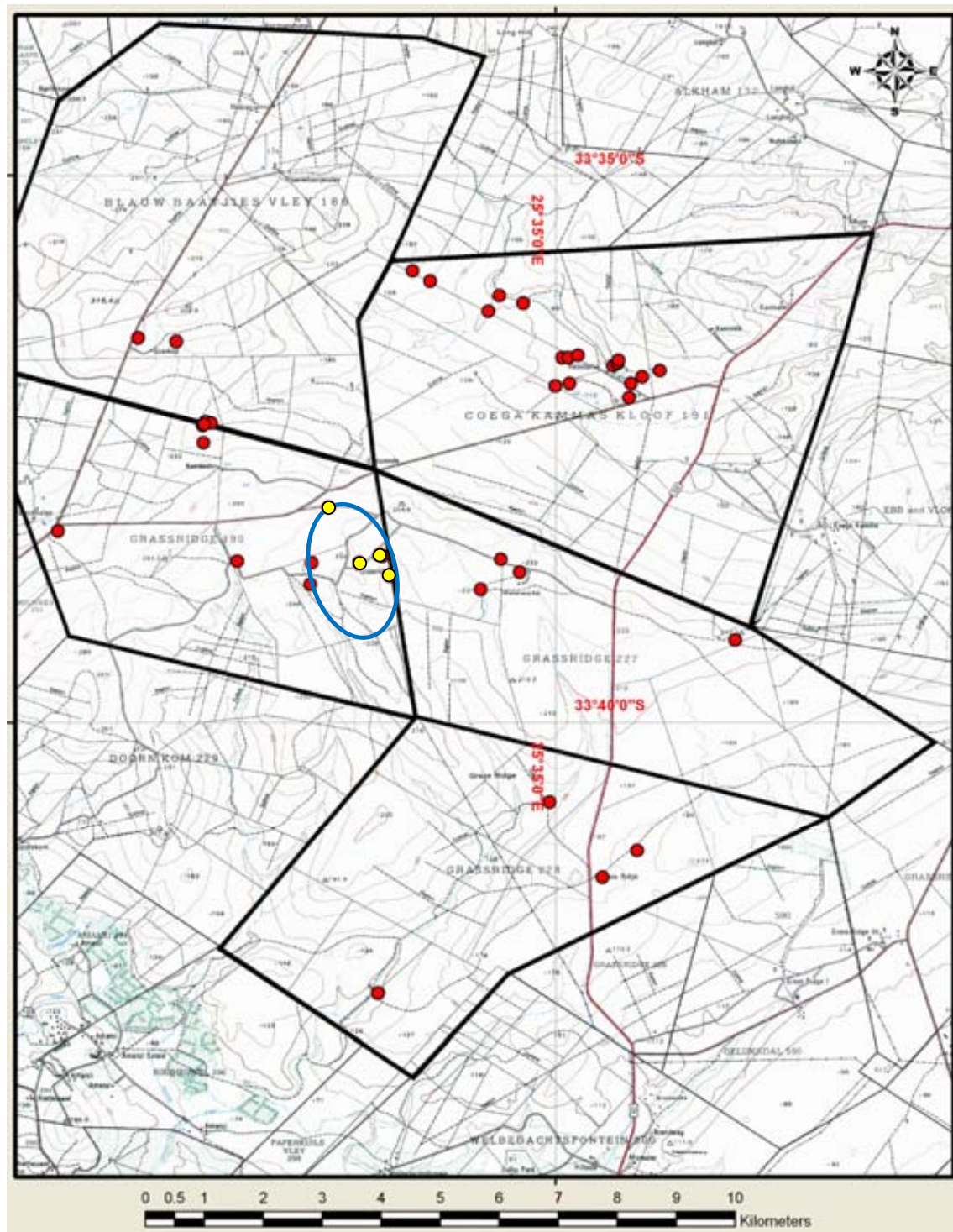


Figure 5: Positions of all boreholes located on the farms Blaauw Baatjies Vley 189, Coega Kammas Kloof 191, Grassridge 190, Grassridge 227 and Grassridge 228. Study area is marked by the blue oval shape area. The new exploration boreholes on Grassridge 190 Remainder are marked in yellow.

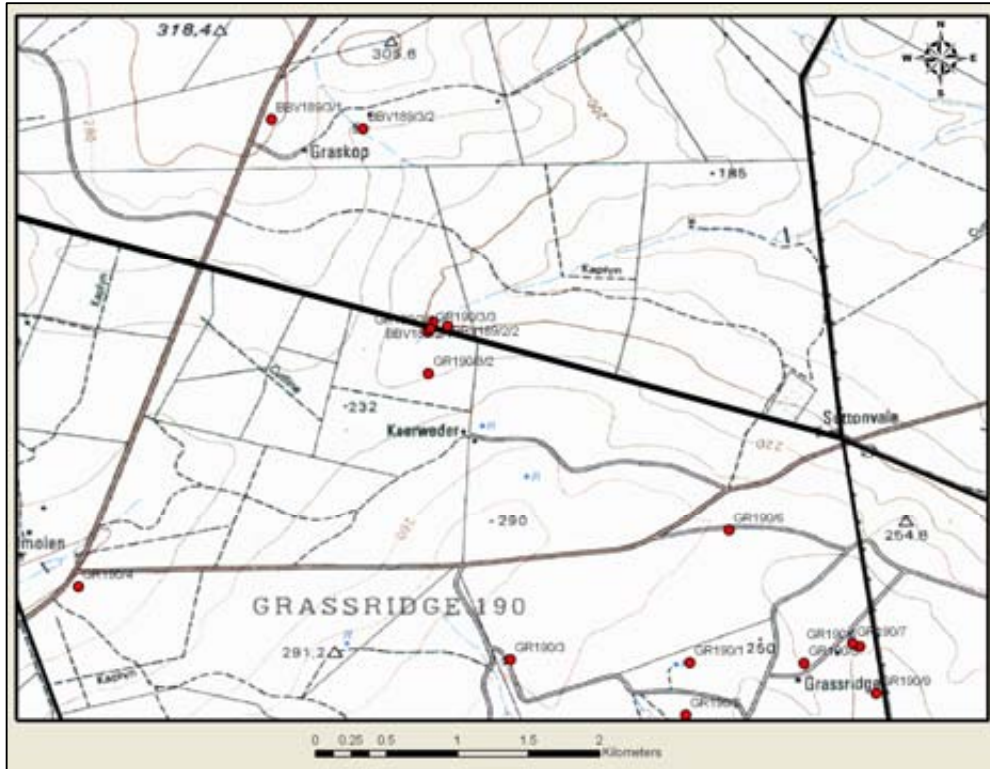


Figure 6: Boreholes located on the farms Blaauw Baatjies Vley 189 and Grassridge 190.

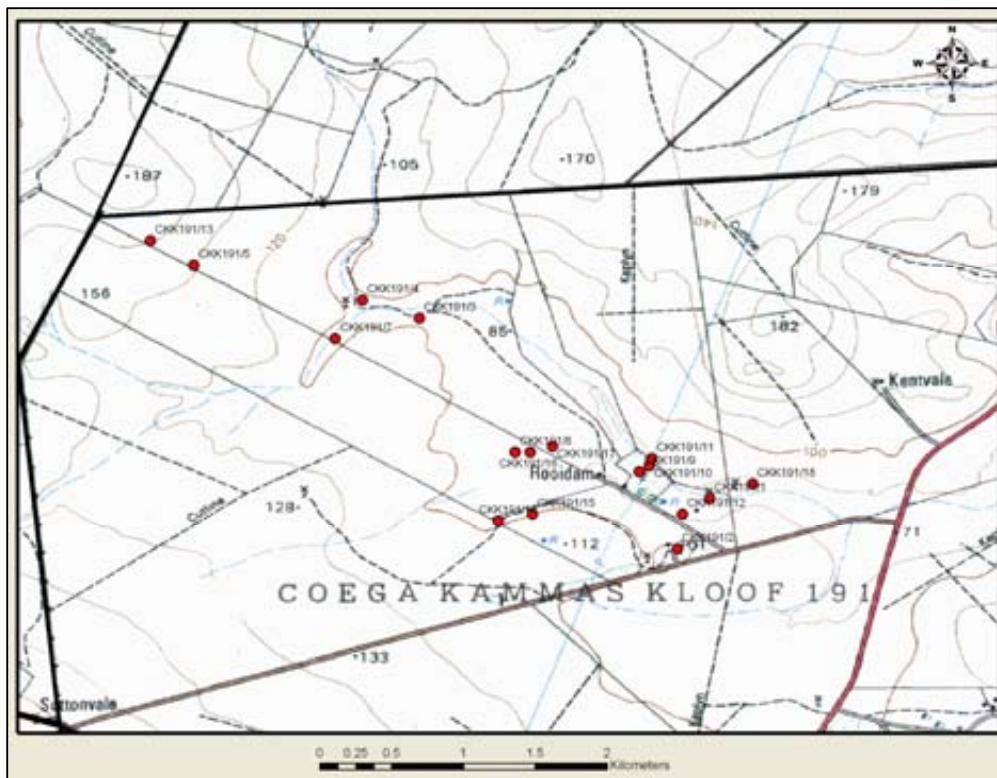


Figure 7: Boreholes located on the farms Coega Kammas Kloof 191.

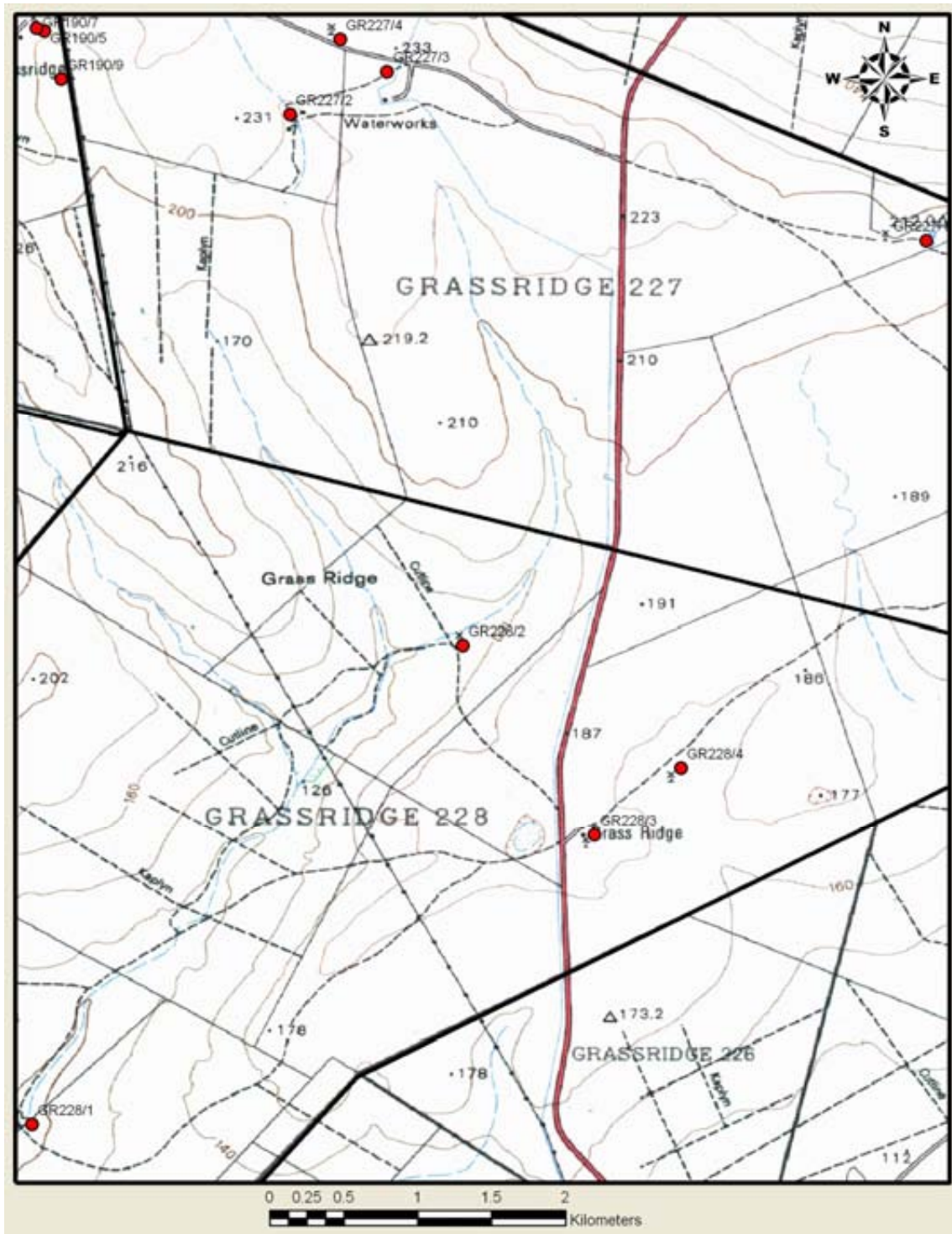


Figure 8: Boreholes located on the farms Grassridge 227 and Grassridge 228.

