

Legal requirement

Some of the remedial measures described above need to be addressed as a legal requirement regardless of their influence at RESM 1. Section 19 of the National Water Act (Act No 36 of 1998) states:

19. (1) An owner of land, a person in control of land or a person who occupies or uses the land on which -

- (a) any activity or process is or was performed or undertaken; or*
- (b) any other situation exists, which causes, has caused or is likely to cause pollution of a water resource, must take all reasonable measures to prevent any such pollution from occurring, continuing or recurring.*

Situations where contaminated runoff and/or process water is not being contained are in contravention of this act. The following is a list of those measures:

- Increasing the volume and pump capacity at Fertiliser dam 8.
- Implementation of management measures for process water from the Twistdraai Export plant silo.
- The clean up of coal (or other contaminated product) stockpile areas outside the water management areas at SCS(E) and SCS(W).
- The clean up of the SCS(W) to Synfuels coal handling area (note that this project is already in progress).
- The clean up of the catchment of the Ash conveyor canal near SCS(W).

High priority

Remedial measures that will have a significant effect on RESM 1 conductivity, but are not necessarily a legal requirement, are listed as high priority (in no particular order):

- Construction of a seepage interception system at Fertiliser dam 7.
- Construction of a seepage cut-off and canal upgrade at SCS(E) PC dam.
- Construction of a cut-off trench and/or lining for the SCS(W) PC dam.

Areas where further monitoring is required before remedial action is taken

Future changes in deposition area on the Twistdraai Export plant discard dump will influence the seepage patterns from this source. It is recommended that the situation is monitored and measures only implemented when the new seepage regime has been established and is well understood.

Monitoring of the effectiveness of measures implemented at the SCS(W) to Synfuels coal handling area should be done once they have been completed. It is suspected that the areas directly to the east and west of the remedial measures being implemented may also be generating contaminated runoff.

Low priority

Some of the areas investigated are seen as low priority areas due to their low contaminant contribution. Remediation of these will not provide sufficient benefit and efforts should be focussed elsewhere. These areas are:

- the Twistdraai Export plant PC dam and
- the Ostrich area.

9.4 Plan of action

The recommended plan of action is as follows. Firstly the improvement of stream flow measurement accuracy is required and a set of process related decisions discussed in this chapter must be taken. Secondly, remediation of the areas that is required legally should be completed. Thirdly, remediation of the remaining significant sources should be addressed.



Dr Martin Rust (Pr. Eng.)
for Jones & Wagener

4 March 2008



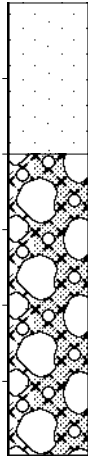
Danie Brink (Pr. Eng.)

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APPENDIX A TEST PIT AND AUGER HOLE LOGS



Scale
1:10



0.00

Moist, dark brown, soft, slightly sandy CLAY; **ALLUVIUM**.

0.20

Relatively closely packed angular and sub rounded dolerite cobbles and boulders to 300mm in a matrix of moist, dark olive brown speckled off white and grey, medium dense? clayey coarse medium fine SAND with fine gravels; **RESIDUAL DOLERITE**.

0.60

NOTES

- 1) Refusal on very closely packed dolerite boulders; possibly closely jointed dolerite.
- 2) Three holes excavated at same location, all refused at 0,6m.
- 3) Holes excavated in Drainage Channel.
- 4) No seepage or water table.
- 5) No samples taken.
- 6) Profiled from spoil.

CONTRACTOR : ESOR
MACHINE : Williams Digger
DRILLED BY : Nelson
PROFILED BY : JR

TYPE SET BY : VALERIE
SETUP FILE : STANDARD.SET

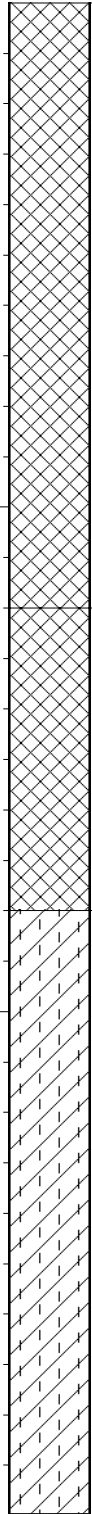
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DIAM : 750mm
DATE : 08/11/2006
DATE : 08/11/2006
DATE : 27/11/06 10:45
TEXT : ..\A839\A839_S~2.DOC

ELEVATION :
X-COORD :
Y-COORD :

HOLE No: F02 A



Scale
1:15



0.00

Moist, brown speckled grey and off white probably medium dense, slightly silty coarse medium fine SAND with abundant gravels and cobbles to 60mm; **FILL**.

1.20

Moist, orange brown, medium dense, silty coarse medium fine SAND with abundant cobbles and angular closely packed GRAVELS; **FILL**.

1.80

Wet, grey, soft, silty CLAY; **ALLUVIUM**.

3.00

NOTES

- 1) Auger requested to stop due to side wall collapse.
- 2) Strong general seepage at 2m. Difficulty sampling. (EC = 398uS/cm).
- 3) River approximately 4m from hole EC in river is 420 uS/cm. Seepage in hole appears to be from river.
- 4) Profiled from spoil.

CONTRACTOR : ESOR
MACHINE : Williams Digger
DRILLED BY : Nelson
PROFILED BY : JR & MT
TYPE SET BY : VALERIE
SETUP FILE : STANDARD.SET

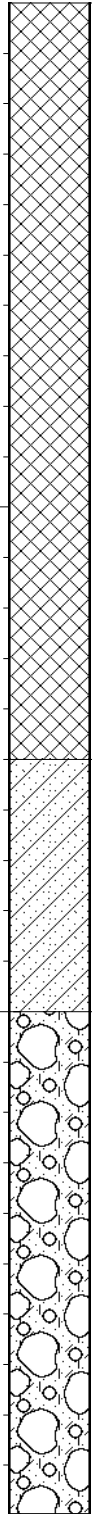
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DATE : 10/11/2006
DATE : 27/11/06 10:45
TEXT : ..\A839\A839_S~2.DOC

ELEVATION :
X-COORD :
Y-COORD :

HOLE No: A7



Scale
1:15



0.00

Moist, brown blotched pale grey speckled off white, probably medium dense, slightly silty clayey fine and medium SAND with fine gravels and cobbles to 60mm; **FILL**.

1.50

Moist, brown mottled grey and orange brown, firm, sandy CLAY to clayey SAND; **ALLUVIUM**.

2.00

Closely packed angular gravels and boulders to 400mm in a matrix of wet, brown, slightly clayey silty fine SAND; **COLLUVIUM**.

3.00

NOTES

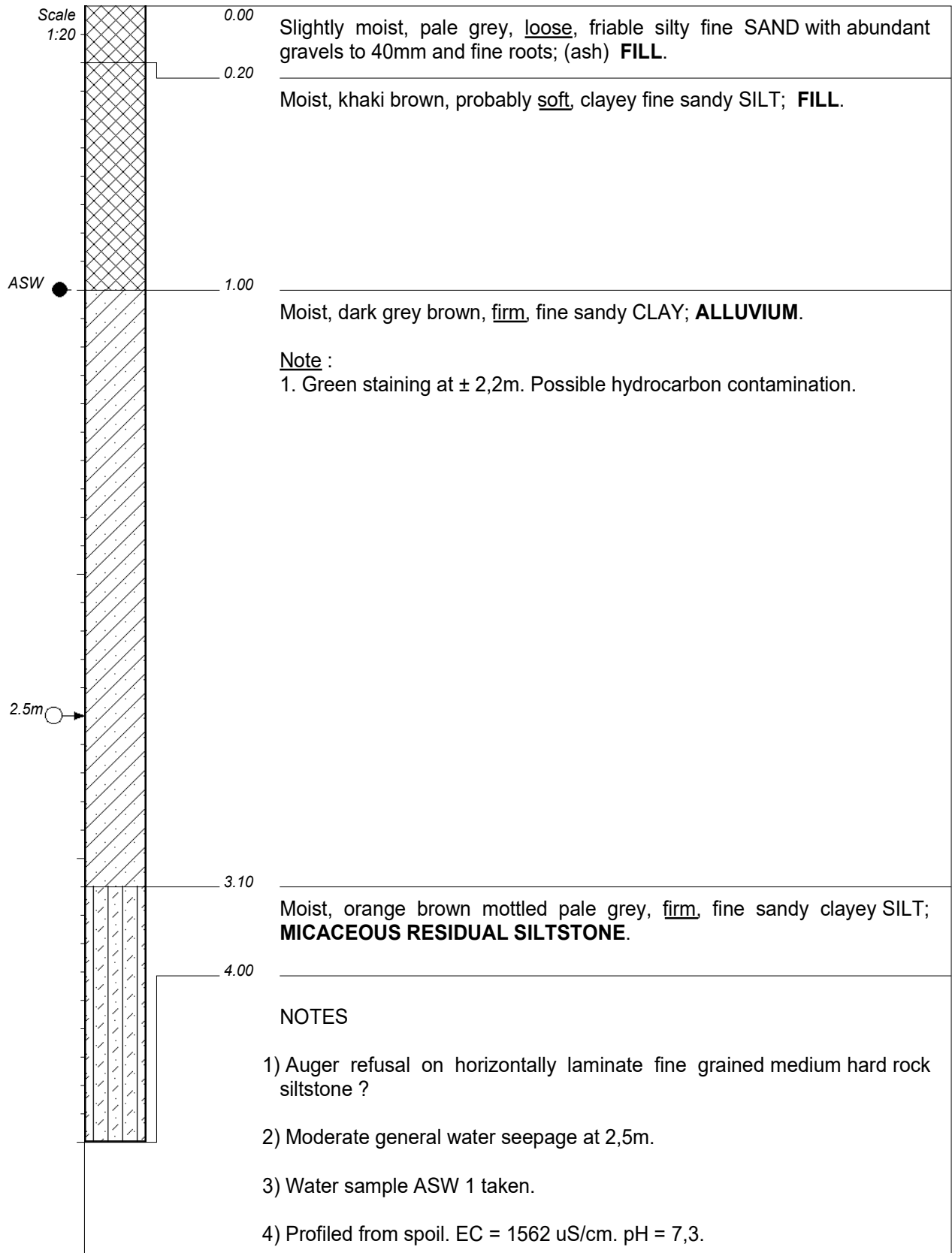
- 1) Auger near refusal on boulders.
- 2) Water sample. ASW 19A
- 3) Moderate general seepage at 2,5m.