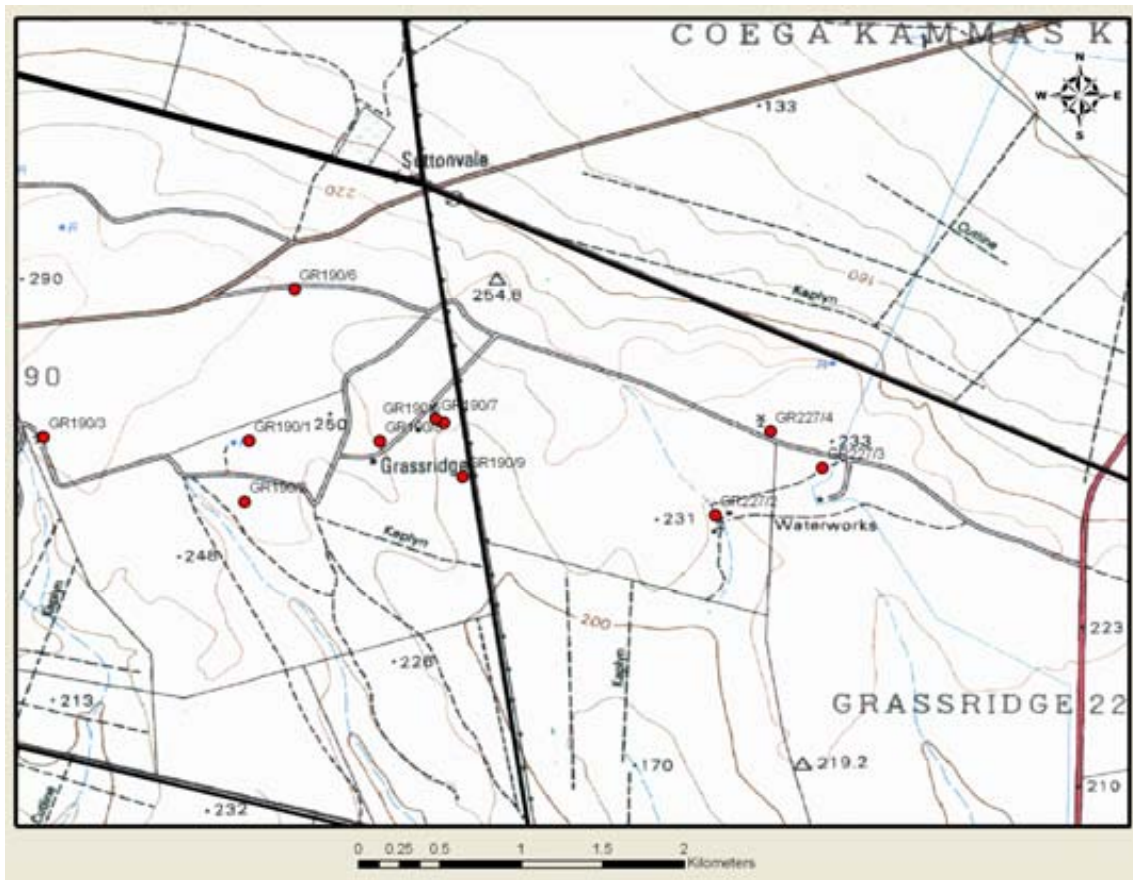


Figure 9: Boreholes in close vicinity of the area identified for the development of the proposed waste disposal site. Boreholes GR190/6 to GR190/9 are the exploration boreholes drilled during this phase of the investigation.

11 REGIONAL AND LOCAL GEOHYDROLOGICAL CONDITIONS

11.1 Regional geohydrology

The coastal sands, alluvial and aeolianite deposits and selected formations in the Table Mountain Group host the more important aquifers in the larger area around Port Elizabeth. The most prominent aquifer in the area is the Uitenhage Artesian Basin Aquifer (UAB) with an estimated total sustainable yield of 80 l/s (Venables, 1985). Yields from individual boreholes are generally in excess of 5 l/s. The natural boundaries of the UAB are formed by the Indian Ocean to the southeast, the Table Mountain Group-Bokkeveld Group contact in the vicinity of the Coega River to the north, the Great Winterhoek Mountains to the west and the St Albans Flats in the south. According to Maclear (2001) the Coega fault (see Section 7.1 of this report) divided the UAB into two main aquifers: the Coega Ridge Aquifer (to the north of the fault) and the deeper Swartkops Aquifer to the south. He suggests a

further subdivision of the Swartkops aquifer into two units, the Kruisrivier and the Bethelsdorp Units. The Coega Ridge, Kruisrivier and Bethelsdorp aquifers are artesian to sub-artesian, intensely fractured secondary aquifers in the quartzites of the Table Mountain Group. Groundwater quality of the artesian aquifer is excellent, with electrical conductivity generally less than 15 mS/m (Maclear, 2001). The work by Maclear (2001) confirms the earlier statement that the combined thickness of the Uitenhage Group formations, that act as confining layers, exceeds 500 m at Grassridge 190. The UAB aquifer provides through, for example the Uitenhage spring, significant baseflow in places to the surface water drainage systems. Groundwater is also used to a limited extent within the larger area to support basic human needs, stock watering and agriculture.

As a result of over-exploitation of the artesian aquifer, a portion of the UAB covering an area of 1 125 km², was declared a Subterranean Government Water Control Area (SGWCA) in 1957. This controlled area has been described in more detail in earlier reports (Godfrey *et al*, 2000; Bohlweki Environmental, 2003). The farms currently under investigation are located outside the boundaries of the Control Area (Bohlweki Environmental, 2003) as the southern boundary of the farms Grassridge 190 and 227 form the part of the northern edge of the old Uitenhage SGWCA (Maclear, 2001). Under the old Water Act (Act 54 of 1956) Government Water Control Areas (GWCA) were proclaimed, two of these within the broader study area, namely:

- The Sundays River GWCA (surface water); and
- The Uitenhage Subterranean GWCA

These GWCA's were established to control and manage the abstraction of water for, amongst others, irrigation purposes. Under the current National Water Act (Act 36 of 1998) where both surface and ground water are now regarded as public water, GWCAs effectively have been extended to include the entire country. The GWCAs declared under the previous Water Act (1956) have therefore been dissolved. However, a number of so called 'water-stressed' areas or catchments have since been identified and relate closely to the previous GWCAs. The use of water within these stressed areas is closely regulated and excluded from the General Authorisations issued by DWAF. The Sunday's River downstream of the Darlington Dam is seen as a water-stressed area and is excluded from the General Authorisations for surface water abstraction. As such any water use within this area, as defined by the National Water Act (1998), will require a water use licence, which in turn will require that a Reserve Determination be undertaken for the area.

As the area under investigation is directly underlain by rocks of the Uitenhage Group, the geohydrological characteristics of the rocks forming part of this Group, are of particular interest. Meyer (1998) reports that close to 40% of the boreholes on record drilled into these formations, have a groundwater yield of less than 0.5 l/s. The percentage of low yielding boreholes is expected to be even higher, as it is known that numerous unsuccessful boreholes have been drilled in the area, but no records of these exist. In addition, the electrical conductivity (EC) of the water from these formations is generally in excess of 300 mS/m, with sodium, calcium, magnesium, chloride and, occasionally sulphate often

exceeding the maximum allowable drinking water limits (SABS 241, 2006; Meyer, 1998). The high salt content is a reflection of the marine conditions under which these formations were deposited.

Generally high yields (up to 15 l/s) can be obtained from the coastal sand and alluvial aquifers associated with the flood plains of the major rivers draining the area. Water quality is variable, but mostly below 300 mS/m (Meyer, 1998).

11.2 Local geohydrology

Over large portions of the farms Grassridge 190, 227 and 228 outcrops of the Alexandria and Nanaga Formations are present. These are only a few metres thick and are extensively mined on the farm Grassridge 227. While closer to the coast the Alexandria formation is often regarded as a separate aquifer unit, in the present study area it appears to be mostly developed above the regional static water level and is therefore not regarded as a separate aquifer unit.

As described in the previous section, the study area is underlain by a thick succession of argillaceous rocks, predominantly mudstones and siltstones of the Sundays River and Kirkwood Formations. The fine grained sedimentary rocks of the Cretaceous Sundays River formation were shown by Bush (1985) and Venables (1985) to be the confining layer in the Uitenhage artesian aquifer system. This is also an indication of the low hydraulic conductivity (or permeability) of the succession. A further indication of its low permeability is shown by the use of the term “Uitenhage Aquiclude” for the combination of these two formations (Parsons, 1994; Maclear, 2001). In addition, the underlying sediments of the Bokkeveld Group are hydrogeologically described by Maclear (2001) as an “aquitard”. Wiid (1990) reports on laboratory permeability tests on shale from the Sundays River Formation near Aloes which indicated permeability values around 1×10^{-9} cm/sec or $\sim 8.6 \times 10^{-7}$ m/d. To put this value in perspective, the liner requirements at waste disposal sites specified in the DWAF Minimum Requirements for Waste Disposal by Landfill (1998), should have a permeability of the order of 1×10^{-7} cm/sec (8.6×10^{-5} m/d). The dominant clay mineral group in these argillaceous rocks is montmorillonite, a clay mineral that is characterized by its swelling in water. From these descriptions it is clear that the geological formations underlying the proposed site all have a very low hydraulic conductivity. The outcrops of limestone and calcareous sandstone of the Nanaga Formation form a relatively thin cover and are in turn underlain by thin marine deposits of calcareous sandstone of the Alexandria Formation. Both of these formations are not regarded as aquifers in the study area.

From the information supplied Mr Jakkie Erasmus, Farm Manager of the PPC farms, the maximum yield of the boreholes drilled on the farms Grassridge 190 and 227 is approximately 2 l/s, but this would however, be an exception rather than the rule. Many boreholes in the area are only equipped with wind pumps, which often is a reflection of low yield conditions. The observed low borehole yields are typical of the type of basement

geology ('tight' or massive mudstone and siltstone). Parsons (1983) found the borehole yield in the Kirkwood and Sundays River formations to range between 0.1 and 1.5 l/s with 0.5 l/s being the average. Meyer (1998) reports that close to 40% of the boreholes drilled into formations of the Uitenhage Group have a groundwater yield of less than 0.5 l/s. Low yielding or "dry" boreholes in these formations is further confirmed by the recent drilling of four exploration boreholes at the site under investigation. All four boreholes were dry at completion (see Section 9 of this report). It must also be emphasised that no groundwater is currently used, whether for domestic, stock watering or irrigation purposes, within a radius of 2-3 km around the site.

Depth to static water level as measured in 20 boreholes on surrounding farms, ranges between 4 m and >120 m below ground level. The shallower water levels are mostly confined to topographically lower areas such as in valleys or near drainage courses. The distribution of water level information was used to construct a ground water level map shown in **Figure 10**. This map clearly shows a ground water divide near the surface water divide and that groundwater flow is in a north-easterly and south-easterly direction. Several of the boreholes are situated on a plateau area close to the watershed between Quaternary catchments N40F (Sundays River), and M30A and M30B (Coega River) where static groundwater levels are generally deeper than 75 m below surface. Static groundwater levels around the proposed site are between 69 m and 73 m below surface.

12 AQUIFER CLASSIFICATION AND PROTECTION

From the above descriptions it is clear that two hydrogeological units or aquifers are present in the area. These are an upper aquifer associated with the Sundays River and Kirkwood Formations, and a deeper aquifer (>200 m below surface) associated with the Table Mountain Group formations. According to the Aquifer System Management Classification developed by Parsons (1995) the aquifer associated with the Uitenhage Group (Sundays River and Kirkwood Formations) would be classified as a Non-Aquifer System, while the aquifers associated with the Table Mountain Group could be classified as a Major Aquifer System. *Non-aquifer systems* are defined as formations or potentially fractured rocks which do not have a high primary permeability, or other formations of variable permeability. Aquifer extent may be variable and water quality variable. *Major aquifer Systems* on the other hand, are defined as highly permeable formations, usually with a known or probable presence of significant fracturing. They may be highly productive and able to support large abstractions for public supply and other purposes (Parsons, 1995). The Uitenhage Artesian Basin is part of the Table Mountain Group Aquifer System, and although it is situated to the south of the study area, could be classified as a Special Aquifer System, because it has previously been classified as an Underground Water Control Area. The deeper Table Mountain Group aquifer is artesian where overlain by the Uitenhage Group due to the argillaceous nature of the overlying succession. This geological composition and the associated very low hydraulic

conductivity create a very thick natural protection layer that will ensure that no potential contamination originating at the proposed waste disposal site will reach the artesian aquifer.