CONTRACTOR : ESOR
MACHINE : Williams Digger
DRILLED BY : Nelson
PROFILED BY : JR & MT
TYPE SET BY : VALERIE
SETUP FILE : STANDARD.SET

INCLINATION :
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DATE : 08/11/2006
DATE : 27/11/06 10:45
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ELEVATION :
X-COORD :
Y-COORD :

HOLE No: 19A

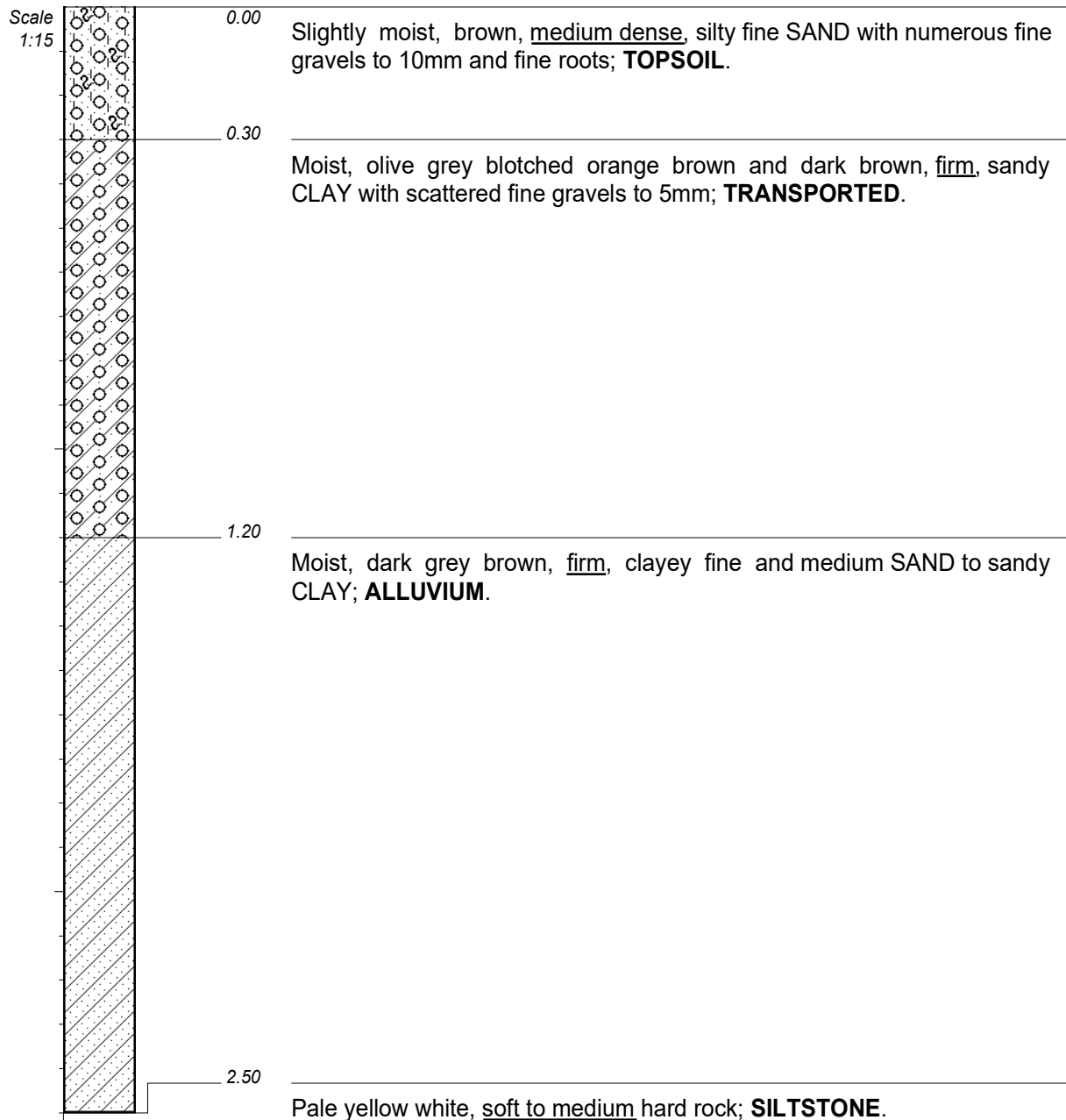


CONTRACTOR : ESOR
MACHINE : Williams Digger
DRILLED BY : Nelson
PROFILED BY : JR & MT
TYPE SET BY : VALERIE
SETUP FILE : STANDARD.SET

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DIAM : 750mm
DATE : 09/11/2006
DATE : 09/11/2006
DATE : 27/11/06 10:45
TEXT : ..\A839\A839_S~2.DOC

ELEVATION :
X-COORD :
Y-COORD :

HOLE No: A01



NOTES

- 1) Auger refusal on soft to medium hard rock *f* Siltstone.
- 2) Slight general seepage on contact between alluvium and siltstone at 2,5m.
- 3) Water sample ASW3 taken. EC = 1660 uS/cm, pH = 7,3.
- 4) Profiled from spoil.

CONTRACTOR : ESOR
MACHINE : Williams Digger
DRILLED BY : Nelson
PROFILED BY : JR & MT
TYPE SET BY : VALERIE
SETUP FILE : STANDARD.SET

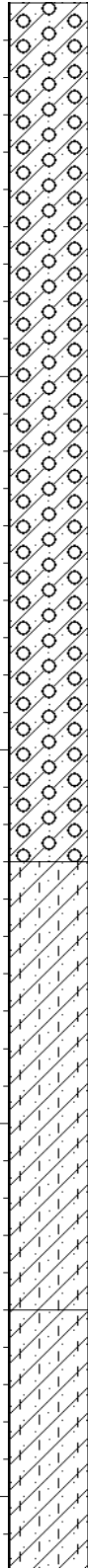
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DATE : 09/11/2006
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ELEVATION :
X-COORD :
Y-COORD :

HOLE No: A03



Scale
1:20



0.00

Moist, greenish brown speckled orange brown, soft becoming firm with depth, sandy CLAY with scattered fine gravels; **ALLUVIUM**.

Note :

1. Green staining at 1,5m. Possible hydrocarbon contamination.

2.30

Moist, dark grey brown becoming grey with depth, probably firm becoming shattered and polished from 3m to 3,5m, slightly silty sandy CLAY; **ALLUVIUM**.

3.50

Moist, grey, firm, sandy silty CLAY; **ALLUVIUM**.

4.20

NOTES

- 1) Auger refusal on medium hard rock, **siltstone**.
- 2) Slight to moderate general seepage at 2,3m.
- 3) Water sample ASW6. EC = 1184 uS/cm and pH = 7,4.
- 4) Profiled from spoil.

CONTRACTOR : ESOR
MACHINE : Williams Digger
DRILLED BY : Nelson
PROFILED BY : JR & MT
TYPE SET BY : VALERIE
SETUP FILE : STANDARD.SET

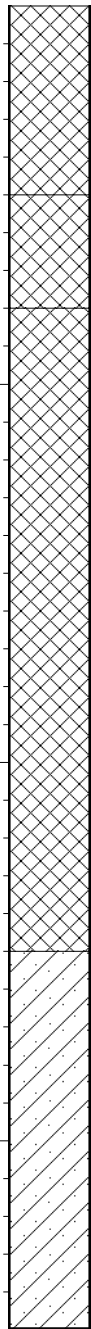
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DATE : 27/11/06 10:45
TEXT : ..\A839\A839_S~2.DOC

ELEVATION :
X-COORD :
Y-COORD :

HOLE No: A06



Scale
1:20



0.00

Slightly moist, pale grey speckled off white, medium dense, silty fine and medium SAND with abundant fine and medium gravels; **FILL**.

Note :

1. Gravel road.

0.50

Slightly moist, orange brown, silty fine and medium SAND with scattered fine and medium gravels; **FILL**.

Note:

1. Road sub grade

0.80

Closely packed angular gravels and boulders to 300mm in a matrix of slightly moist, orange brown, silty fine and medium SAND, overall consistency probably dense; **FILL**.

2.50

Wet, dark grey brown, firm, fine sandy CLAY; **ALLUVIUM**.

3.50

NOTES

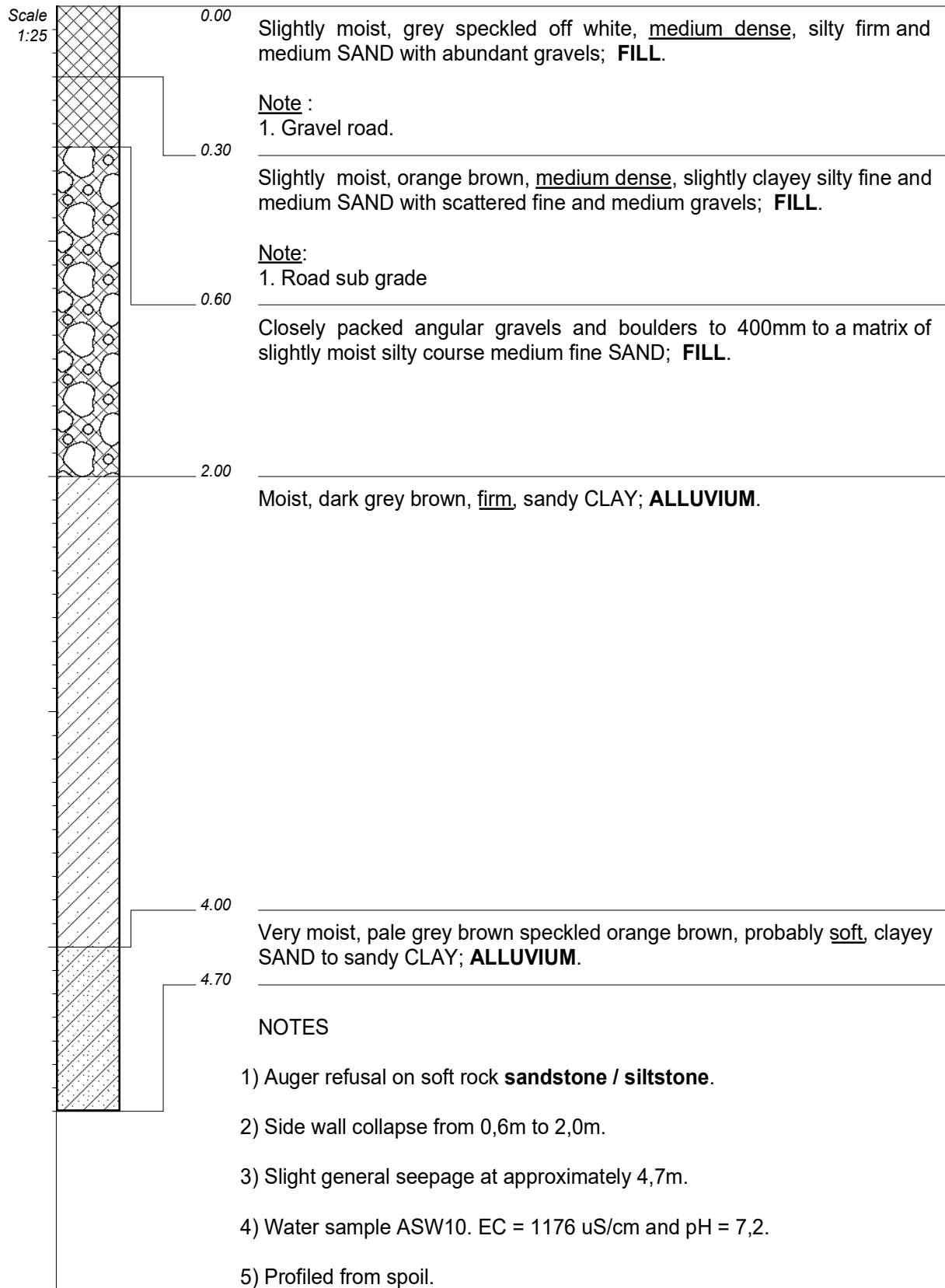
- 1) Side walls of hole collapsing from 1m to 2,5m.
- 2) Very strong general seepage.
- 3) Not able to sample due to hole collapse.