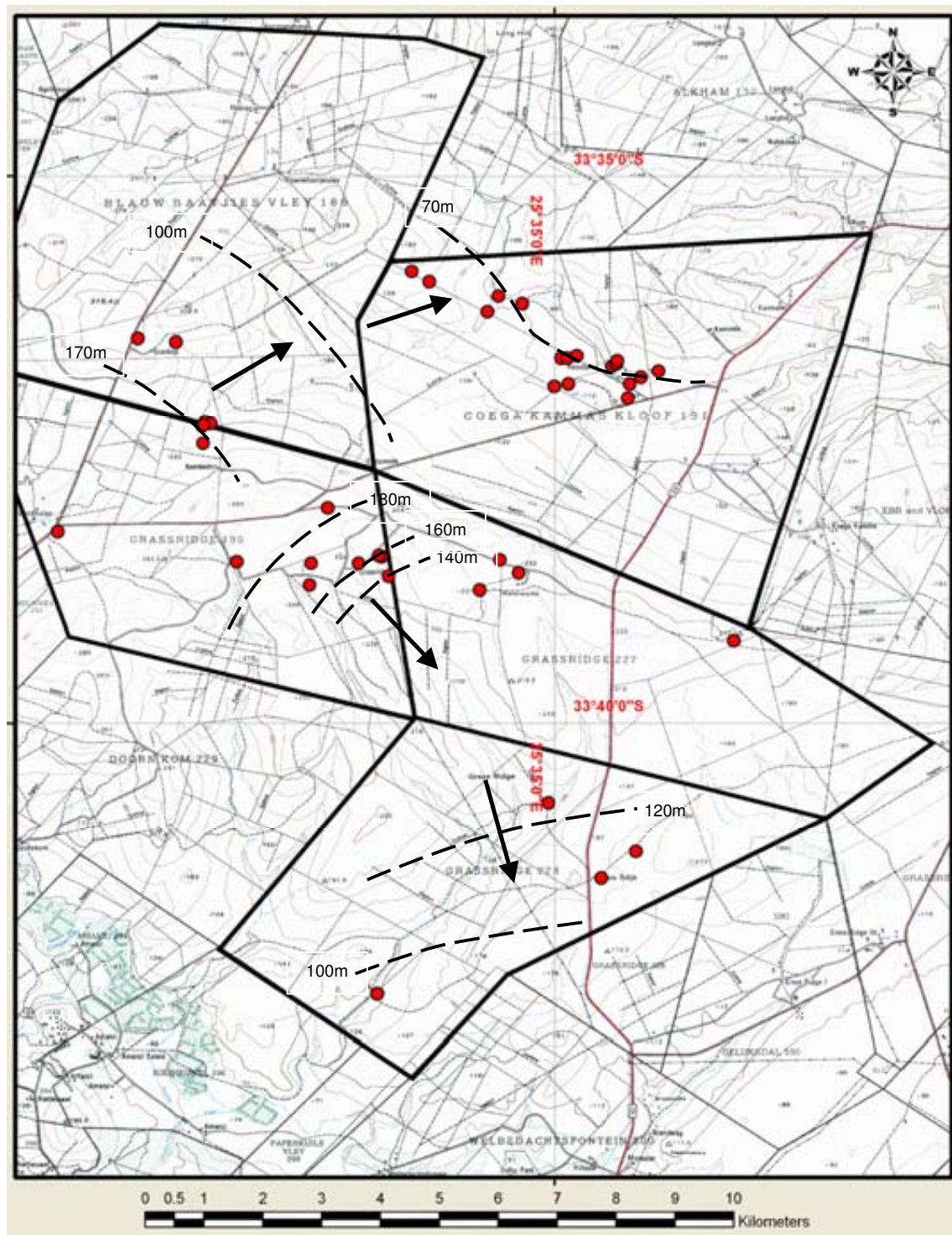


Figure 10: Map of the study area showing the inferred static groundwater level contours (mamsl) based on limited water level information and the inferred groundwater flow directions.

13 GROUNDWATER USE AND QUALITY

Of the 43 existing boreholes on the farm Grassridge 190 and surrounding farms, only two were found to be used currently for domestic or stock watering purposes. Both of these are on the farm Grassridge 190 Portion 3; a distance of approximately 4 km from the proposed waste disposal site. The main reasons for the very limited use of groundwater in the area are threefold:

- The general very poor quality of the groundwater
- The low yield of boreholes, and
- The reliable and easy access farmers have to very good quality water at affordable cost from the Sundays River/ Port Elizabeth pipeline that traverses the area.

Water samples could be obtained from 17 of the boreholes on the surveyed farms, including three from the recently drilled boreholes. With the exception of one borehole (GR190/3/1), none of the boreholes are equipped with pumps that are still in operation, and therefore all samples could only be obtained from those open boreholes accessible with a bailer. Water quality information is captured in **Table 8**. For reference purposes the SABS 241 (2006) Drinking Water Standard for Class I (Ideal condition) and Class II (Maximum allowable), as well as the analysis of a water sample taken from the reservoir supplied from the Sundays River pipeline on the farm Grassridge 227, are listed in **Table 8**.

The sediments of the Sundays River Formation were deposited under marine conditions. Sea water and salts trapped during the depositional process, explain the general poor quality of the groundwater in the area. This has been recognised in reports by Maclear (1994), Bush (1985), Venables (1985) and Parsons (1983). Maclear (1994) compiled a map showing the electrical conductivity (EC) distribution of groundwater between Uitenhage and Addo. According to this map EC values of >500 mS/m are the dominant feature. In the present study area, his map shows values in the range of 70 to 1500 mS/m. EC measurements on samples collected during the recent borehole census are shown in **Table 8** and range between 99 and 804 mS/m. This confirms the observations by Maclear (1994). From the above it is clear that the Sundays River and Kirkwood geohydrological units in terms of the groundwater quality, have no strategic potential or value as a water resource.

As referred to earlier, the most prominent regional aquifer of strategic importance in the area is the Uitenhage Artesian Basin Aquifer (UAB) with an estimated total sustainable yield of 80 l/s (Venables, 1985) and yields from individual boreholes often in excess of 5 l/s. The artesian nature of this aquifer is mainly due to two factors: (i) the natural recharge area is the high great Winterhoek Mountains to the north, and (ii) the Sundays River and Kirkwood formations overlying this aquifer and forming the confining layer. At the site under investigation and in the immediate surrounding area, the deeper Table Mountain sandstone aquifer is however not exploited for its groundwater potential due to the excessive depth (estimated to be in the order of 300 m to 500 m below surface).

14 GROUNDWATER MONITORING

In the documents *Minimum Requirements for Waste Disposal by Landfill (DWAF, 2nd edition, 1998 and draft 3rd edition, 2005a)* and the *Minimum Requirements for Water Monitoring at Waste Management Facilities (DWAF, 2005b, 3rd edition)* issued by the Department of Water Affairs and Forestry, specifications for the monitoring of groundwater at waste disposal facilities are discussed. Groundwater monitoring can be described as the repetitive and continued observation, measurement and evaluation of geohydrological information such as water level and groundwater quality to follow changes over a period of time to assess the efficiency of control measures. In essence, monitoring serves as an early warning system so that any corrective actions required can be taken promptly. A detailed account of the proposed monitoring specifications, including that for groundwater, is contained in the report entitled "Draft Operating Manual for the proposed Hazardous Waste Disposal Facility" prepared by Jones & Wagener (2008b) for the Coega Development Corporation.

Should the site receive a permit, it is recommended that the newly drilled boreholes GR190/6 to GR190/9 as well as the existing borehole GR190/5 be used as monitoring boreholes. Apart from obtaining geological and geohydrological information, it was also the intention to use borehole GR190/6 as a background monitoring borehole. However, no water was encountered in the borehole during drilling and even a few days after completion it was still dry. Should this borehole remain dry, and depending on the final approved design of the site, a position for a new background monitoring borehole may have to be selected. According to the 3rd edition draft of the *Minimum Requirements for Water Monitoring at Waste Management Facilities (2005)*, between five and ten boreholes would typically be required for a hazardous waste disposal site. It is therefore possible that additional boreholes will be required for monitoring. The existing exploration boreholes have also not been equipped to serve as monitoring boreholes. Therefore, in the event of the proposed site being approved for further development, the design of the groundwater monitoring network will have to be revised. Some of the existing boreholes may be included in this design provided they suitable uPVC casing can still be installed. Because of unstable formation conditions, some minor water seepage into the boreholes shortly after drilling and the fact that the boreholes were not cased, some collapse of the boreholes was already recognised shortly after completion. It is therefore recommended that the groundwater monitoring network be reviewed should a permit be issued for the site be issued. This may include the re-drilling of some of the existing boreholes due to either collapse of the existing boreholes, or if the final design and layout of the different components of the facility necessitate that boreholes be moved.

In the draft operating manual prepared by Jones & Wagener (2008b) a detailed account of the proposed monitoring specifications, including that for groundwater, can be found. In this preliminary specification it is recommended that ground water monitoring and sampling should be done on a quarterly basis (January, April, July and October), with detailed

analyses to be undertaken once a year (July). In their report (Jones & Wagener (2008b) only pH, electrical conductivity and chemical oxygen are required during the other three sampling exercises. Field measurements for all sample runs must include temperature, pH and electrical conductivity, and must be recorded on a log sheet while on site. Post-closure monitoring is to continue for 30 years following closure of the site, unless otherwise motivated, and authorised by the authorities.

A list of constituents to be analysed during the July sampling is also included in the Jones and Wagener (2008) draft operating manual. This list is based on sampling for Holfontein Hazardous Waste Disposal Facility in Gauteng. Although this list can be used as a guideline, the final list of constituents to be analysed for at the Grassridge site, will however depend on the type of waste accepted for disposal at this site and when the site-specific authorizations are issued.

15 RISK ASSESSMENT

15.1 Aquifer management classification and vulnerability

Parsons (1995) developed a South African aquifer system management classification consisting of two parts: (i) a weighted aquifer class classification and (ii) a groundwater quality management index, that when combined, provides a decision support tool to define the required level of protection of the aquifer. The Ground Water Management Classification System ratings are given in **Table 9**. In Section 12 above the two hydrogeological units or aquifers present in the area, the upper aquifer associated with the Sundays River and Kirkwood Formations, and a deeper aquifer (>200 m below surface) associated with the Table Mountain Group formations, have already been classified as a *Non-Aquifer System* and a *Major Aquifer System* respectively, while the Uitenhage Artesian Basin (which is regarded as part of the Table Mountain Aquifer System) would be classified as a *Special Aquifer System*.

The deeper Table Mountain Group aquifer is artesian where overlain by the Uitenhage Group due to the argillaceous nature of the overlying succession. This geological composition and the associated very low hydraulic conductivity create a very thick natural protection layer that will ensure that no potential contamination originating at the proposed waste disposal site will reach the artesian aquifer.

According to this classification system the aquifers underlying the proposed site on the farm Grassridge 190 can be described as a '*Non-Aquifer System*' (score = 0) with a '*Low Aquifer Vulnerability*' (score = 1), and requiring only a limited degree of protection (score = 0).

Table 9: Ground Water Management Classification System (Parsons, 1995)

AQUIFER SYSTEM MANAGEMENT CLASSIFICATION		AQUIFER VULNERABILITY CLASSIFICATION		GROUNDWATER QUALITY MANAGEMENT INDEX	LEVEL OF PROTECTION
<i>Class</i>	<i>Points</i>	<i>Class</i>	<i>Points</i>		
Sole Source Aquifer System	6			<1	Limited protection
Major Aquifer System	4	High	3	1 – 3	Low level protection
Minor Aquifer System	2	Medium	2	3 – 6	Medium level protection
Non-aquifer System	0	Low	1	6 – 10	High level protection
Special Aquifer System	0-6			>10	Strictly non-degradation

On the adjacent farm (Grassridge 227) and approximately one kilometre east of the proposed waste disposal facility PPC is mining surface calcrete. The mining operation covers an area of approximately 1.5 km x 1.5 km, while the thickness of the deposit is on average about 3 m. The calcrete layer is broken into smaller blocks with large mechanical excavators and then taken to a crushing plant. Occasionally hard calcrete layers are encountered at a depth of approximately 1.5 m that cannot be broken up by the normal mining technique. According to Mr Erasmus of PPC blasting using 3 m deep drill holes, is occasionally used (approximately once every two years) to mine these layers. These hard calcrete deposits sometimes have to be mined to ensure the availability of a continuous supply of ore to the crushing plant at times when mechanical failure of excavating equipment is encountered. The mining techniques applied in this mining operation, are totally different to deep level underground and some open cast mining operations, and therefore mining induced seismicity and earth tremors as a risk to the stability of the waste disposal cells, can be ruled out.

Hattingh and Goedhart (1997) report that no modern seismic activity has been recorded in the southern part of the Eastern Cape by either of the two seismic stations located at Grahamstown and Port Elizabeth.

15.2 Evaluation of the site for waste disposal

The results of the geological and geohydrological investigation were used in assessing the Waste-Aquifer Separation Principle (WASP) index of the proposed site, i.e. a risk assessment of the proposed landfill site with respect to the groundwater environment (Parsons and Jolly, 1994). The WASP index is an indication of the suitability of a site for waste disposal, which takes into account:

- The threat factor, i.e. the threat of the size and type of waste facility to the ground water;
- The barrier factor, i.e. the potential for pollutant attenuation in the upper unsaturated zone and the resultant potential for ground water pollution; and
- The resource factor, i.e. the significance of the aquifer for local and/or regional water supply.

Threat Factor

The size of the landfill (final landfill footprint) is estimated to be approximately 25 ha and will be classified as a H:H site. According to DWAF Minimum Requirements (DWAF, 1998) such a landfill should be designed, engineered and operated to the most stringent standards and must be a containment landfill with a liner and leachate detection and collection system.

Barrier Factor

The underlying siltstone and the significant depth to groundwater, is shown to have a good barrier effect against the vertical movement of possible ground water pollutants. Estimated travel time, based on hydraulic parameters and water level typical for the area, from on-surface to the aquifer are calculated to be ~566 days. Due to the lack of water in the newly drilled boreholes, no pumping tests could be done and travel times were calculated using the estimated permeability of the underlying geological formations and depth to water level.

Resource Factor

The site overlies a non-aquifer system containing very poor quality water and with a low potential for use. Groundwater is currently not used in the immediate vicinity of the site.

Summary

The results of the WASP assessment is given in **Appendix C** and shows the site to be 'suitable' for the development of a landfill site, in terms of the geology and geohydrology of the area.

16 IMPACT DESCRIPTION AND ASSESSMENT

16.1 General comments

It is clear from the above discussion that there is no significant difference in the geohydrological and hydrological conditions at the site. The aquifers present in the area can be described as being of low significance, deep, and with an extremely poor water quality and generally low yield, except for in the low lying areas along drainage lines, for example boreholes GR227/2 and GR228/1. There are no known perched aquifers of any significance. Hydrologically, there are no perennial drainage systems at or in the immediate vicinity of the site.

16.2 Impact assessment

Potential impacts on the ground and surface water environment are described under three headings:

- Site construction phase
- Operational phase, and

Decommissioning phase

Notes:

1. *The impacts described only pertain to operations on the waste site itself and in the immediate vicinity, but does not include for example impacts on ground and surface water along the access routes to the site.*
2. *On the impact assessment tables (Tables 10-12) an indication is given of the severity of the impacts before and after mitigation. Mitigation measures are addressed in Table 13.*
3. *Terms used in the assessment are defined and listed in Appendix D.*

Design and construction phase

Table 10: Impact assessment during design and construction phase

Activity / Aspect	Potential Impact	Nature	Status	Extent	Duration	Probability	Severity / Beneficial scale (see note)		Significance
							Before mitigation	After mitigation	
Excavation and site preparation	Disruption of natural runoff conditions	Excavations may cause interception and/or disruption of natural runoff resulting in less surface water entering natural drainage lines	Negative	Local	Short term	Improbable	Slight	No mitigation	Low
Existing boreholes	Groundwater contamination	Development of a site over an existing open borehole	Negative	Local	Long term	Probable	Severe	No effect	Medium
Storage and stockpiling areas for construction material	Soil and groundwater contamination	Uncontrolled storage of harmful products used during construction resulting in possible soil and groundwater contamination	Negative	Local	Short term	Probable	Slight	Slight	Low
Construction camp and temporary infrastructure such as workshops, wash bays. etc.	Soil, surface water and groundwater contamination	Disposal of domestic and construction process waste water and effluent affecting surface water quality	Negative	Local	Short term	Probable	Slight	No effect	Low
Domestic sewage	Soil, surface and groundwater contamination	Irresponsible disposal of domestic sewage eventually affecting soil, surface and groundwater quality	Negative	Local	Long term	Probable	Slight	No effect	Low
Storm water on and around site	Natural surface water flow in drainage lines	Natural storm water runoff pattern disrupted and end destination affected through excavations and stockpiling areas	Negative	Local	Permanent	Probable	Slight	Slight	Low
Groundwater recharge	Improving groundwater recharge	Excavations for construction and liner material may leave open pits that can enhance infiltration of rainfall	Positive	Local	Long term	Probable	Slight	Slight	Low
Fuel storage and distribution point	Soil and groundwater contamination	Irresponsible housekeeping around fuel depot and distribution point can contaminate shallow soil profile through spillages	Negative	Local	Long term	Probable	Slight	No effect	Low

Note: Proposed mitigation measures are listed in Table 11.

Operational phase

Table 11: Impact assessment during operational phase

Activity / Aspect	Potential Impact	Nature	Status	Extent	Duration	Probability	Severity / Beneficial scale (see note)		Significance
							Before mitigation	After mitigation	
Waste disposal	Soil, Surface and groundwater contamination	Poor liner design/construction and ineffective leachate collection system causing leakage through liner resulting in leachate infiltration into ground. Too high volumes of leachate generated in cells resulting in high leachate levels in waste pile and eventual seepage from waste pile	Negative	Local	Long term	Probable	Moderately severe	Moderately severe	Medium
Leachate holding dams	Surface and groundwater contamination	Poor design/construction or insufficient capacity causing leakage resulting in leachate infiltration into ground, storm water or natural drainage systems	Negative	Local	Long term	Probable	Moderately severe	Slight	Medium
Leachate treatment facilities	Soil and surface water and eventually groundwater contamination	Spillages affecting soil conditions	Negative	Local	Medium term	Probable	Slight	No effect	Low
Waste storage areas (temporary storage, recycling facilities, , etc.	Soil, surface and groundwater contamination	Inappropriate storage facilities resulting in leaching of contaminated effluent into ground and storm water system	Negative	Local	Medium term	Probable	Slight	No effect	Low
Sewage disposal (septic tank systems)	Surface and groundwater contamination	Inappropriately designed/constructed sewage disposal systems and bad maintenance resulting in groundwater contamination	Negative	Local	Long term	Low	Slight	No effect	Low
Runoff and storm water management on and around site	Surface and groundwater contamination	Insufficient storage capacity causing overflow of storm water holding facilities and impacting negatively on stream water quality and eventually groundwater	Negative	Local	Medium term	Low	Slight	No effect	Low
Washing areas (Vehicles, re-useable containers, etc)	Surface and groundwater contamination	Inappropriate design/construction of wash bays, bunding areas and effluent control resulting in soil contamination	Negative	Local	Medium term	Probable	Slight	No effect	Low
Workshops	Surface and groundwater contamination	Bad housekeeping and irresponsible disposal of workshop waste products (oil, cleaning agents, etc.) resulting in soil contamination through leaching.	Negative	Local	Long term	Probable	Slight	No effect	Low

Note: Proposed mitigation measures are listed in Table 11.

Decommissioning phase

Table 12: Impact assessment during decommissioning phase.

Activity / Aspect	Potential Impact	Nature	Status	Extent	Duration	Probability	Severity / Beneficial scale		Significance
							Before mitigation	After mitigation	
Closure/ capping of individual waste disposal cells	Uncontrolled leachate generation and build-up of leachate level	Insufficient/inappropriate cover construction resulting in rainwater infiltration, leachate generation and eventually leachate seepage from disposal cells	Negative	Local	Medium term	Probable	Moderately severe	No effect	Medium
Treating/dis-posal of surplus leachate and storm water in holding dams at final closure	Contamination of ground and surface water resources	Poor leachate management resulting in surplus at closure	Negative	Local	Medium	Probable	Moderately severe	Slight	Medium
Maintenance of storm water control systems	"Soil" erosion at closed disposal cells	Erosion of cells resulting in collapse and exposure of waste material	Negative	Local	Medium	Probable	Moderately severe	No effect	Medium
Maintenance of capping	Uncontrolled leachate generation	Capping losing its low permeability character resulting in rainwater infiltration and leachate generation	Negative	Local	Medium	Probable	Moderately severe	No effect	Medium
Maintenance of water monitoring systems (boreholes and surface water) and maintaining a sampling and analysis programme after closure according to permit conditions	Quality deterioration of water resources	Poor maintenance and control of groundwater and surface water monitoring points and boreholes, as well as neglecting regular sampling and analyses as stipulated in permit conditions..	Negative	Local	Long term	Probable	Moderately severe	Slight	High

17 RECOMMENDED MITIGATION AND MANAGEMENT ACTIONS

From the tables below it will be noticed that the impact related to ground and surface water are in most cases rated as low. This rating is applicable in the case of the extent of the impact, the duration, the probability, the severity and the significance. Definitions of terms used in the assessment are listed in Appendix B. The reason for the expected low impact on the groundwater environment is due to the favourable geological and geohydrological conditions. Similarly, the impact on surface water is also expected to be low, as the proposed sites are all located outside important and high yielding surface water catchment areas. Nevertheless, this should not lead to compromises on mitigation and management actions during the design, construction, operation and closure phases of the project. The recommended mitigation and management actions for the different phases of the project are listed in Table 13.

18 CONCLUSIONS

Based on the available geological and geohydrological information for the proposed site and the immediate surrounding farms, the identified site on the farm Grassridge 190 Remainder is considered suitable for the development of a large H:H type waste disposal facility provided the design, construction and operational requirements as specified in the DWAF guideline document are adhered to. The main reasons for the site being regarded a suitable area, are the following:

- The geological conditions of the underlying formations, both in terms of lithology and depth extent are very favourable.
- The static groundwater level in the vicinity of the site is of the order of 70 m below surface.
- Borehole yields are generally very low as illustrated by the four recently drilled boreholes that were all dry on completion of drilling.
- The groundwater quality in the region is generally poor to very poor and as a result very little use is being made of groundwater for domestic, stock watering or irrigation. The poor water quality is a direct result of the marine depositional conditions that existed during the formation of the geological formations hosting the groundwater.
- The underlying formations, the Sundays River and Kirkwood formations, comprise of a very thick succession (estimated to be >300 m) of predominantly siltstone and mudstone, with minor interlayered sandstone layers. These formations have a very low hydraulic conductivity and will prevent the migration of contaminants in the case of liner system failure.

Table 13: Proposed mitigation actions during the different phases of the hazardous waste disposal facility

Phase	Activity	Impact description	Proposed mitigation
Design and construction phase	Installation of required infrastructure for water quality (surface and groundwater) monitoring and design of monitoring programme		Approval of water quality monitoring systems by the relevant government authorities
	Design of site including an approved sewage disposal system suitable for the local soil conditions	Ground and surface water contamination	Design to be done according to the latest Minimum Requirement documents and specifications of the Departments of Water Affairs and Forestry (DWAF) and Environment and Tourism (DEAT). Approval of all designs to be obtained from the relevant National and Regional/Provincial regulatory authorities.
	Closure of boreholes	Groundwater contamination	Sealing of all boreholes with cement and final bentonite at the top. Sanitary seal consisting of a bentonite and sand mixture around the upper 4 m of the borehole.
	Excavation and site preparation, Storm water control on and around site	Disruption of natural runoff conditions	Proper storm water control measures to be implemented to minimize storm water collection within the excavated areas and to reduce erosion
	Construction and installation of liners and leachate collection and drainage systems.	Groundwater contamination	Selection of good quality natural clay for liner construction, alternatively addition of bentonite to liner material to attain the prescribed permeability for liners. Regular inspection of construction and testing of liner permeability and compaction characteristics during construction. Proper control and supervision during the placement of synthetic liners, and testing after completion.
	Construction camp and temporary infrastructure such as workshops, wash bays, fuel storage and distribution point etc.	Soil, groundwater and surface water contamination	Proper management of all construction material storage area and bunding of facilities where required.
Operational phase	Leachate generation control and management	Soil, Surface and groundwater contamination	Minimize leachate generation through proper landfill management and control of ratio between liquid and solid waste disposed in each cell. Proper control of leachate seepage and collection thereof and diverting to properly designed holding and/or treatment facility.
	Leachate holding dams	Surface and groundwater contamination	Approved designed and constructed leachate holding dams.
	Waste storage areas (temporary storage, recycling facilities, storage for incineration, etc.	Soil, Surface and groundwater contamination	Bunding of all storage facilities and disposal of all effluent collected in bunded area to leachate or storm water holding dams.
	Approved sewage disposal system suitable for the local soil conditions	Surface and groundwater contamination	Properly designed and constructed according to building regulations of all sewage disposal systems on site and regular removal of sewage from tank to prevent overflow..
	Runoff and storm water management on and around site	Surface and groundwater contamination	Proper storm water control and drainage canals around disposal area, together with storm water control dams with sufficient capacity to support a 1:50 year rainfall event. Monitoring programme for storm water quality and disposal of storm water to be in place.
	Washing areas (Vehicles, re-useable containers, etc)	Surface and groundwater contamination	Approved design and constructed wash bays and effluent collection and disposal systems.
	Workshops	Surface and groundwater contamination	All workshop waste to be disposed of in accordance to regulations.

Decommissioning phase	Closure/capping of individual waste disposal cells	Uncontrolled leachate generation and seepage, build-up of leachate level	Proper capping of each cell and regular maintenance of capping according to permit conditions to avoid infiltration of rainwater and thus leachate generation within the waste pile. Installation of leachate level monitoring facility for each cell monitoring point
	Treating/disposal of surplus leachate and storm water in holding dams at final closure	Contamination of ground and surface water resources	Treating and/or proper disposal of final leachate volumes and draining of holding dams.
	Maintenance of storm water control systems	"Soil" and waste pile erosion after closure	Development and implementation of a storm water management plan as well as the proper maintenance of storm water control systems on site after closure according to permits and regulations issued from time to time by relevant authorities. Regular inspections by authorities.
	Maintenance of water monitoring systems (boreholes and surface water) and programme	Quality deterioration of water resources	Regular water quality monitoring according to permit conditions and in compliance to Minimum Requirement documents of DWAF. Reporting of results to the authorities on a six monthly basis.

- The deep artesian aquifer associated with the Table Mountain Group sediments, is well protected from any contamination by the thick succession of Uitenhage Group sediments. That the latter sediments form an effective barrier to groundwater flow is illustrated by the artesian nature of the deeper aquifer.
- The site is situated close to a local surface water divide and none of the drainage lines at or upstream of the site represent perennial flow conditions.
- The WASP analysis, which takes into consideration a number of geological, geohydrological, water use and design criteria, also indicated that the site can be classified as “suitable”
- No geological or geohydrological conditions within the study can be regarded as “fatal flaws” according to the definitions described in the DWAF guideline documents.