CONTRACTOR : ESOR
MACHINE : Williams Digger
DRILLED BY : Nelson
PROFILED BY : JR & MT
TYPE SET BY : VALERIE
SETUP FILE : STANDARD.SET

INCLINATION :
DIAM : 750mm
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DATE : 09/11/2006
DATE : 27/11/06 10:45
TEXT : ..\A839\A839_S~2.DOC

ELEVATION :
X-COORD :
Y-COORD :

HOLE No: A09



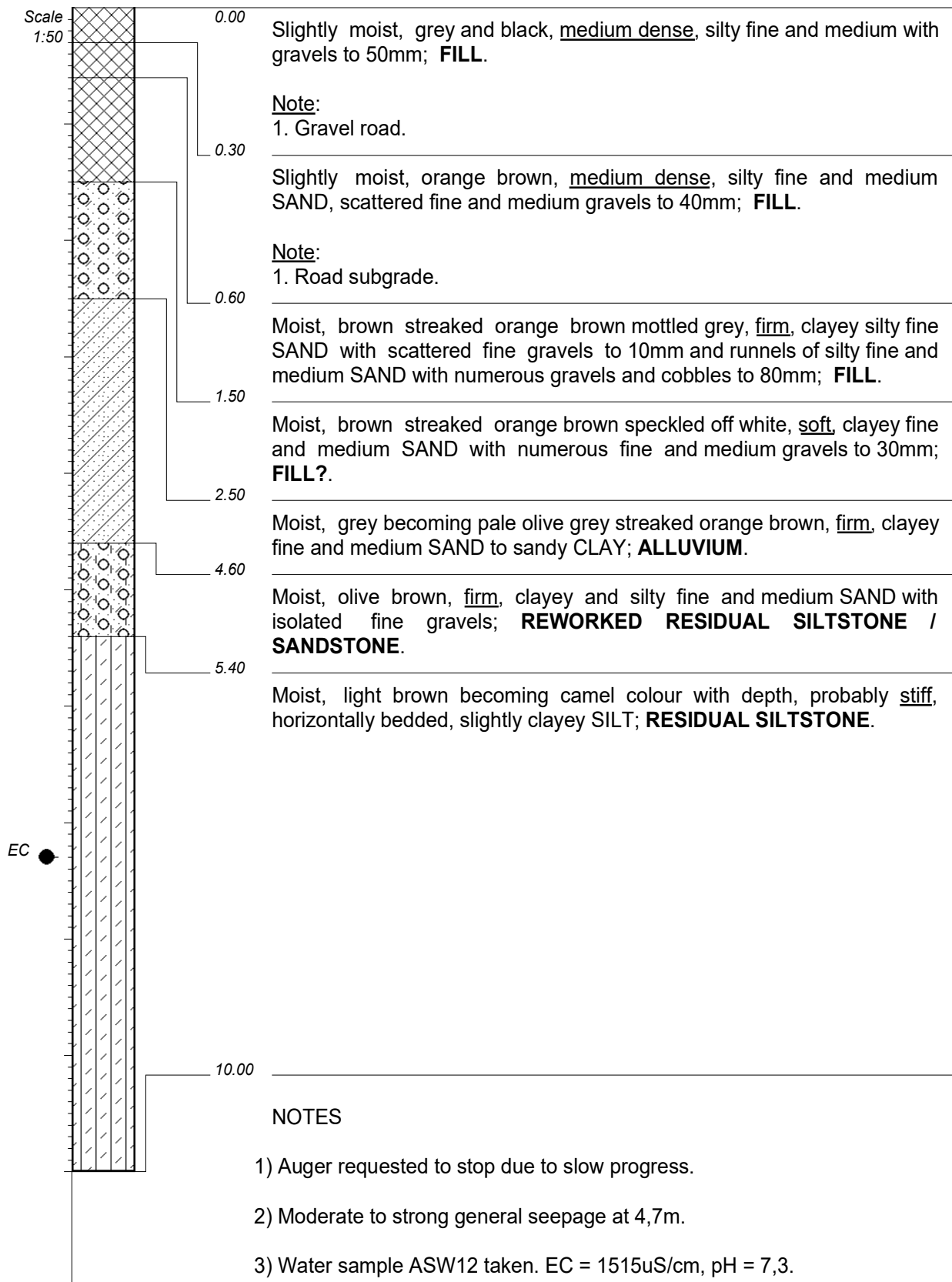
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MACHINE : Williams Digger
DRILLED BY : Nelson
PROFILED BY : JR

TYPE SET BY : VALERIE
SETUP FILE : STANDARD.SET

INCLINATION :
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DATE : 10/11/2006
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ELEVATION :
X-COORD :
Y-COORD :

HOLE No: A10

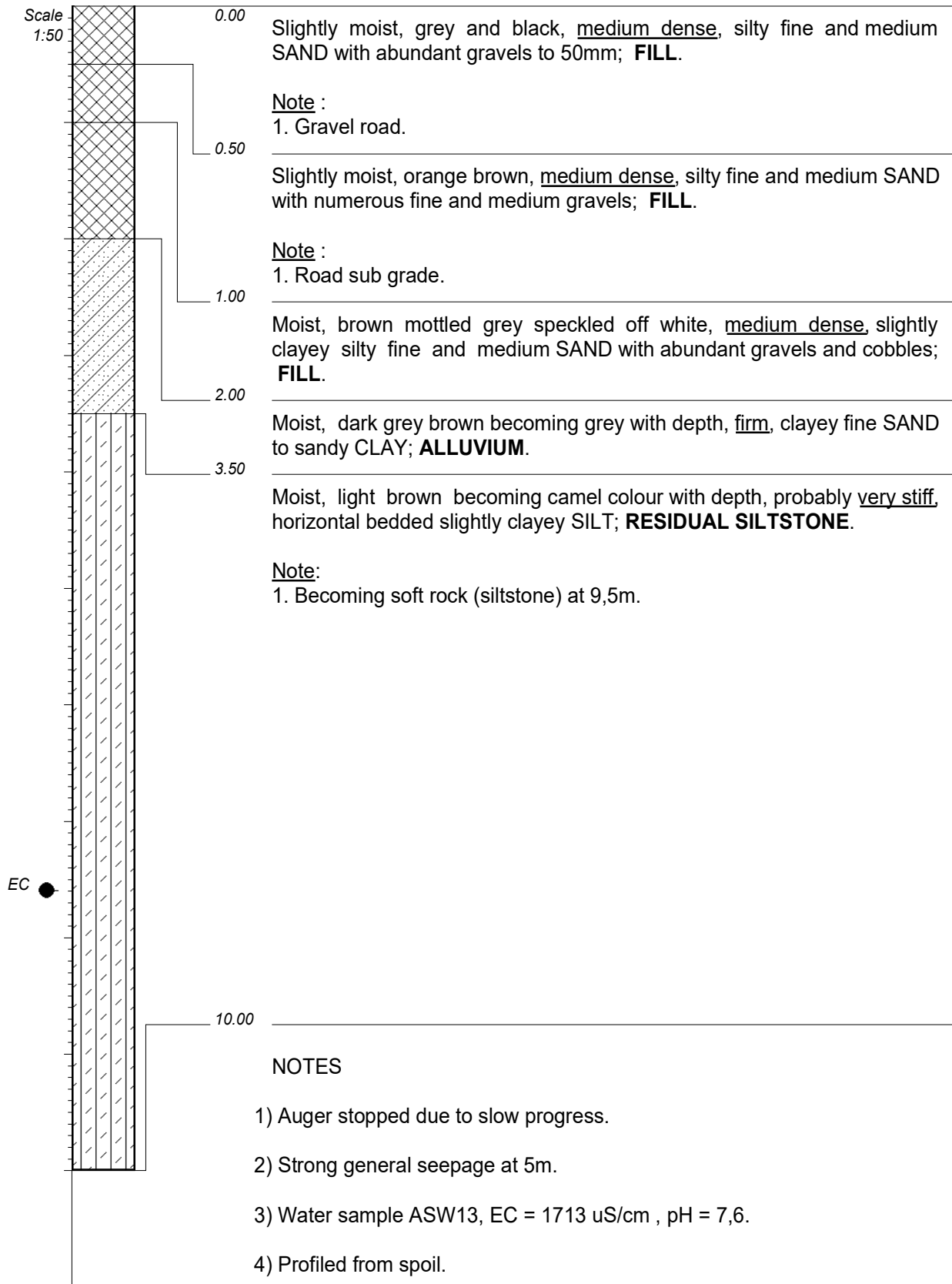


CONTRACTOR : ESOR
MACHINE : Williams Digger
DRILLED BY : Nelson
PROFIED BY : JR & MT
TYPE SET BY : VALERIE
SETUP FILE : STANDARD.SET

INCLINATION :
DIAM : 750mm
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DATE : 09/11/2006
DATE : 27/11/06 10:45
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ELEVATION :
X-COORD :
Y-COORD :

HOLE No: A12

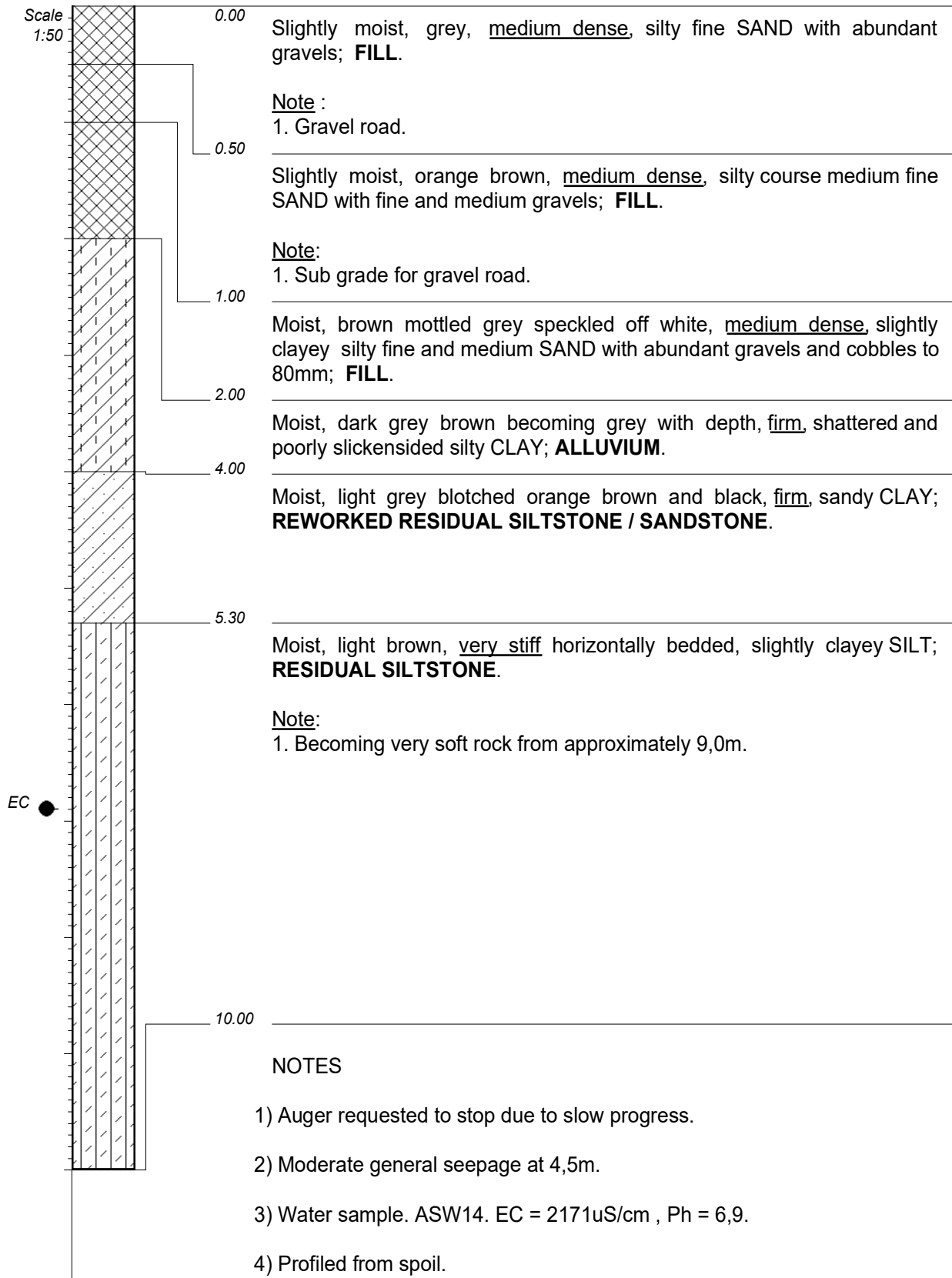


CONTRACTOR : ESOR
MACHINE : Williams Digger
DRILLED BY : Nelson
PROFILED BY : JR & MT
TYPE SET BY : VALERIE
SETUP FILE : STANDARD.SET

INCLINATION :
DIAM : 750mm
DATE : 09/11/2006
DATE : 09/11/2006
DATE : 27/11/06 10:45
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ELEVATION :
X-COORD :
Y-COORD :

HOLE No: A13

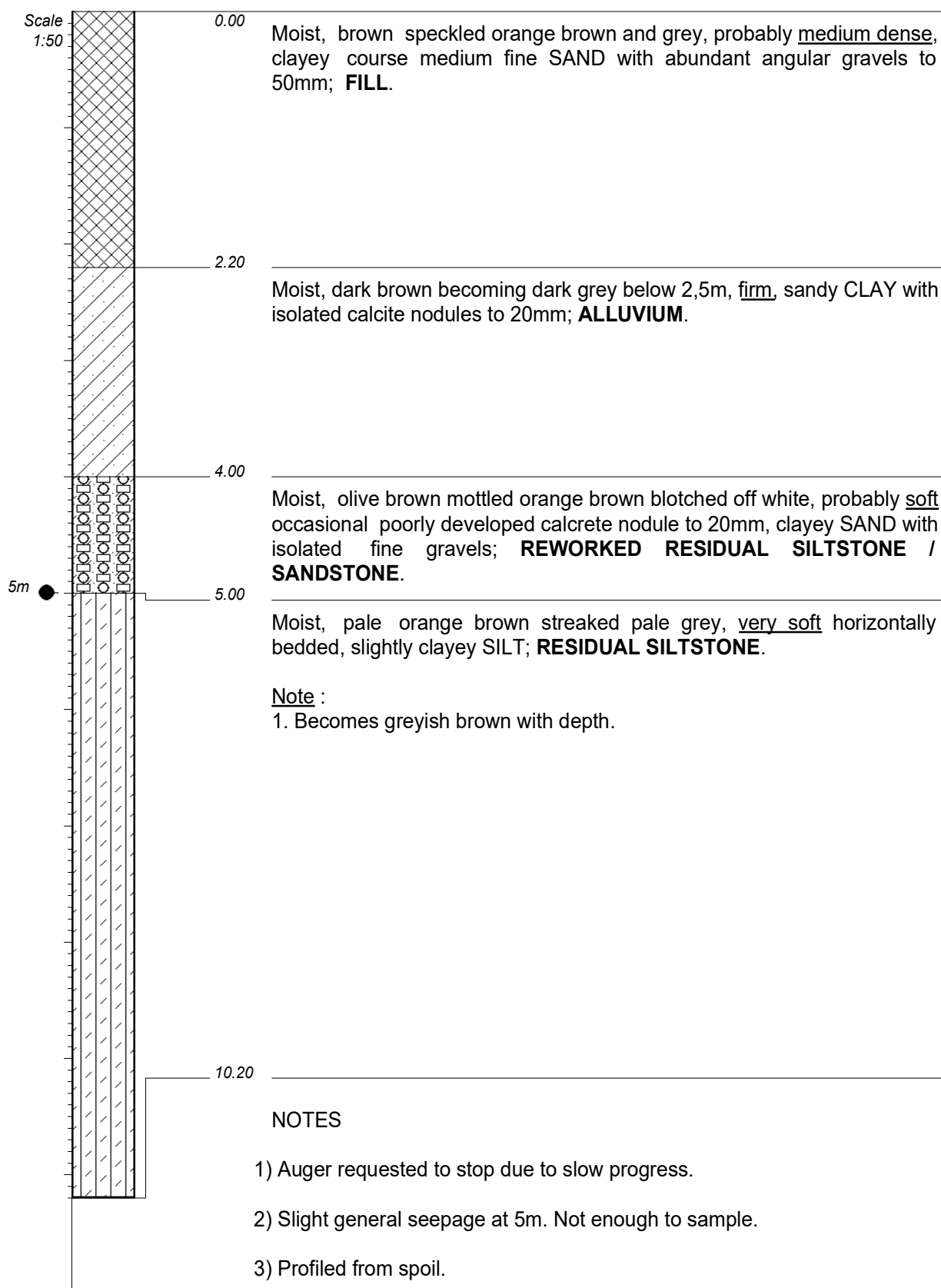


CONTRACTOR : ESOR
MACHINE : Williams Digger
DRILLED BY : Nelson
PROFILED BY : JR
TYPE SET BY : VALERIE
SETUP FILE : STANDARD.SET

INCLINATION :
DIAM : 750mm
DATE : 09/11/2006
DATE : 09/11/2006
DATE : 27/11/06 10:45
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ELEVATION :
X-COORD :
Y-COORD :

HOLE No: A14

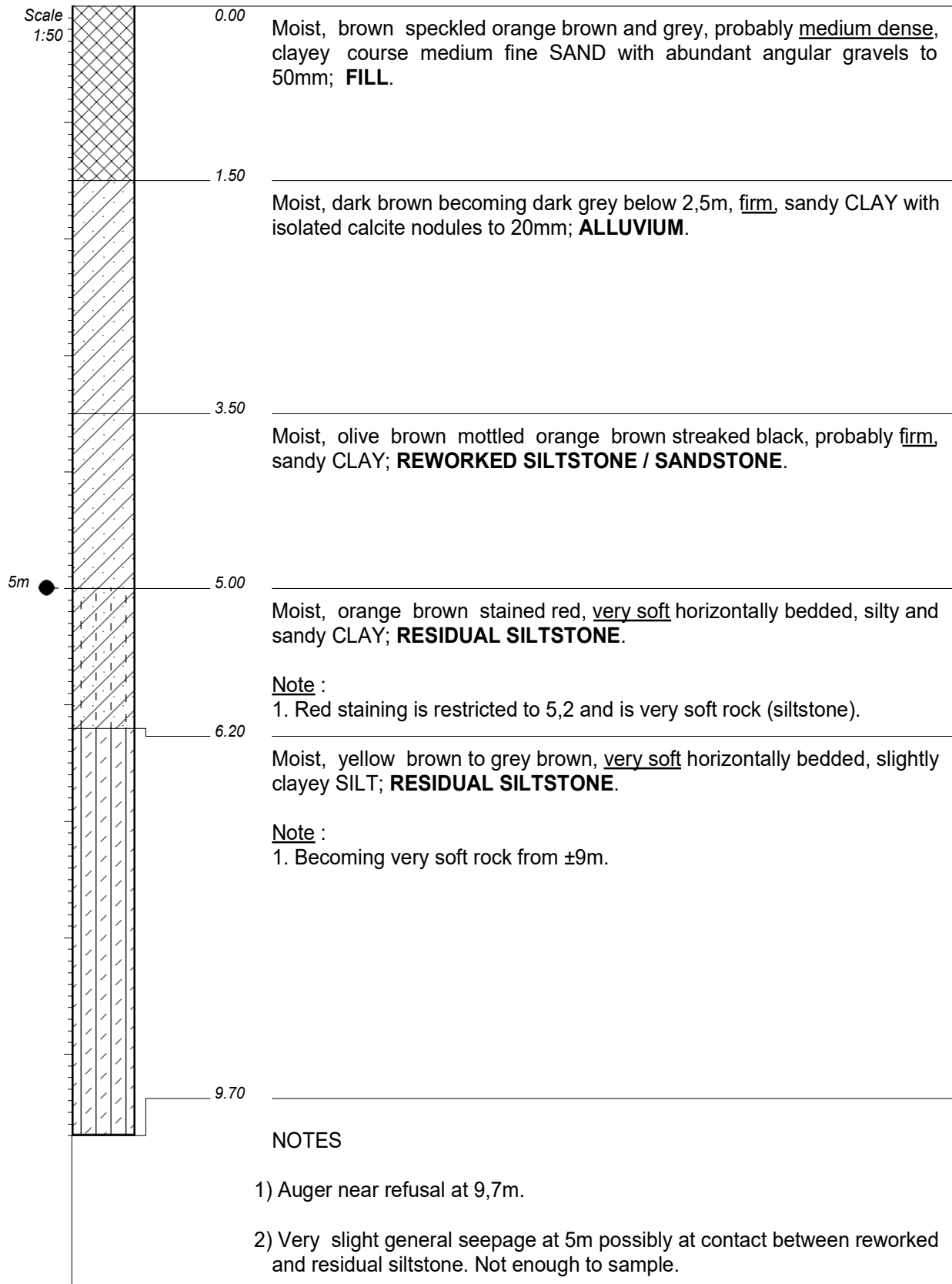


CONTRACTOR : ESOR
MACHINE : Williams Digger
DRILLED BY : Nelson
PROFIED BY : JR & MT
TYPE SET BY : VALERIE
SETUP FILE : STANDARD.SET

INCLINATION :
DIAM : 750mm
DATE : 08/11/2006
DATE : 08/11/2006
DATE : 27/11/06 10:45
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ELEVATION :
X-COORD :
Y-COORD :

HOLE No: A16

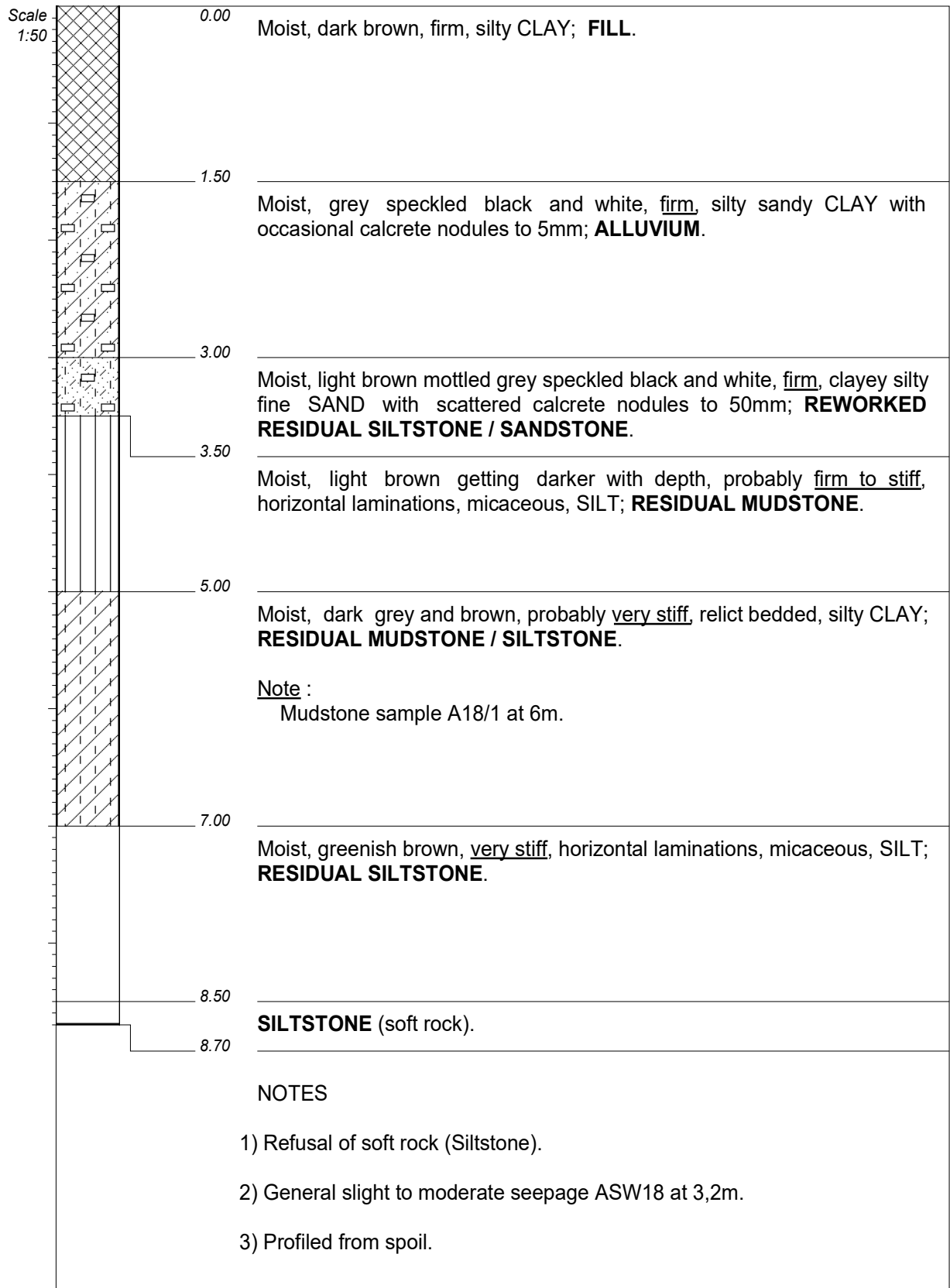


CONTRACTOR : ESOR
MACHINE : Williams Digger
DRILLED BY : Nelson
PROFIED BY : JR & MT
TYPE SET BY : VALERIE
SETUP FILE : STANDARD.SET