REFERENCES

- BOHLWEKI ENVIRONMENTAL SERVICES (PTY) LTD. (2003). Footprint Ranking Report for the Proposed Regional Hazardous Waste Processing Facility in the Eastern Cape. Bohlweki Environmental Services (Pty) Ltd., Midrand.
- BUSH, R A (1985). A geohydrological assessment of the Kruisrivier / Bethelsdorp Systems, Uitenhage. Technical Report Gh 3458, Directorate of Geohydrology, Dept. of Water Affairs, Pretoria.
- COUNCIL FOR GEOSCIENCE, SOUTH AFRICA (2000). Geological Map Sheets 3325DC and DD, Port Elizabeth, 3325 CD and 3425 AB Uitenhage, 3325 CB Uitenhage North and 3325 DA Addo (Scale 1:50 000). Council for Geoscience, Pretoria.
- DEPARTMENT OF WATER AFFAIRS AND FORESTRY (1998). Waste Management Series. Minimum Requirements for Waste Disposal by Landfill. Second edition, DWAF, Pretoria.
- DEPARTMENT OF WATER AFFAIRS AND FORESTRY (2005a). Waste Management Series. Minimum Requirements for Waste Disposal by Landfill. Draft Third edition, DWAF, Pretoria.
- DEPARTMENT OF WATER AFFAIRS AND FORESTRY (2005b). Waste Management Series. Minimum Requirements for Water Monitoring at Waste Management Facilities. 3rd edition, DWAF, Pretoria.
- DEPARTMENT OF WATER AFFAIRS AND FORESTRY (1956). Water Act , Act 54 of 1956. DWAF, Pretoria.
- DEPARTMENT OF WATER AFFAIRS AND FORESTRY (1998). National Water Act No 36 of 1998. DWAF, Pretoria.
- GEOLOGICAL SURVEY, SOUTH AFRICA (1989). Geological Map Sheet 3324 Port Elizabeth (1:250 000). Geol. Surv., Pretoria.
- GODFREY, L., MEYER, R., CONRAD, J., SILINGA, A AND HUGHES, S. (2000). Report on the Identification of potentially suitable areas for the development of the proposed regional, general and hazardous waste processing facility within the Eastern Cape. A GIS Approach. Division of Water, Environment and Forestry Technology, CSIR, Confidential Report No. ENV-P-C 2000-024, March 2000.
- GODFREY, L., AND MEYER, R. (2000A). Report on the preliminary identification of farms for the development of a regional, general and hazardous waste processing facility within the Eastern Cape. Division of Water, Environment and Forestry Technology, CSIR, Confidential Report no: ENV-P-C 2000-051, May 2000.

- GODFREY, L., AND MEYER, R. (2000B). Report on the selection of the most suitable farms for the development of a regional, general and hazardous waste processing facility within the Eastern Cape. Based on a pre-feasibility assessment of geohydrological and geological criteria, transport logistics and fauna and flora. Preliminary identification of farms for the development of a regional, general and hazardous waste processing facility within the Eastern Cape. Division of Water, Environment and Forestry Technology, CSIR, Confidential Report no: ENV-P-C 2000-059, August 2000.
- HARTNADY, C H J (1990). Seismicity and plate boundary evolution in south-eastern Africa. South African Journal of Geology, 93, pp. 473-484.
- HATTINGH, J AND GOEDHART, M L (1997). Neotectonic control on drainage evolution in the Algoa Basin, South-eastern Cape Province, South African Journal of Geology, 100, pp. 43-52.
- JONES AND WAGENER (2008a). Geotechnical site investigation. Detailed geotechnical investigation of the Grassridge site. Report No. 15/08/B494. Jones & Wagener, Rivonia.
- JONES & WAGENER (2008b). Draft Operating Manual for the proposed Hazardous Waste Disposal Facility". Report No. JW50/08/B494 prepared by for the Coega Development Corporation.
- LE ROUX, F G (2000). The geology of the Port Elizabeth-Uitenhage area. Explanation of Sheets 3325DC and DD, Port Elizabeth, 3325 CD and 3425 AB Uitenhage, 3325 CB Uitenhage North and 3325 DA Addo. Council for Geoscience, Pretoria.
- MACLEAR, L G A (1994). A groundwater hydrocensus and water quality investigation of the Swartkops River basin – Uitenhage. Technical Report Gh 3817, Directorate of Geohydrology, Department of Water Affairs and Forestry, Pretoria.
- MACLEAR, L G A (2001). The hydrogeology of the Uitenhage Artesian Basin with reference to the Table Mountain Group Aquifer. Water SA, 27(4), 499-506.
- MARAIS, A J AND SNYMAN, C H (1965). 'n Geologies-Geofisiese ondersoek van die Uitenhage Artesiese Kom. Department of Water Affairs and Forestry, Technical Report G1516, Pretoria.
- MEYER, P S (1998). An explanation of the 1:500 000 General Hydrogeological Map Port Elizabeth 3324. Department of Water Affairs and Forestry, Pretoria.
- MEYER, R (2004). Report on proposed new regional hazardous waste site for Coega and the Eastern Cape. – EIA Phase 1. The identification and evaluation of four proposed and potentially suitable areas for the development of a new waste site.

- Geohydrological Specialist report. Confidential CSIR report Number ENV-P-C 2004/021.
- MEYER, R (2007). The identification and evaluation of three potentially suitable areas for the development of a new waste disposal facility north of Port Elizabeth. Confidential CSIR Report Number CSIR/NRE/WR/ER/2007/0073/C.
- MIDGLEY, D C, PITMAN, W V AND MIDDLETON, B J (1994). Surface water resources of South Africa 1990. Volume V, Book of Maps. Water Research Commission Report No. 298/5.1/94.
- MIDGLEY, D C, PITMAN, W V AND MIDDLETON, B J (1994). Surface water resources of South Africa 1990. Volume V, Appendices. Water Research Commission Report No. 298/5.2/94.
- PARSONS, R (1983). A Geohydrological Investigation of the Coegakop Area of the Uitenhage Artesian Area. Unpublished BSc (Hons.) Thesis, Dept. of Geography, Rhodes University, Grahamstown.
- PARSONS, R (1995). A South African Aquifer System Management Classification. Water Research Commission Report No KV77/95, Water Research Commission, Pretoria.
- PARSONS, R AND JOLLY, J (1994). A systematic method for evaluating site suitability for waste disposal based on geohydrological criteria. Water Research Commission Report No. TT67/94, Water Research Commission, Pretoria.
- SABS (2006). South African Standard: Drinking Water. SABS 241-2006, Edition 6.1. Standards South Africa, South African Bureau of Standards, Pretoria.
- TOERIEN, D K AND HILL, R S (1989). The geology of the Port Elizabeth area. Explanation: Sheet 3324 (1:250 000). Geological Survey of South Africa, Pretoria.
- VENABLES, A G (1985). The geology, geohydrology and hydrochemistry of the Uitenhage-Coega Artesian System. Department of Water Affairs and Forestry Technical Report Gh3437, Pretoria.
- WEATHER BUREAU (1984). Climate of South Africa. Climate Statistics up to 1984. Report WB 40, Weather Bureau, Pretoria.
- WIID, B L (1991). Report on the Ground and Geohydrological Conditions with Specific Reference to the Extended Monitoring System at the Wells Estate (Aloes and Martins) Disposal Sites, Port Elizabeth. Confidential and Unpublished Report, B L Wiid, Consulting Engineering Geologist, Pretoria.
- WINTER, H DE LA R (1973). Geology of the Algoa Basin South Africa. In *Sedimentary Basins of the African coasts, 2nd Part, South and East Coast*, (G Blant, ed.), Assoc. Afr. geol. Survs., Paris, p. 17-48.

APPENDIX A

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Bohlweki Environmental (Pty) Ltd
P O Box 867,
Gallo Manor, 2052.

Attn: Mr R. Meyer

Dear Sir

GEOPHYSICAL SURVEY ON CDC REGIONAL WASTE DISPOSAL FACILITY

Apparent conductivity and magnetic field measurements have been carried out on a candidate waste disposal facility near Addo, about twenty kilometre north of Port Elizabeth. The site is underlain by clay, silt and sand of the Sundays River Formation, overlain in places by Tertiary and Quaternary-age deposits, and has a gently undulating topography. The geophysical work was undertaken to prove that the site is uniform in character, or alternatively that there are preferred site for monitoring boreholes.

The bulk of the fieldwork was undertaken from the 1st to the 5th March. Check data were gathered on the 9th whilst two infill lines were collected on the 3rd April. Most of the work comprised apparent conductivity measurements with a Geonics EM34-3 using a twenty-metre coil separation. Horizontal and vertical dipole readings were taken every ten metres, apart from the infill lines where a station separation of twenty metres was employed. Magnetic field measurements were taken around the perimeter of the site with a proton magnetometer at a spacing of five metres. A Garmin GPS was used to record the locations of the various traverses.

Traverse positions are shown on the background of a satellite photograph in Figure 1. The apparent conductivity data were merged with GPS positions, then gridded and contoured. The HD (horizontal-dipole) results are shown in Figure 2 whilst the VD (vertical dipole) results are presented in Figure 3. Finally, in Figure 4, one line of magnetic field data is presented as an example along with the associated apparent conductivity profiles. The location of the line is indicated on the previous figures by the annotations A-A'.

The horizontal-dipole results in particular show a strong NNW-SSE trend with apparent conductivities ranging from 30 to 120 mS/m (milliSiemens per metre) (Figure 2). Peak values are often lower with the dipole vertical (Figures 3 and 4) indicating that conductivity decreases with depth.

The conductivity trends appear partially linked to both the topography and geology, perhaps because the geology has an influence on the topography. In particular, a low that bisects two highs in the south-east appears to follow the floor of a shallow valley whilst the flanking conductivity highs seem restricted to higher ground, though high ground does not always coincide with high conductivity. According to the 1:50 000 geological map, the conductivity highs overlie the Sunday's River Formation, close to its contact with the overlying Alexandria Formation, whilst the conductivity low that separates them lies more centrally within the Sunday's River Formation outcrop. Elsewhere, low conductivity values coincide with the younger Alexander and Nanaga Formations. More detailed topographic and geological maps may improve these tentative observations.

Magnetic profiling did not reveal any significant magnetic bodies. All the profiles are similar to the example shown in Figure 4.

No fracture zones or intrusions were identified, and no borehole sites are suggested on that account. The variation in conductivity, however, suggests different sedimentary layers that may have different hydro-geological properties. Thus the distribution of boreholes should include the conductivity highs and lows.

Yours sincerely,

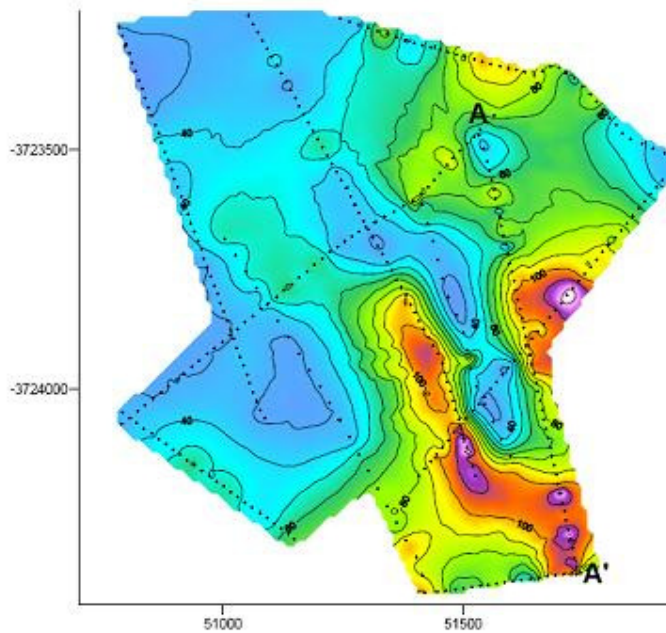
A handwritten signature in blue ink, appearing to read 'R W Day', is written over a light blue rectangular background.

R W Day Pr.Sci.Nat.