INCLINATION :
DIAM : 750mm
DATE : 08/11/2006
DATE : 08/11/2006
DATE : 27/11/06 10:45
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ELEVATION :
X-COORD :
Y-COORD :

HOLE No: A17

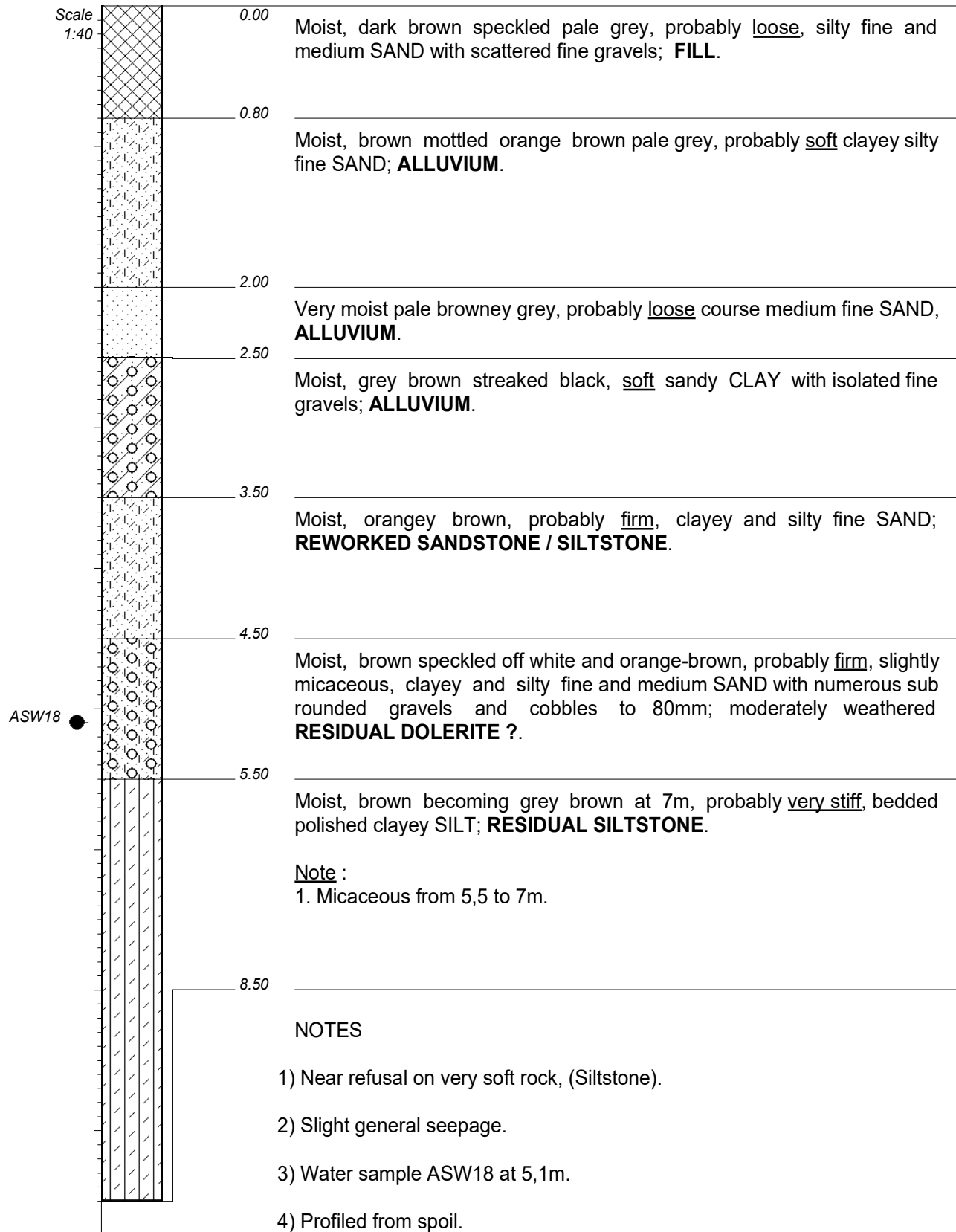


CONTRACTOR : ESOR
MACHINE : Williams Digger
DRILLED BY : Nelson
PROFILED BY : JR & MT
TYPE SET BY : VALERIE
SETUP FILE : STANDARD.SET

INCLINATION :
DIAM : 750mm
DATE : 08/11/2006
DATE : 08/11/2006
DATE : 27/11/06 10:45
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ELEVATION :
X-COORD :
Y-COORD :

HOLE No: A18

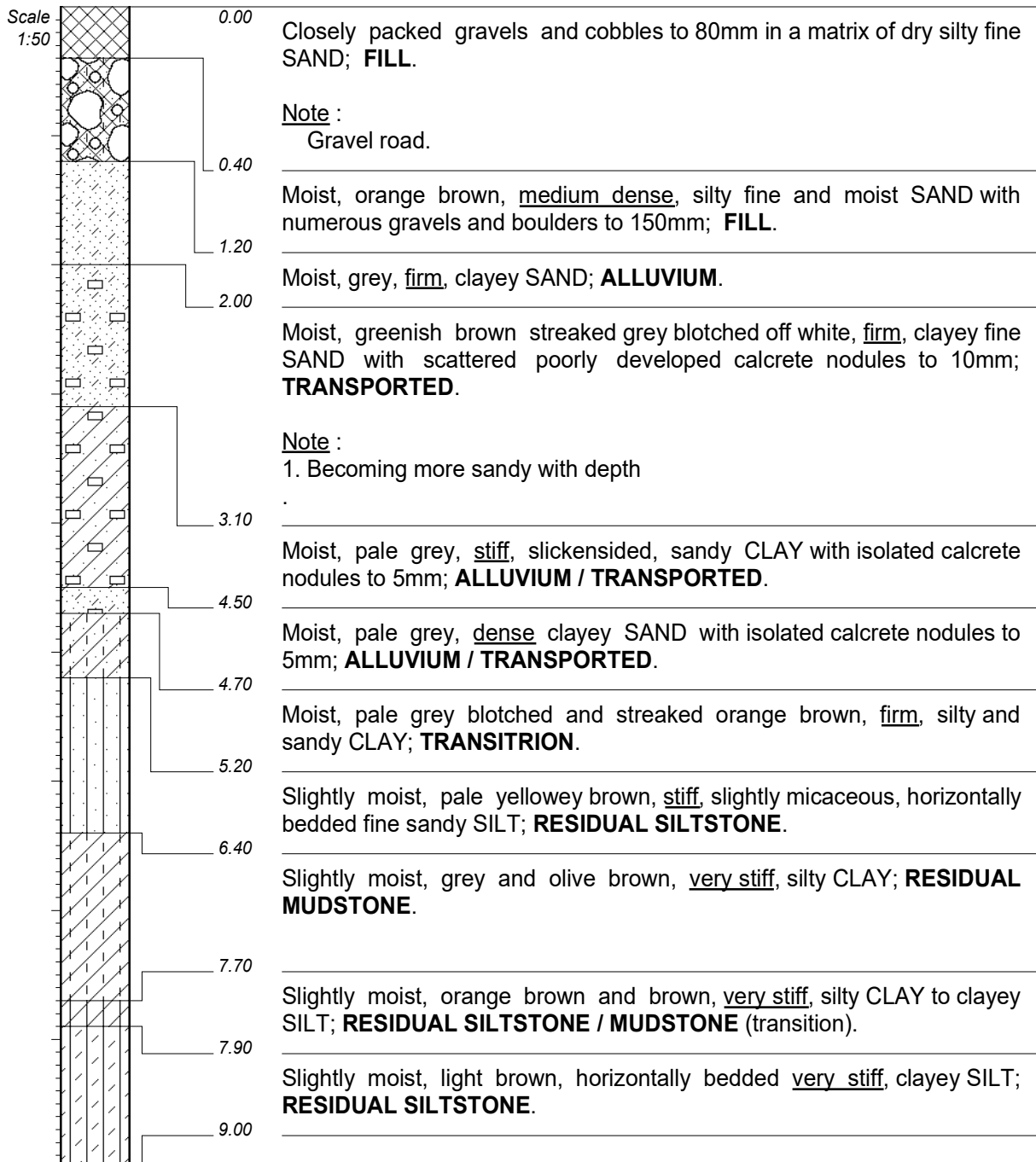


CONTRACTOR : ESOR
MACHINE : Williams Digger
DRILLED BY : Nelson
PROFILED BY : JR & MT
TYPE SET BY : VALERIE
SETUP FILE : STANDARD.SET

INCLINATION :
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DATE : 08/11/2006
DATE : 08/11/2006
DATE : 27/11/06 10:45
TEXT : ..\A839\A839_S~2.DOC

ELEVATION :
X-COORD :
Y-COORD :

HOLE No: A19



NOTES

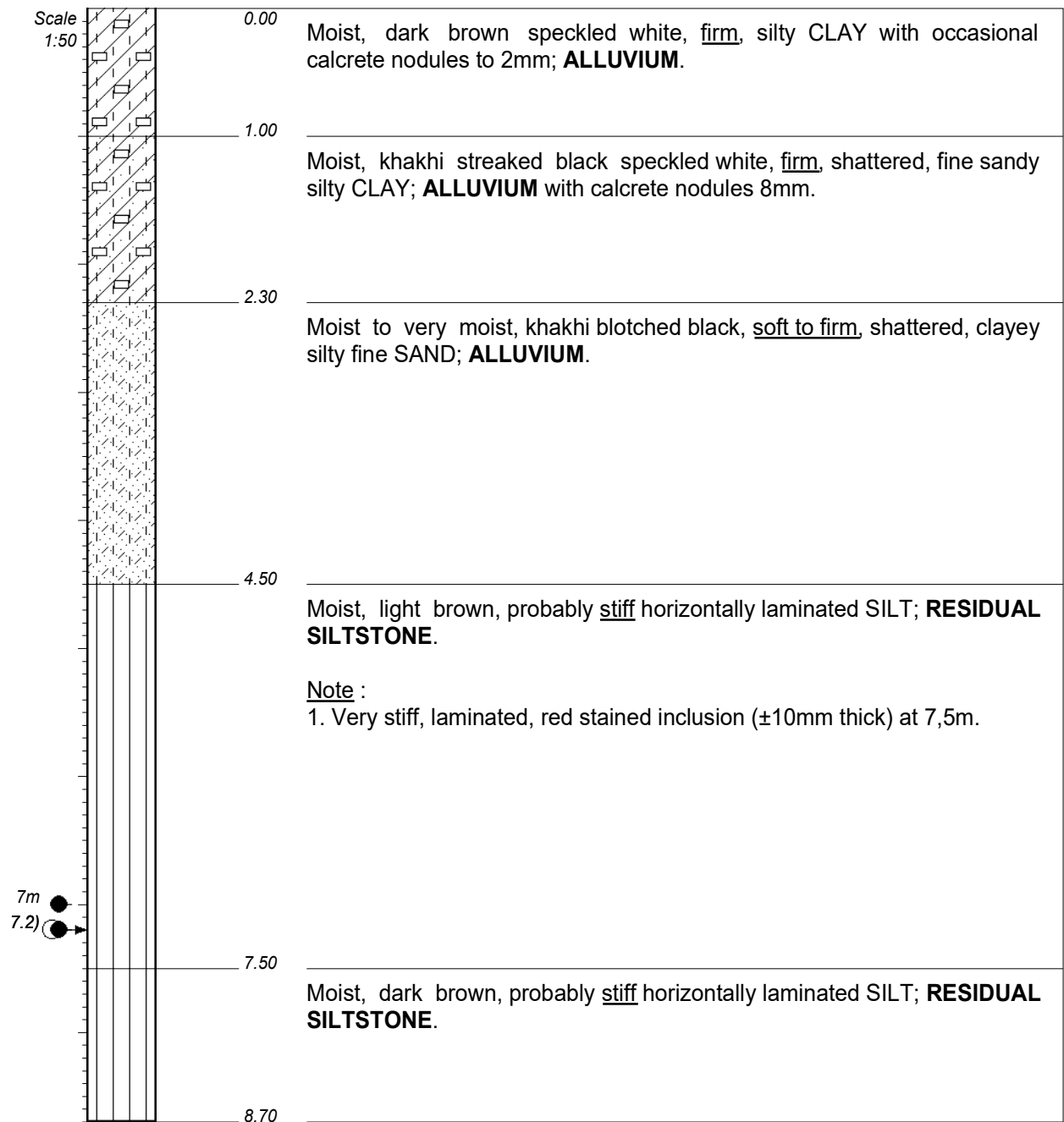
- 1) Auger stopped due to slow progress.
- 2) Moderate general seepage at 3,8m.
- 3) Bottled seepage ESW01. EC = 3250 uS/cm, pH = 7,3.
- 4) Profiled from spoils.

CONTRACTOR : ESOR
MACHINE : Williams Digger
DRILLED BY : Nelson
PROFILED BY : JR & MT
TYPE SET BY : VALERIE
SETUP FILE : STANDARD.SET

INCLINATION :
DIAM : 750mm
DATE : 10/11/2006
DATE : 10/11/2006
DATE : 27/11/06 10:45
TEXT : ..\A839\A839_S~2.DOC

ELEVATION :
X-COORD :
Y-COORD :

HOLE No: E01



NOTES

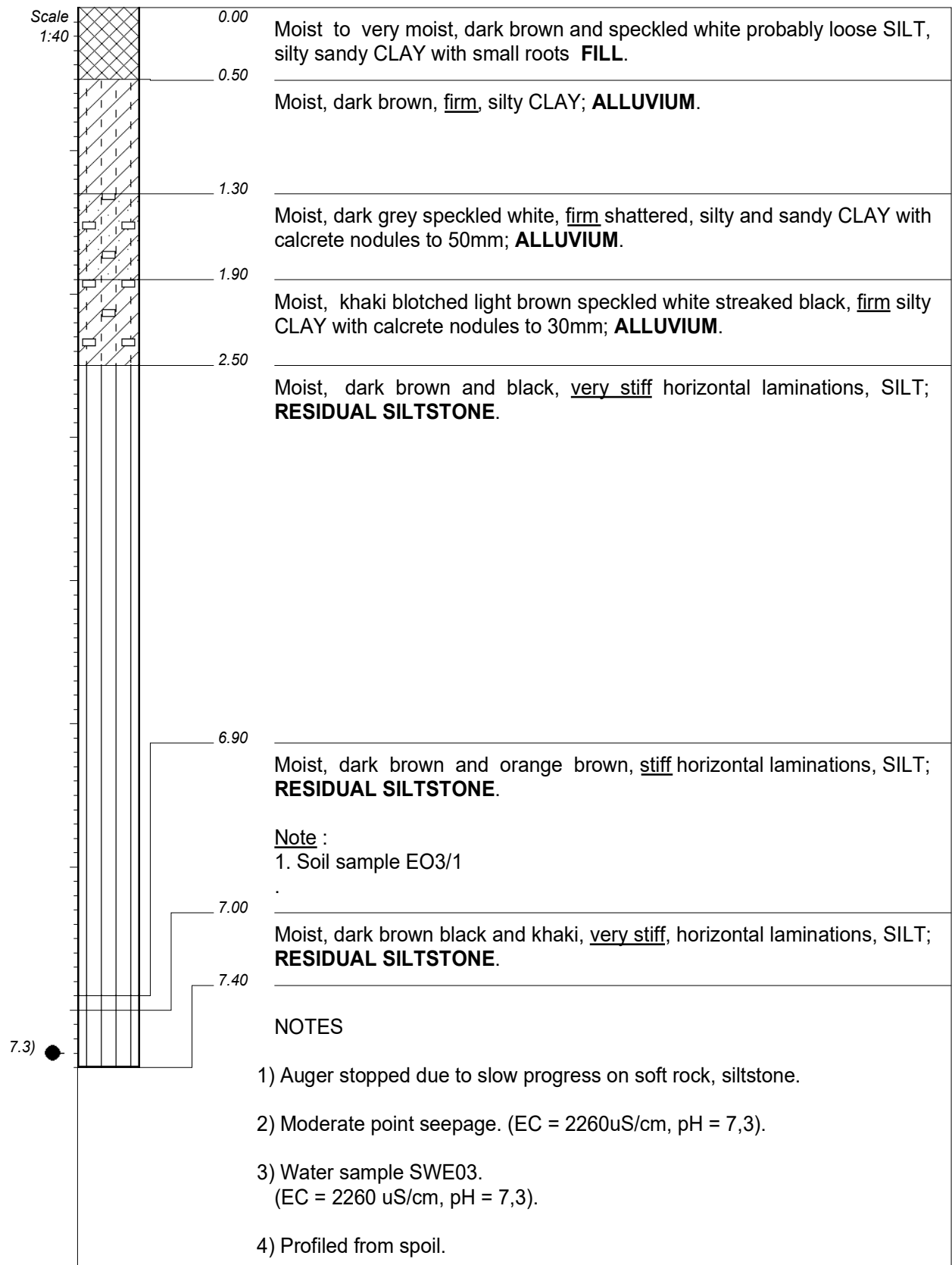
- 1) Auger stopped due to slow progress on soft rock siltstone.
- 2) Moderate general seepage. (EC = 6460uS/cm and pH = 7,2).
- 3) Water sample SWE02at 7m. (EC = 6460 uS/cm and pH = 7,2).
- 4) Profiled from spoils.

CONTRACTOR : ESOR
MACHINE : Williams Digger
DRILLED BY : Nelson
PROFILED BY : MT
TYPE SET BY : VALERIE
SETUP FILE : STANDARD.SET

INCLINATION :
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ELEVATION :
X-COORD :
Y-COORD :

HOLE No: E02

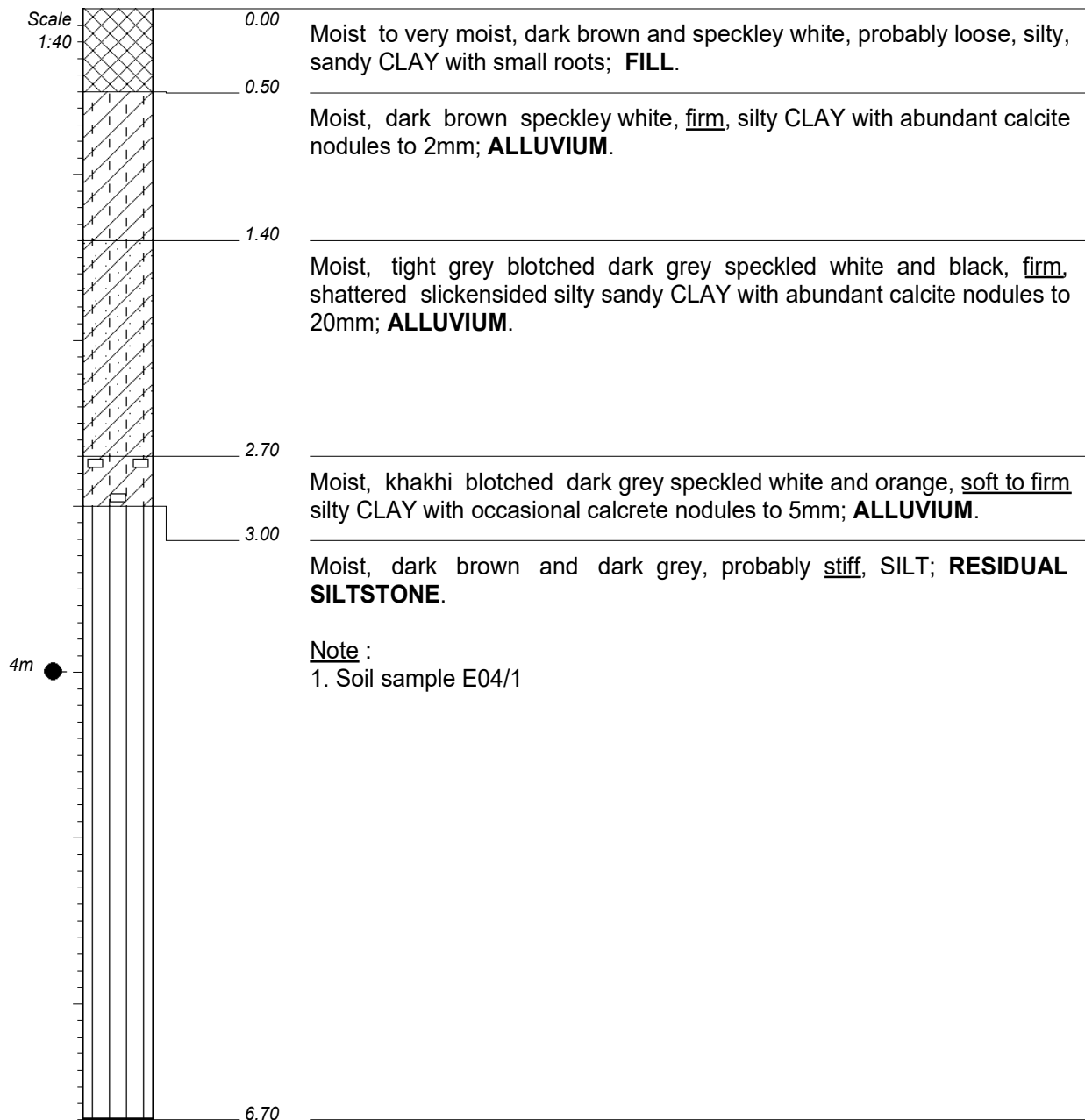


CONTRACTOR : ESOR
MACHINE : Williams Digger
DRILLED BY : Nelson
PROFILED BY : JR & MT
TYPE SET BY : VALERIE
SETUP FILE : STANDARD.SET

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DATE : 13/11/2006
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ELEVATION :
X-COORD :
Y-COORD :