**Coega Development Corporation
Regional Waste processing Facility**

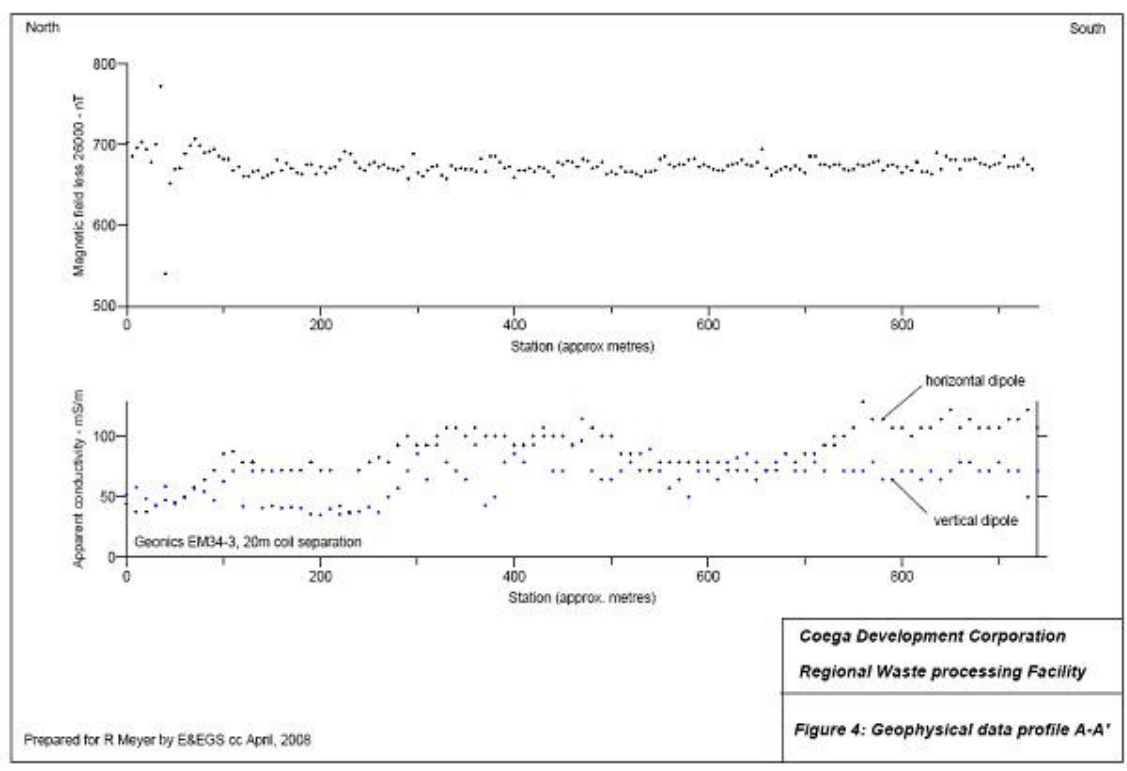
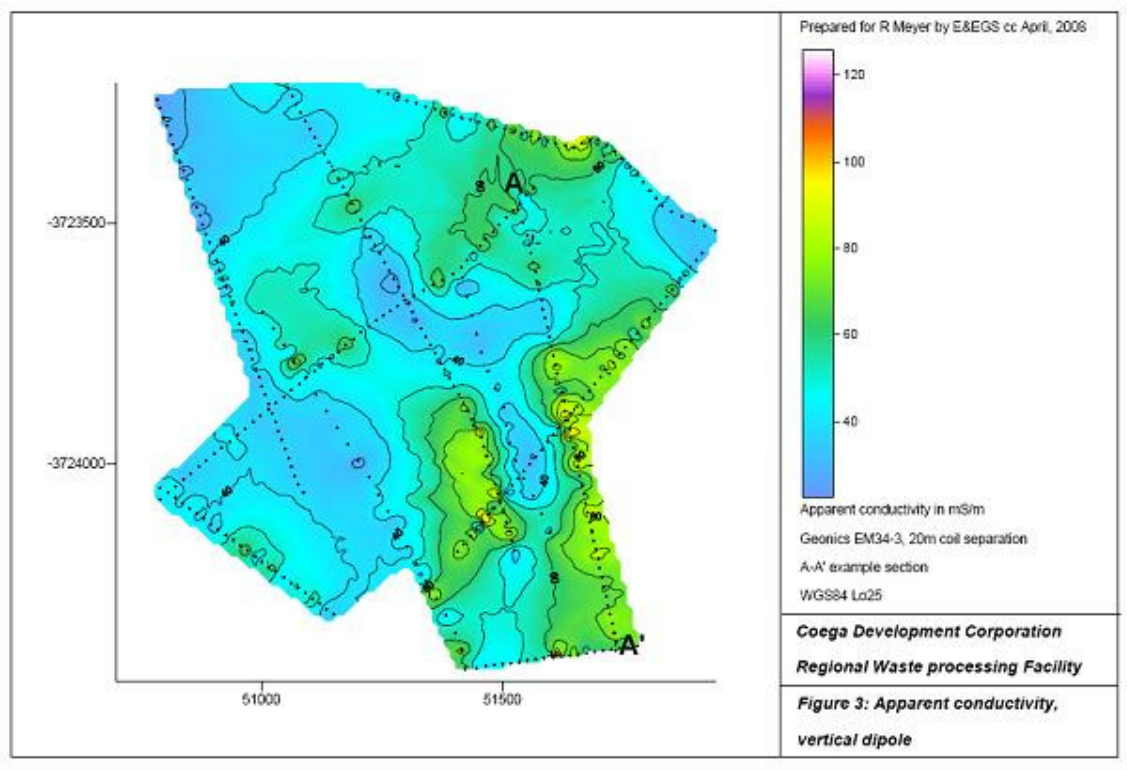
**Figure 1: Overview of
geophysical traverses**



Apparent conductivity in mS/m
Geonics EM34-3, 20m coil separation
A-A' example section
WGS84 Lo25

**Coega Development Corporation
Regional Waste processing Facility**

**Figure 2: Apparent conductivity,
horizontal dipole**



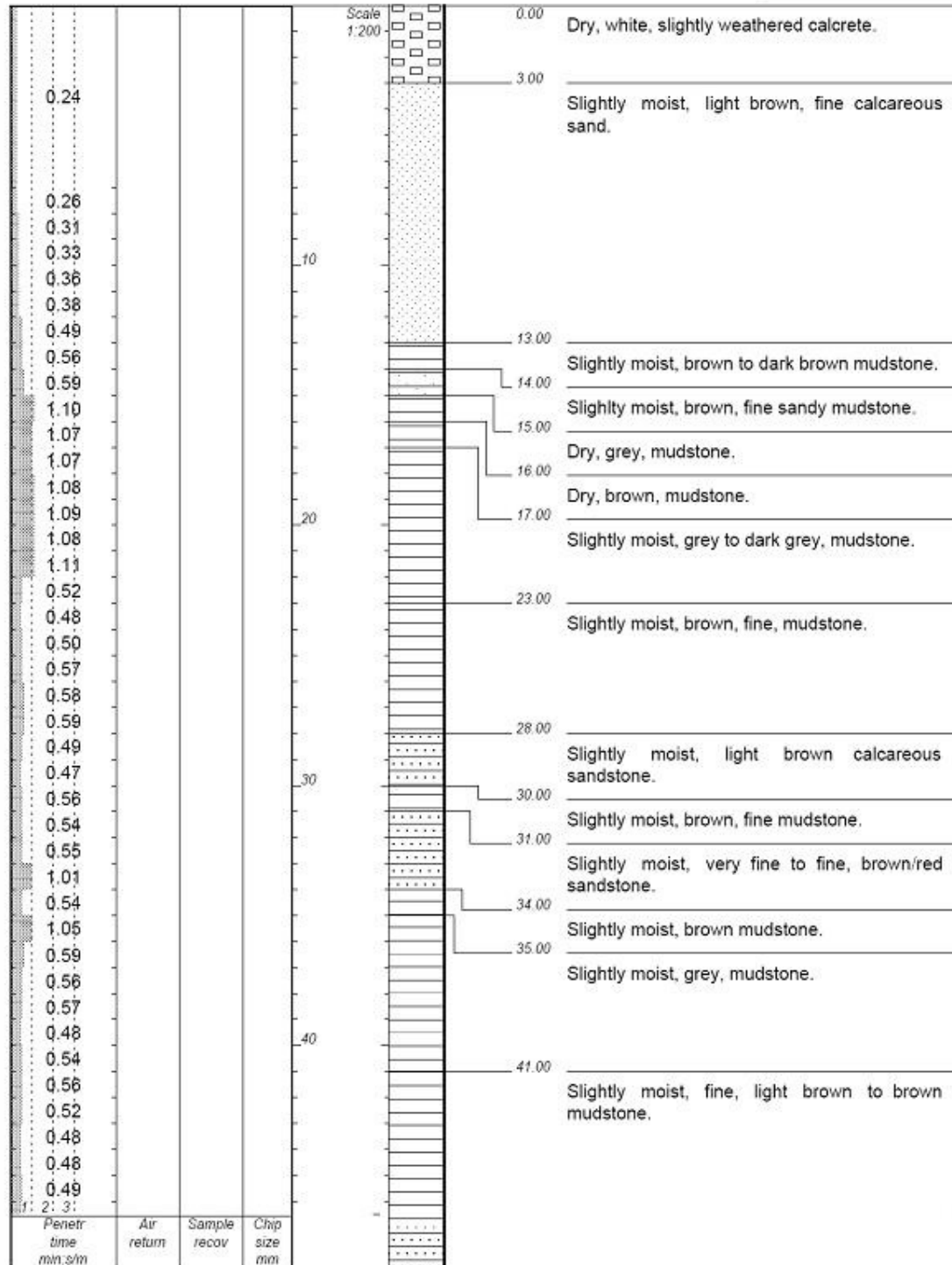
APPENDIX B

GEOLOGICAL DESCRIPTIONS OF NEW BOREHOLES (GR190/6 to GR190/9)

Coega Development Corporation
PROPOSED COEGA HAZARDOUS
WASTE FACILITY

HOLE No: BH GR190/6
Sheet 1 of 2

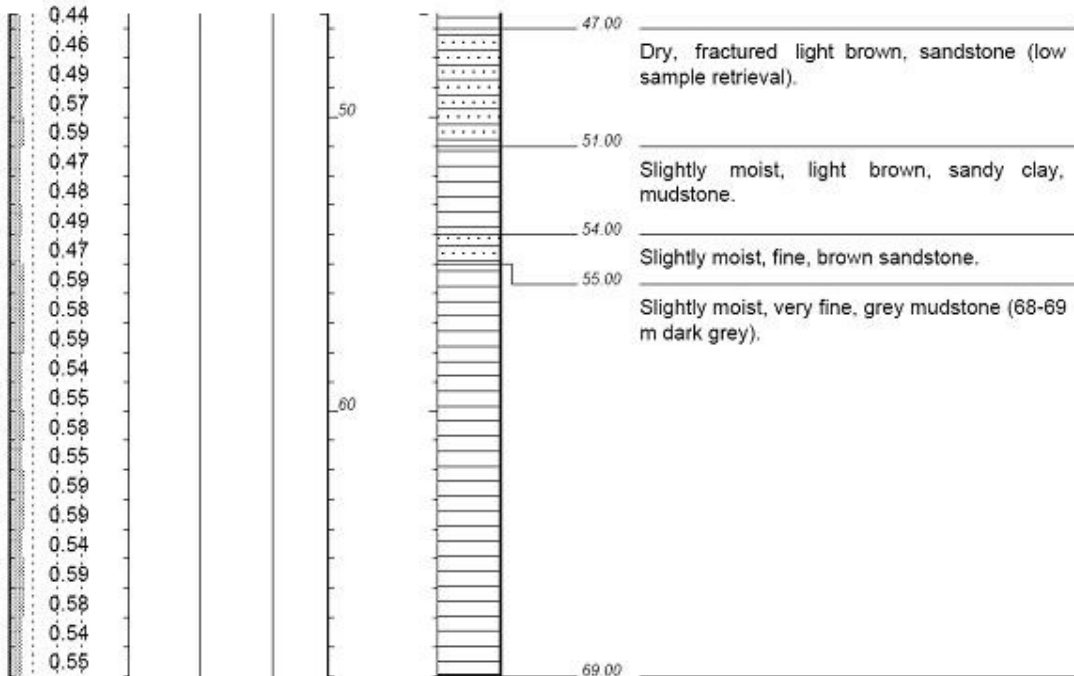
JOB NUMBER: 000



Coega Development Corporation
PROPOSED COEGA HAZARDOUS
WASTE FACILITY

HOLE No: BH GR190/6
Sheet 2 of 2

JOB NUMBER: 000



NOTES

- 1) Borehole dry on completion and dry 4 days after completion.
- 2) Sanitary seal installed.
- 3) Inferred stratigraphic sequence:
0-3 m Surface calcrete;
3-13m Alexandria Formation.
13-69m Sundays River Formation.
- 4) Casing
0-6m (Solid Steel 177 mm OD x 4 mm)
6-69m (No casing).

1	2	3
Penetr	Air	Sample
time	return	recov
min.s/m		mm
		mm

CONTRACTOR: Joint Aid Management (JAM) INCLINATION: Vertical
MACHINE: SUPER ROCK 1000
DRILLED BY: F CHAMBERS
PROFIED BY: R MEYER
TYPE SET BY: K STEWART
SETUP FILE: Y.SET

DIAM: 165mm
DATE: 2008-05-15
DATE: 2008-05-15
DATE: 29/05/08 15:47
TEXT: ..COEGA\GR190-1.TXT

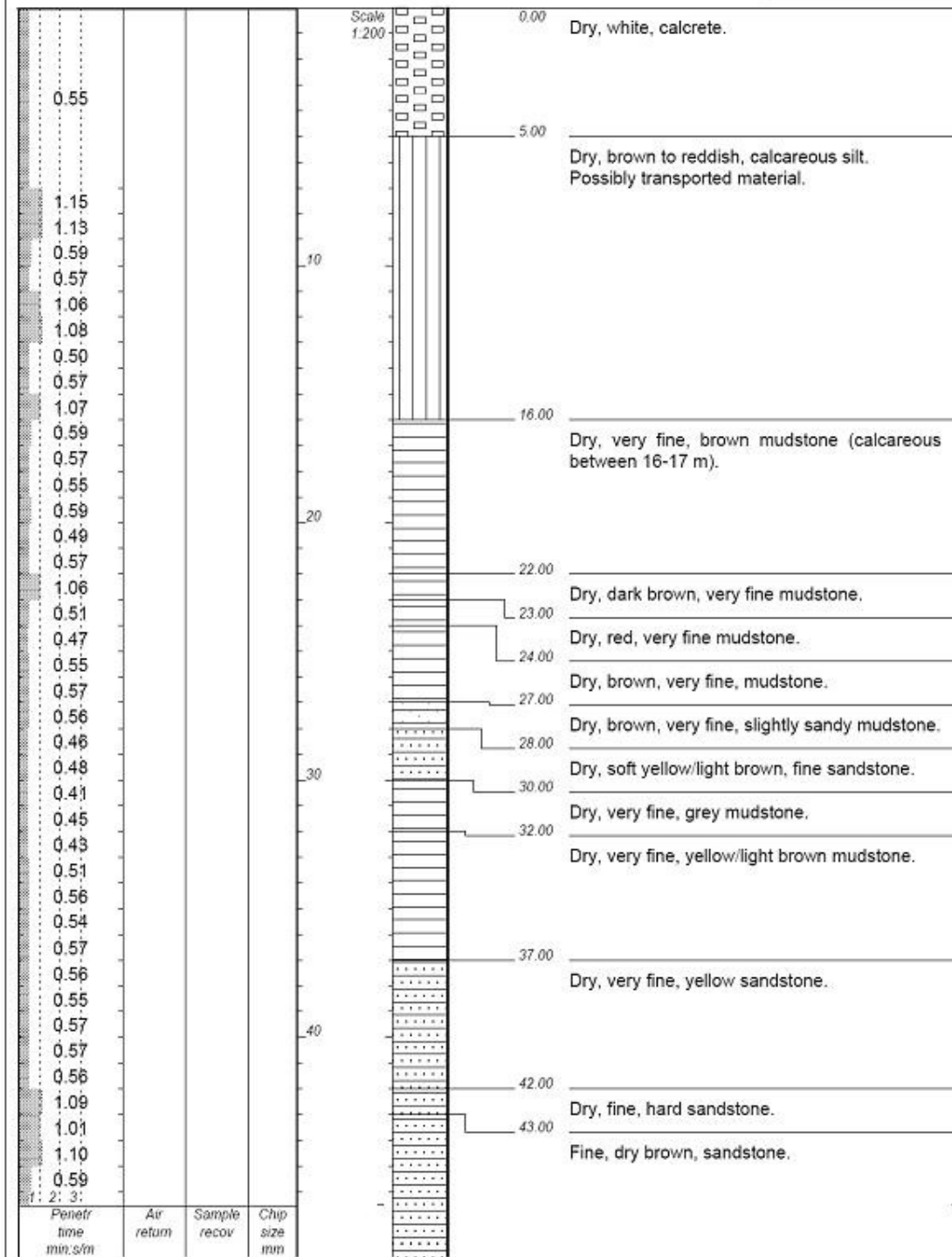
ELEVATION: Approx 251m
X-COORD: 37 23 228 m
Y-COORD: -50 864 m

HOLE No: BH GR190/6

Coega Development Corporation
PROPOSED COEGA HAZARDOUS
WASTE FACILITY

HOLE No: BH GR190/7
Sheet 1 of 2

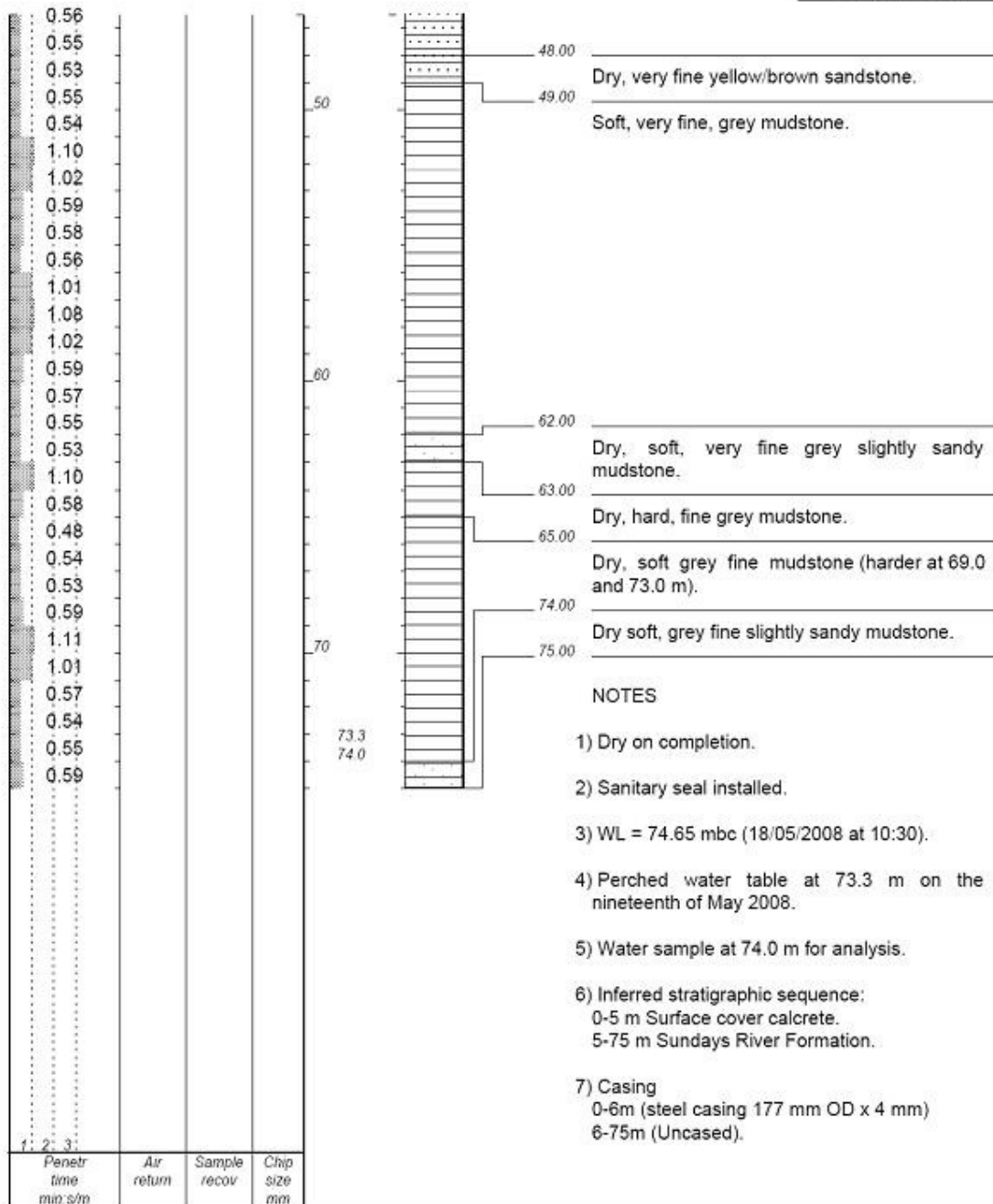
JOB NUMBER: 000



Coega Development Corporation
PROPOSED COEGA HAZARDOUS
WASTE FACILITY

HOLE No: BH GR190/7
Sheet 2 of 2

JOB NUMBER: 000



CONTRACTOR: Joint Aid Management (JAM) INCLINATION:

MACHINE: SUPER ROCK 1000

DRILLED BY: F CHAMBERS

PROFILED BY: R MEYER

TYPE SET BY: K STEWART

SETUP FILE: Y.SET

DIAM: 165mm

DATE: 2008-05-17

DATE: 2008-05-17

DATE: 29/05/08 15:47

TEXT: ..COEGA\GR190~1.TXT

ELEVATION: Approx 215m

X-COORD: 3 724 017 m

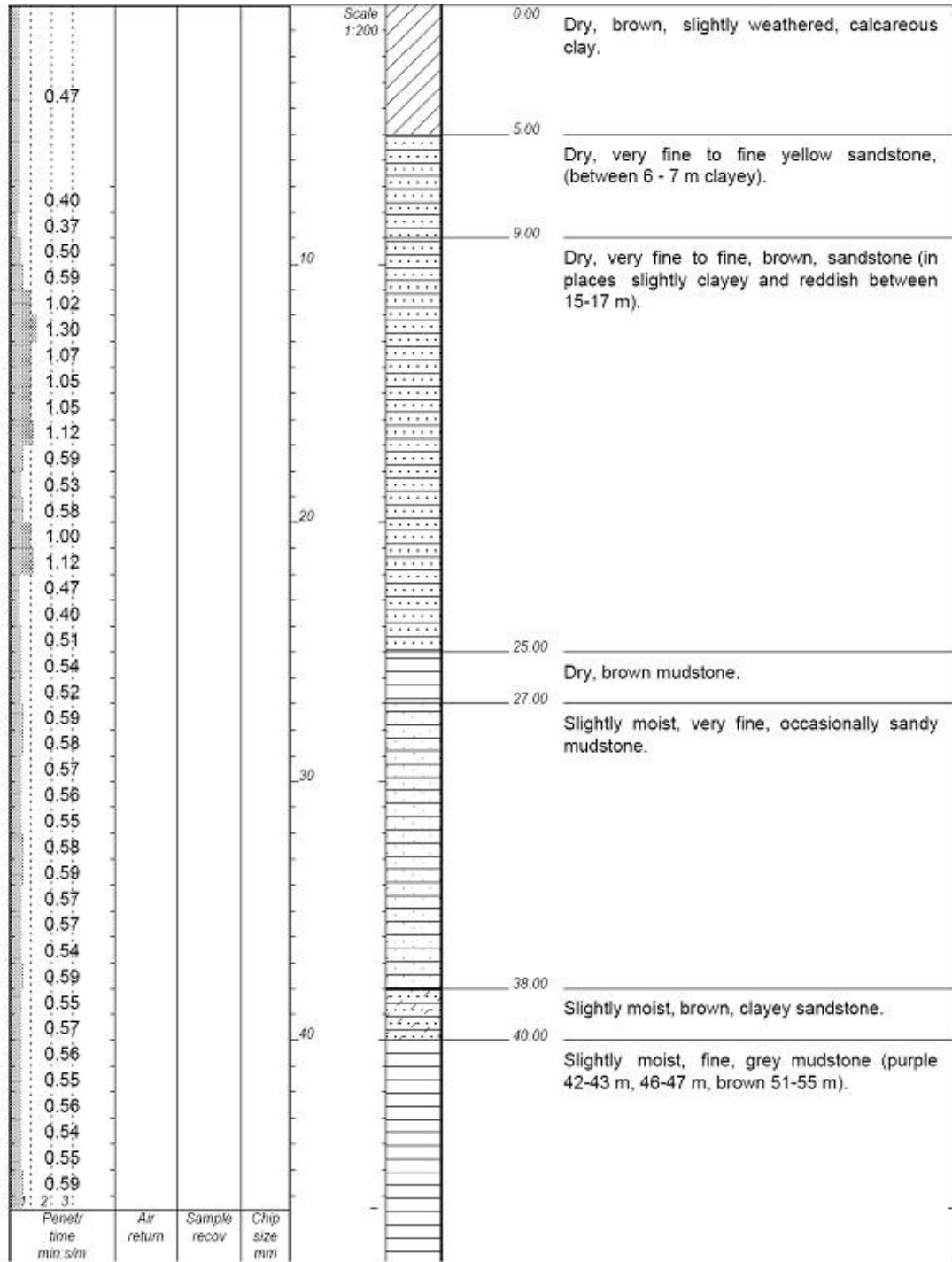
Y-COORD: -51 584 m

HOLE No: BH GR190/7

Coega Development Corporation
PROPOSED COEGA HAZARDOUS
WASTE FACILITY

HOLE No: BH GR190/8
Sheet 1 of 2

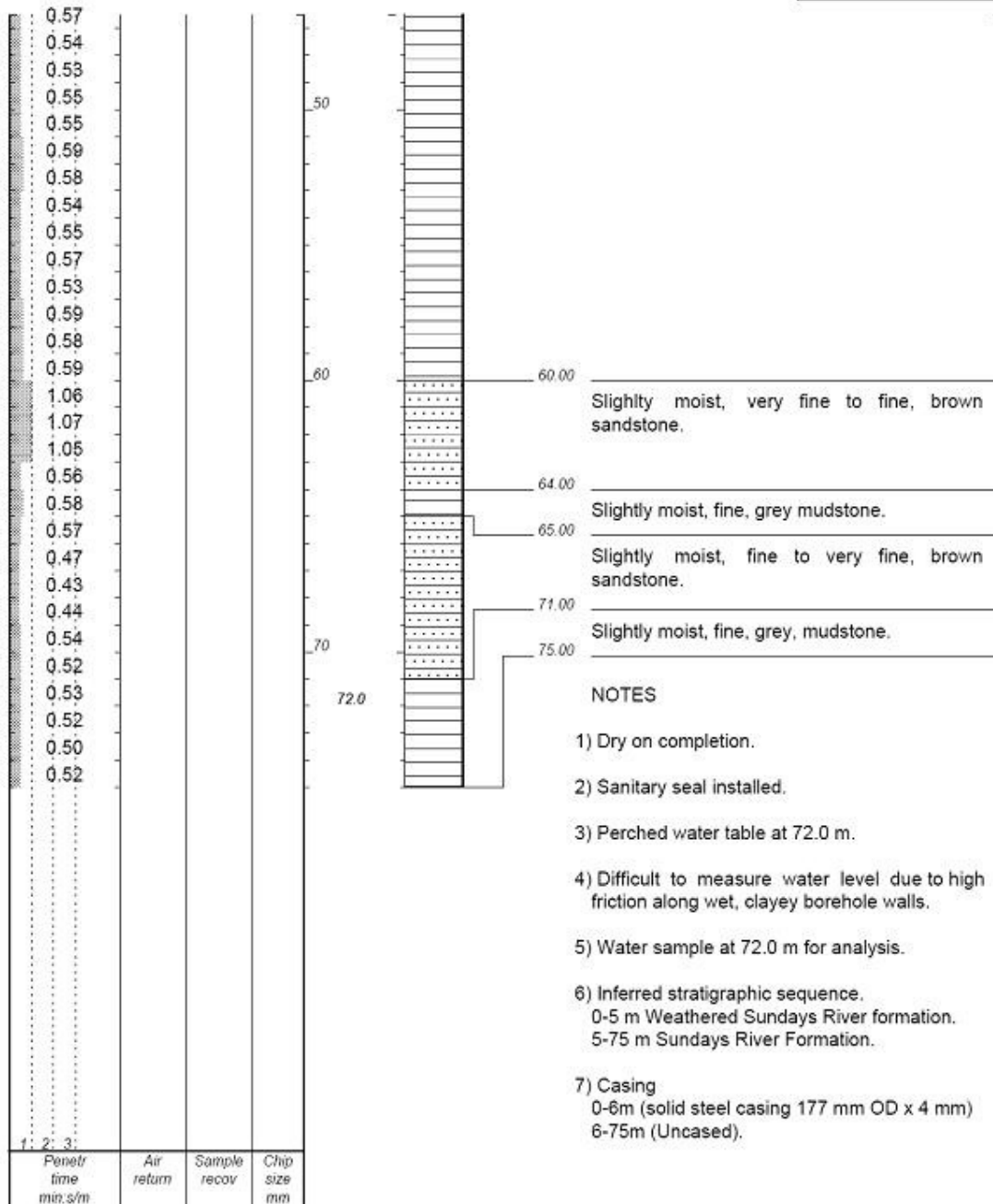
JOB NUMBER: 000



Coega Development Corporation
PROPOSED COEGA HAZARDOUS
WASTE FACILITY

HOLE No: BH GR190/8
Sheet 2 of 2

JOB NUMBER: 000



CONTRACTOR: Joint Aid Management (JAM) INCLINATION:
MACHINE: SUPER ROCK 1000 DIAM: 165mm
DRILLED BY: F CHAMBERS DATE: 2008-05-16-17
PROFIED BY: R MEYER DATE: 2008-05-17
TYPE SET BY: K STEWART DATE: 29/05/08 15:47
SETUP FILE: Y.SET TEXT: ..COEGA\GR190--1.TXT