HOLE No: E03



NOTES

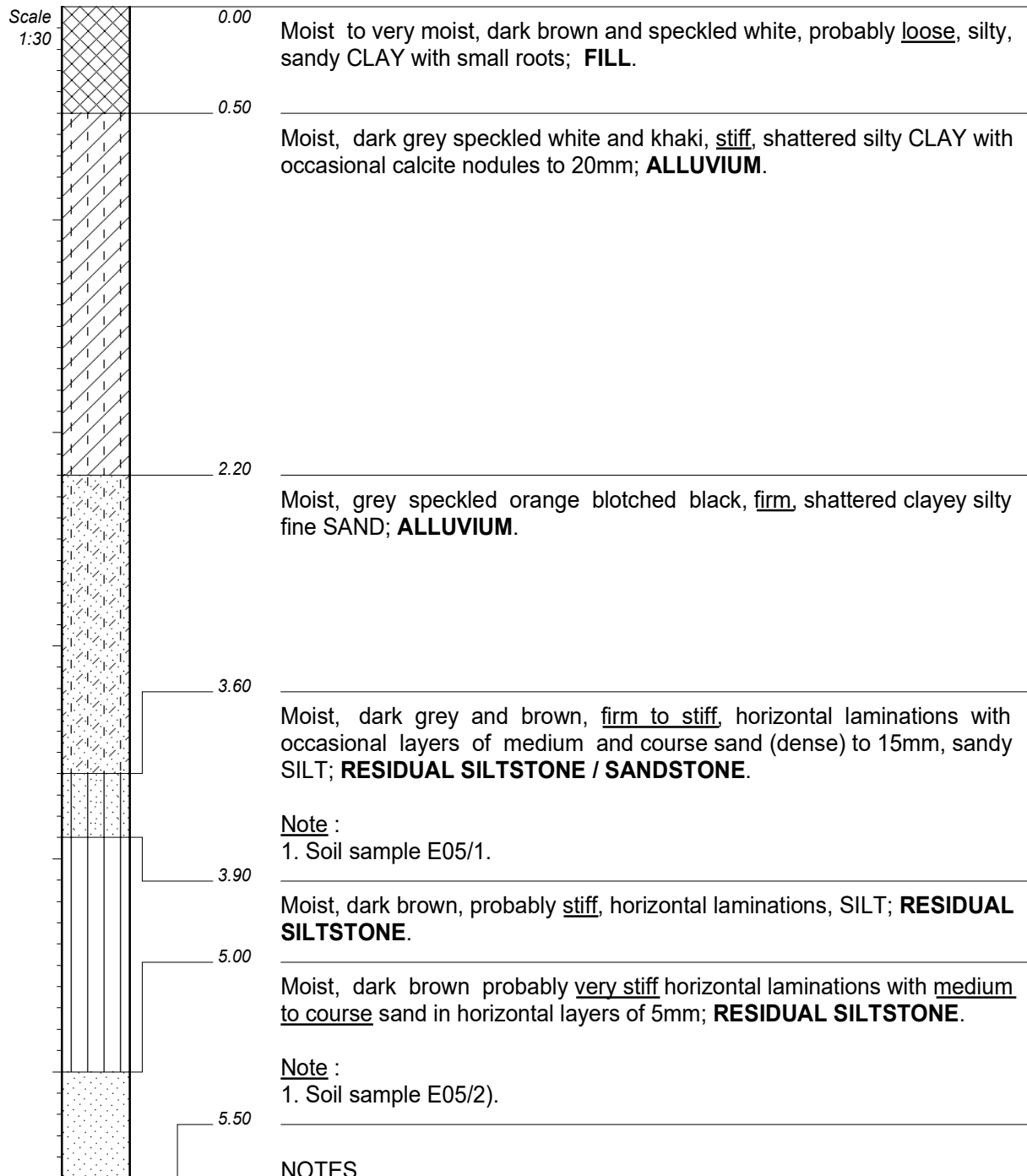
- 1) Stopped due to slow progress on siltstone.
- 2) Very slight point seepage at 4m. Not enough to sample. Depth estimate not very accurate due to cloudy weather conditions.
- 3) Profiled from spoil.

CONTRACTOR : ESOR
MACHINE : Williams Digger
DRILLED BY : Nelson
PROFILED BY : MT
TYPE SET BY : VALERIE
SETUP FILE : STANDARD.SET

INCLINATION :
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ELEVATION :
X-COORD :
Y-COORD :

HOLE No: E04



NOTES

- 1) Auger stopped due to slow progress on siltstone.
- 2) Moderate to strong general seepage at bottom of hole.
- 3) Bottled seepage SWE05 at 5,5m. (EC = 3070 uS/cm and pH = 7,0).
- 4) Profiled from spoil.

CONTRACTOR : ESOR
MACHINE : Williams Digger
DRILLED BY : Nelson
PROFILED BY : MT
TYPE SET BY : VALERIE
SETUP FILE : STANDARD.SET

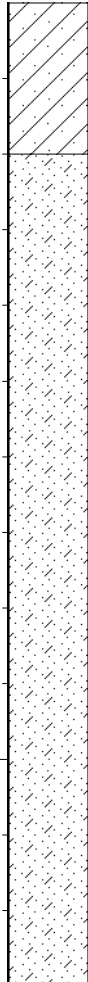
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ELEVATION :
X-COORD :
Y-COORD :

HOLE No: E05



Scale
1:10



0.00

Moist, dark brown, probably soft, sandy CLAY; **ALLUVIUM**.

0.20

Moist, olive brown speckled off white and grey, probably medium dense, clayey coarse medium fine SAND; **RESIDUAL DOLERITE WITH SCATTERED FINE GRAVELS**.

1.30

NOTES

- 1) Refusal 1,3m (Dolerite).
- 2) No seepage or water table.
- 3) Profiled from spoil.

CONTRACTOR : ESOR
MACHINE : Williams Digger
DRILLED BY : Nelson
PROFILED BY : JR & MT
TYPE SET BY : VALERIE
SETUP FILE : STANDARD.SET

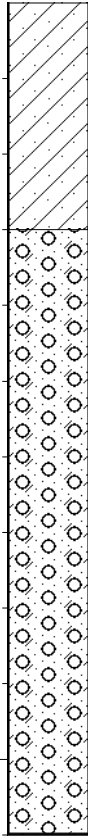
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DATE : 27/11/06 10:45
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ELEVATION :
X-COORD :
Y-COORD :

HOLE No: F01



Scale
1:10



0.00

Moist, dark brown, soft, slightly sandy CLAY; **ALLUVIAM**.

0.30

Moist, olive brown speckled off white and grey, medium dense? clayey
course medium fine SAND with fine gravels; **RESIDUAL DOLERITE**.

Note :

1. With sub rounded cobbles to base of hole.

1.10

NOTES

- 1) Refusal on medium hard rock, Dolerite.
- 2) No seepage or water table.
- 3) No samples taken.
- 4) Profiled from spoil.

CONTRACTOR : ESOR
MACHINE : Williams Digger
DRILLED BY : Nelson
PROFILED BY : JR

TYPE SET BY : VALERIE
SETUP FILE : STANDARD.SET

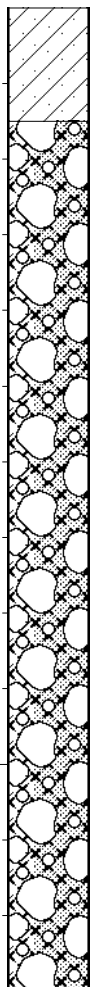
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DATE : 27/11/06 10:45
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ELEVATION :
X-COORD :
Y-COORD :

HOLE No: F02



Scale
1:10



0.00

Moist, dark brown, soft, sandy clay; **ALLUVIUM**.

0.15

Moist, dark olive brown speckled grey, medium dense, slightly clayey coarse medium fine SAND with abundant fine angular dolerite gravels and scattered sub rounded dolerite cobbles and boulders to 200mm; **RESIDUAL DOLERITE**.

1.30

NOTES

- 1) Refusal on grey speckled off white, medium hard rock; dolerite.
- 2) No samples taken.
- 3) No seepage or water table.
- 4) Profiled from spoil.

CONTRACTOR : ESOR
MACHINE : Williams Digger
DRILLED BY : Nelson
PROFILED BY : JR

TYPE SET BY : VALERIE
SETUP FILE : STANDARD.SET

INCLINATION :
DIAM : 750mm
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ELEVATION :
X-COORD :
Y-COORD :

HOLE No: F04

APPENDIX B BOREHOLE LOGS AND CHEMICAL ANALYSES

Sample No.	Description	Co-ordinate	
		Y	X
B1	Upstream of Bossiespruit dam wall	-19,572	2,940,939
B2	Twistdraai Export plant conveyor PC dam	-18,830	2,940,305
B3	Twistdraai Export plant stockpile PC dam	-18,972	2,940,593
B4	Twistdraai Export plant bin PC dam	-17,931	2,940,481
B5	Bossiespruit before confluence with Groot Bossiespruit	-15,463	2,939,320
B6	RESM 10	-15,505	2,939,263
G1	RESM12	-15,930	2,939,365
G2	Groot Bossiespruit between SCS(E) and SCS(W)	-16,161	2,940,562
G4	SCS(E) pollution control dam	-16,451	2,940,948
G5	Water released from Nitro into Groot Bossiespruit	-17,593	2,942,353
G6	Fertiliser Dam No. 3	-17,587	2,942,170
G7	RESM 15	-18,198	2,942,987
G8	Canal near SCS(W) passing under conveyor	-14,721	2,939,385
G9	SCS(W) pollution control dam	-15,186	2,939,571
G10	Groot Bossiespruit below bridge to Bossiespruit mine	-19,654	2,943,664
Disc 1	Twistdraai Export plant, discard dump return water dam	-20,613	2,937,990
Disc 2	Next to road and pump house of Twistdraai Export plant pollution control dam, north of discard dump	-20,819	2,938,245
Disc 3	Pollution control dam for discard dump of Twistdraai Export plant	-20,714	2,939,331
P1	Channel from plant to Bossiespruit, before confluence with Groot Bossiespruit	-15,736	2,939,294
TPW100	Next to stream north west of PC dam of load out silo (Twistdraai Export plant)	-31,198	2,951,235
TPW101	Next to stream below PC dam of load out silo (Twistdraai Export plant)	-31,198	2,951,235
TPW102	Next to stream east of PC dam of load out silo (Twistdraai Export plant)	-31,286	2,951,322
TPW103	Next to stream downstream of PC dam of load out silo (Twistdraai Export plant)	-31,006	2,950,984
TPW108	Inside Twistdraai Export plant railway loop, between Bossiespruit and rifle range	-30,855	2,950,446
TPW109	Inside Twistdraai Export plant railway loop, between Bossiespruit and rifle range	-30,885	2,950,507
TPW112	Inside Twistdraai Export plant railway loop, between railway line and Bossiespruit (north west of load out silo)	-31,390	2,950,998
TPW113	Inside Twistdraai Export plant railway loop, between railway line and Bossiespruit (north west of load out silo)	-31,449	2,951,088
TPW114	Close to Twistdraai Export plant load out silo	-31,052	2,953,527
TPW118	Next to stream in Ostrich area draining to Groot Bossiespruit, south of dirt road	-31,467	2,956,680
TPW119	Between Groot Bossiespruit and dirt road in Ostrich area	-31,738	2,956,878
TPW120	Next to stream in Ostrich area draining to Groot Bossiespruit, north of dirt road	-31,867	2,956,565

Sample No.	Description	Co-ordinate	
		Y	X
TPW125	North of SCS(E) discard dump, below conveyor belt	-28,215	2,950,519
TPW131	Ash conveyor channel	-27,115	2,951,928
TPW132	Down stream of SCS(W) PC dam	-27,054	2,952,192
TPW133A	Next to stream between Groot Bossiespruit and PC dam	-27,152	2,952,515
OSTR	In PC dam in Ostrich area	-31,412	2,956,198
V-1	Groot Bossiespruit in Ostrich area, below culvert crossing the road to Bossiespruit mine	-32,240	2,957,134
V-2	Groot Bossiespruit, upstream of TPW118 in Ostrich area	-31,578	2,956,712
V-3	Groot Bossiespruit downstream of TWPW118 in Ostrich area	-30,968	2,956,522
WK	Channel leading to Wollie se gat, next to railway	-32,144	2,948,043
Q1	Quarry dam east of plant	-30,542	2,949,500
E1W	Western corner of plant, next to road, north of pylon	-23,896	2,948,130
E3W	Western corner of plant, next to road, south of pylon	-23,832	2,948,557
EW6	South western corner of plant, between plant and Bossiespruit below big tower	-24,359	2,949,176
EW7	South western corner of plant, between plant and Bossiespruit	-24,547	2,949,310
EW13	After confluence of Groot Bossiespruit and Bossiespruit, between Bossiespruit and road, upstream of ash conveyor and the plant	-25,385	2,949,494
E4W	Western corner of plant, next to road, south of pylon	-24,895	2,949,681
E8W	After confluence of Groot Bossiespruit and Bossiespruit, between Bossiespruit and road, downstream of conveyor between SCS(W) and the plant	-25,128	2,949,414
E10W	North of SCS(W) discard dump between road and conveyor belt	-24,754	2,949,637
E15W	Next to channel from plant draining to Bossiespruit, before confluence with Groot Bossiespruit	-25,599	2,949,448
E16W	South of plant between road and Bossiespruit	-25,506	2,949,444
E19W	South eastern corner of plant, close to work permit training office	-29,421	2,950,084
E24	Channel between railway and Wollie se gat	-32,102	2,948,024
E12-A-W	Between Bossiespruit and Groot Bossiespruit before confluence	-25,599	2,949,448
SW108	Pond inside Twistdraai Export plant railway loop, north of TPW108	-25,506	2,949,444
ASW01	South of plant, next to road below wash down area	-27,312	2,949,901
ASW03	South of plant, next to road leading to wash down area	-27,143	2,949,896
ASW06	South of plant, next to road between wash down and parking areas	-26,911	2,949,868
ASW10	South of plant, next to road, east of parking area	-26,498	2,949,566
ASW12	South of plant, next to road, west of parking area	-25,918	2,949,493
ASW13	South of plant, next to road, below discard area in plant	-25,816	2,949,478
ASW14	Next to road, below coal stockpile in plant	-25,705	2,949,463