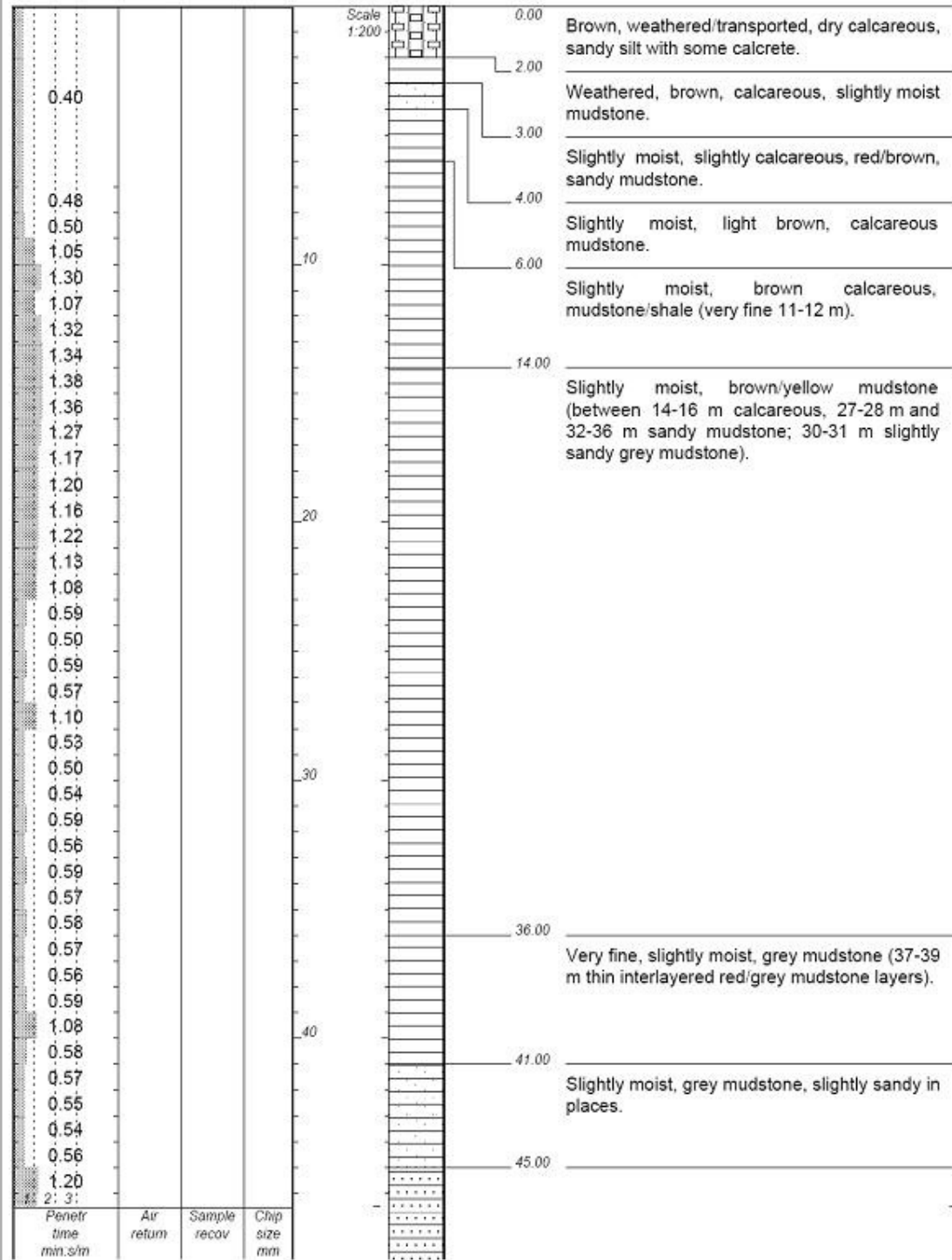
ELEVATION: Approx 238 m
X-COORD: 3 724 145 m
Y-COORD: -51 300 m

HOLE No: BH GR190/8

Coega Development Corporation
PROPOSED COEGA HAZARDOUS
WASTE FACILITY

HOLE No: BH GR190/9
Sheet 1 of 3

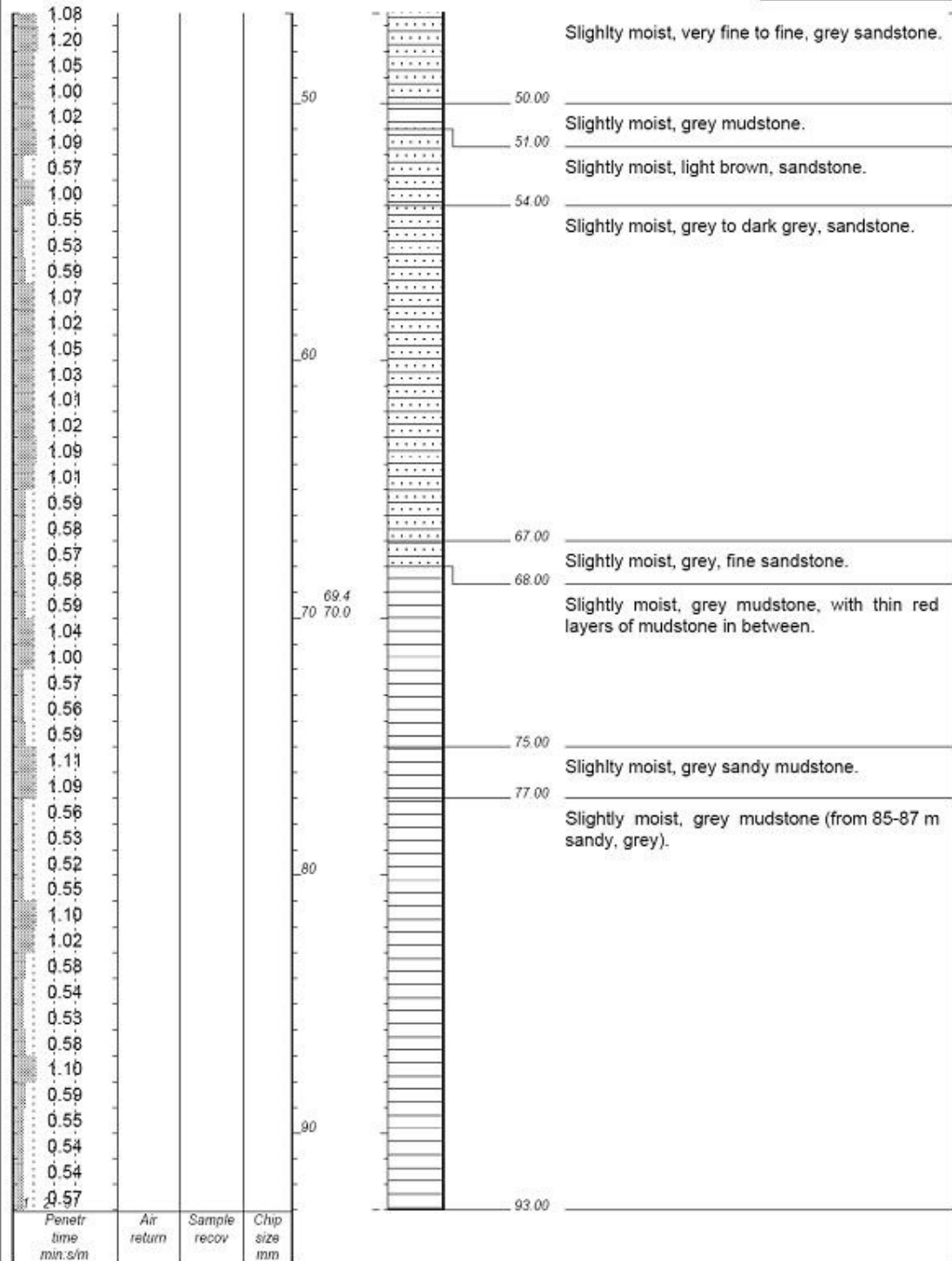
JOB NUMBER: 000



Coega Development Corporation
PROPOSED COEGA HAZARDOUS
WASTE FACILITY

HOLE No: BH GR190/9
Sheet 2 of 3

JOB NUMBER: 000



Coega Development Corporation
PROPOSED COEGA HAZARDOUS
WASTE FACILITY

HOLE No: BH GR190/9
Sheet 3 of 3

JOB NUMBER: 000

93.00

NOTES

- 1) Dry at completion.
- 2) Sanitary seal installed.
- 3) WI= 71.25 mbc (18/05/2008 at 10:45).
- 4) Perched water table at 69.4 m on the nineteenth of May 2008.
- 5) Water sample at 70.0 m for analysis.
- 6) Inferred stratigraphic sequence.
0-3 m Soil.
3-14 m Transported (valley fill?) or weathered Sundays River Formation.
14-75 m Sundays River Formation.
- 7) Casing
0-6m (steel casing 177 mm OD x 4mm)
6-93m (Uncased).

f: 2: 3:			
Penetr time min s/m	Air return	Sample recov	Chip size mm

CONTRACTOR: Joint Aid Management (JAM) INCLINATION:
MACHINE: SUPER ROCK 1000 DIAM: 165mm
DRILLED BY: F CHAMBERS DATE: 2008-05-15-16
PROFILED BY: R MEYER DATE: 2008-05-16
TYPE SET BY: K STEWART DATE: 29/05/08 15:47
SETUP FILE: Y.SET TEXT: ..COEGA\GR190~1.TXT

ELEVATION: Approx 204m
X-COORD: 3 724 369 m
Y-COORD: -51 729 m

HOLE No: BH GR190/9

APPENDIX C

WASP INDEX

WASP DATA SHEET

NAME OF SITE	: Grassridge 190, Coega	OWNER: PPC	: Local Authority
TOWN	: Port Elizabeth		
SPECIAL FEATURES	:		
	:		
COMMENTS	:		
	:		
NAME OF ASSESSOR	: R Meyer	DATE	: May 2008

THREAT FACTOR			
Designed Final Area (ha)	: 25 (Phase 1)	Data Reliability Rating	: Level 1
Type of Waste	: Hazardous	Data Reliability Rating	: Level 1
THREAT FACTOR SCORE:	: 10	DATA RELIABILITY RATING:	: 2

BARRIER FACTORS				
Layer	Thickness (m)	Hydraulic Conductivity (m per day)	Porosity (%)	Travel time (days)
1 (dry & slightly moist mudstone and siltstones)	65 (to SWL)	10^{-5}	40	>100 000
Total				>100 000 days

BARRIER FACTOR SCORE	: 1.5	DATA RELIABILITY RATING	: 2.0
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RESOURCE FACTOR			
Groundwater Usage Component Score	: 1	Data Reliability Rating	: 1.5
Groundwater Potential Component Score	: 2	Data Reliability Rating	: 1.4
Combined Groundwater Score	: 3		
RESOURCE FACTOR SCORE	: 2	DATA RELIABILITY RATING	: 1

WASP INDEX			
Wasp Index	: 4.5	Data Reliability Index:	1.3
Site Suitability Interpretation	: <i>Suitable</i>		

APPENDIX D

CRITERIA AND DEFINITIONS USED IN IMPACT ASSESSMENT TABLES

Impact Assessment Criteria and Definitions

In order to evaluate the significance of potential impacts, the following criteria and terminology is used to identify and describe the characteristics of each potential impact:

- the ***nature***, which shall include a description of what causes the effect, what will be affected and how it will be affected;
- the ***status***, which will be described as either a **positive** impact or a **negative** impact.
- the ***extent***, wherein it will be indicated whether the impact will be **local** (limited to the immediate area or site of development) or **regional**;
- the ***duration***, wherein it will be indicated whether the lifetime of the impact will be of a **short duration (0–5 years)**, **medium-term (5–15 years)**, **long term (> 15 years)** or **permanent**;
- the ***probability***, which shall describe the likelihood of the impact actually occurring, indicated as **improbable** (low likelihood), **probable** (distinct possibility), **highly probable** (most likely), or **definite** (impact will occur regardless of any preventative measures);
- the ***severity/beneficial scale***: indicating whether the impact will be **very severe/beneficial** (a permanent change which cannot be mitigated/permanent and significant benefit, with no real alternative to achieving this benefit), **severe/beneficial** (long-term impact that could be mitigated/long-term benefit), **moderately severe/beneficial** (medium- to long-term impact that could be mitigated/ medium- to long-term benefit), **slight or have no effect**; and
- the ***significance***, which shall be determined through a synthesis of the characteristics described above and can be assessed as **low**, **medium** or **high**.