Sample No.	Description	Co-ordinate	
		Y	X
ASW18	After confluence of Groot Bossiespruit and Bossiespruit, between Bossiespruit and road, downstream of conveyor between SCS(W) and the plant	-25,108	2,949,414
18	After confluence of Groot Bossiespruit and Bossiespruit, between Bossiespruit and road, downstream of conveyor between SCS(W) and the plant	-24,977	2,949,368
ASW19A	South western corner of plant, between plant and Bossiespruit	-24,826	2,949,323
ESW01	North of SCS(W) discard dump between road and conveyor belt	-25,086	2,949,745
SWE02	North of SCS(W) discard dump between road and conveyor belt	-25,021	2,949,726
SWE03	North of SCS(W) discard dump between road and conveyor belt	-24,955	2,949,700
SWE05	North of SCS(W) discard dump between road and conveyor belt	-24,766	2,949,637
WO	Wollie se gat	-31,971	2,947,974
ASW02	South of plant, next to road below wash down area		
H10W	Groot Bossiespruit, Ostrich area	-19,078	2,943,252
H25W	Below conveyor, south of SCS(E)	-16,904	2,941,398
H26W	Canal south of SCS(E) discard dump	-16,671	2,941,145
H27W	Fertiliser Dam 7	-17,393	2,941,440
H58W	Cannel north of SCS(E), next to road	-16,405	2,939,728
H61W	Bossiespruit, south of plant	-16,329	2,939,549
DD1	Groot Bossiespruit below Nitro fertiliser dams	-31,883	2,950,729
DD2	Outside Twistdraai Export plant railway loop, below discard dump	-31,576	2,950,799
CAN 1	Inside Twistdraai Export plant railway loop, below discard dump	-31,704	2,948,805
SMX Magazine dam	PC dam in Ostrich area	-19,920	2,942,559
SMX Bleshoeder dam	PC dam in SMX	-18,671	2,941,121

ANALYSES in mg/ℓ	SAMPLING SITE: SASOL SECUNDA SAMPLE IDENTIFICATION				
	REGM 231S	REGM 231D	REGM 232S	REGM 232D	REGM 233S
SAMPLE NUMBER	4091	4092	4093	4094	4095
pH Value at 25°C	8.1	8.8	8.0	8.5	8.2
Electrical Conductivity in mS/m at 25°C	97.9	107	109	55.7	304
Total Dissolved Solids at 180°C	594	590	650	320	2 430
Total Alkalinity as CaCO₃	368	264	376	248	440
Ammonia as N	<0.2	0.6	<0.2	0.3	<0.2
Nitrate as N	0.2	<0.2	<0.2	<0.2	3.0
Chloride as Cl	66	148	68	31	222
Sulphate as SO₄	97	46	127	<5	1 132
Fluoride as F	0.3	2.6	0.3	1.2	0.2
Sodium as Na	63	215	133	93	310
Potassium as K	3.8	5.2	4.0	5.2	3.0
Calcium as Ca	96	11	63	22	276
Calcium Hardness as CaCO₃	240	28	156	56	688
Total Hardness as CaCO₃	452	36	328	108	1 180
% Balancing	97.2	98.3	98.4	96.3	97.8

ANALYSES in mg/ℓ	SAMPLING SITE: SASOL SECUNDA SAMPLE IDENTIFICATION		
	REGM 233D	REGM 234S	REGM 234D
SAMPLE NUMBER	4096	4097	4098
pH Value at 25°C	8.4	8.3	8.7
Electrical Conductivity in mS/m at 25°C	103	137	98.6
Total Dissolved Solids at 180°C	578	766	588
Total Alkalinity as CaCO₃	344	400	360
Ammonia as N	<0.2	<0.2	0.3
Nitrate as N	<0.2	<0.2	<0.2
Chloride as Cl	112	188	78
Sulphate as SO₄	24	36	28
Fluoride as F	2.2	0.3	3.2
Sodium as Na	213	183	198
Potassium as K	8.0	5.0	8.7
Calcium as Ca	13	61	13
Calcium Hardness as CaCO₃	32	152	32
Total Hardness as CaCO₃	60	300	48
% Balancing	99.8	99.9	98.3



ANALYSES in mg/ℓ	SAMPLING SITE: SASOL SECUNDA SAMPLE IDENTIFICATION				
	B1	B2	B3	B4	B5
SAMPLE NUMBER	6254	6255	6256	6257	6258
pH Value at 25°C	8.0	7.9	8.4	8.3	8.0
Electrical Conductivity in mS/m at 25°C	21.1	704	716	71.3	44.4
Total Dissolved Solids at 180°C	182	5904	5968	5886	290
Total Alkalinity as CaCO₃	76	196	220	208	136
Ammonia as N	2.2	2.2	1.0	1.2	1.4
Nitrate as N	1.6	3.6	3.8	5.0	1.2
Chloride as Cl	14	288	278	278	50
Sulphate as SO₄	32	3242	3448	3326	74
Fluoride as F	0.2	2.1	2.1	2.1	0.3
Sodium as Na	13	1427	1210	1379	30
Potassium as K	3.7	18.0	17.0	15.0	4.4
Calcium as Ca	19	219	211	196	34
Magnesium as Mg	10	127	141	122	23
Aluminium as Al	0.601	<0.100	<0.100	<0.100	<0.100
Iron as Fe	0.971	<0.025	<0.025	<0.025	0.093
Manganese as Mn	< 0.025	0.036	0.038	<0.025	<0.025
% Balancing	97.8	97.5	97.3	99.1	93.9

ANALYSES in mg/ℓ	SAMPLING SITE: SASOL SECUNDA SAMPLE IDENTIFICATION				
	B6	G1	G2	G4	G5
SAMPLE NUMBER	6259	6246	6247	6248	6249
pH Value at 25°C	8.0	8.1	7.4	7.5	8.0
Electrical Conductivity in mS/m at 25°C	50.3	217	291	1241	171
Total Dissolved Solids at 180°C	326	1674	2564	12222	1202
Total Alkalinity as CaCO₃	132	272	228	140	144
Ammonia as N	1.2	1.2	1.2	57	46
Nitrate as N	2.9	56	185	1288	166
Chloride as Cl	30	157	139	377	79
Sulphate as SO₄	81	498	328	2655	72
Fluoride as F	0.4	0.8	0.7	1.5	0.8
Sodium as Na	36	194	158	984	34
Potassium as K	4.9	16	22	32	16
Calcium as Ca	38	155	240	1136	106
Magnesium as Mg	23	95	149	710	75
Aluminium as Al	<0.100	<0.100	<0.100	<0.100	<0.100
Iron as Fe	0.063	<0.025	0.034	0.088	<0.025
Manganese as Mn	<0.025	<0.025	<0.025	0.041	0.092
% Balancing	98.5	99.6	94.7	99.4	94.7

ANALYSES in mg/ℓ	SAMPLING SITE: SASOL SECUNDA SAMPLE IDENTIFICATION				
	G6	G7	G8	G9	G10
SAMPLE NUMBER	6250	6251	6252	6253	6535
pH Value at 25°C	5.3	8.0	7.7	7.6	7.6
Electrical Conductivity in mS/m at 25°C	6010	207	622	855	37.3
Total Dissolved Solids at 180°C	47702	1540	6216	8394	208
Total Alkalinity as CaCO₃	188	504	236	188	112
Ammonia as N	6600	3.0	18	1.8	0.4
Nitrate as N	6892	47	5.8	337	0.8
Chloride as Cl	1856	199	437	278	23
Sulphate as SO₄	1317	301	3275	3490	43
Fluoride as F	18	0.5	1.0	7.3	0.2
Sodium as Na	244	146	670	1275	21
Potassium as K	1656	60	26	29	4.3
Calcium as Ca	512	72	541	528	37
Magnesium as Mg	278	177	384	346	13
Aluminium as Al	<0.100	<0.100	<0.100	<0.100	<0.100
Iron as Fe	0.072	<0.025	0.042	0.045	0.069
Manganese as Mn	2.64	<0.025	0.042	0.073	<0.025
% Balancing	99.7	98.2	97.7	98.9	94.5

ANALYSES in mg/ℓ	SAMPLING SITE: SASOL SECUNDA SAMPLE IDENTIFICATION				
	Disc1	Disc2	Disc3	P1	
SAMPLE NUMBER	6261	6262	6263	6260	
pH Value at 25°C	7.8	7.8	8.9	7.2	
Electrical Conductivity in mS/m at 25°C	1020	964	959	72.4	
Total Dissolved Solids at 180°C	9518	8846	8656	486	
Total Alkalinity as CaCO₃	280	348	100	76	
Ammonia as N	2.2	2.0	1.0	18	
Nitrate as N	0.2	0.4	0.2	0.3	
Chloride as Cl	437	754	347	50	
Sulphate as SO₄	5797	4779	5388	248	
Fluoride as F	1.8	1.2	2.3	5.2	
Sodium as Na	1933	1458	2389	58	
Potassium as K	37	35	21	13	
Calcium as Ca	381	470	320	48	
Magnesium as Mg	287	322	230	18	
Aluminium as Al	<0.100	<0.100	<0.100	<0.100	
Iron as Fe	<0.025	0.025	0.025	0.825	
Manganese as Mn	0.086	7.95	0.027	0.716	
% Balancing	95.9	94.5	94.2	97.7	



ANALYSES in mg/ℓ	SAMPLING SITE: SASOL SECUNDA SAMPLE IDENTIFICATION				
	TPW100	TPW101	TPW102	TPW103	TPW108
SAMPLE NUMBER	7725	7726	7727	7728	7729
pH Value at 25°C	7.5	7.6	7.5	7.4	7.7
Electrical Conductivity in mS/m at 25°C	303	364	241	216	145
Total Dissolved Solids at 180°C	2734	3404	2034	1818	1136
Total Alkalinity as CaCO₃	512	508	492	380	356
Ammonia as N	<0.2	<0.2	<0.2	<0.2	<0.2
Nitrate as N	0.2	0.2	0.2	1.7	8.6
Chloride as Cl	79	125	83	70	28
Sulphate as SO₄	1398	1852	998	876	455
Fluoride as F	0.3	0.2	0.2	0.3	0.2
Total hardness as CaCO₃	1580	1620	1460	1140	828
Calcium hardness as CaCO₃	764	596	640	548	336
Sodium as Na	164	368	68	112	28
Potassium as K	4.5	1.9	2.6	7.9	13.1
Calcium as Ca	306	238	256	219	134
Magnesium as Mg	196	246	197	142	118
Aluminium as Al	6.03	3.05	19	28	80
Iron as Fe	5.63	2.76	35	33	106
Manganese as Mn	0.096	0.115	1.79	0.269	0.638
% Balancing	96.3	95.9	98.5	99.5	99.8

ANALYSES in mg/ℓ	SAMPLING SITE: SASOL SECUNDA SAMPLE IDENTIFICATION				
	TPW109	TPW112	TPW113	TPW114	TPW118
SAMPLE NUMBER	7730	7731	7732	7733	7734
pH Value at 25°C	7.8	7.8	7.7	7.9	8.1
Electrical Conductivity in mS/m at 25°C	195	288	243	144	137
Total Dissolved Solids at 180°C	1660	2680	2166	1024	926
Total Alkalinity as CaCO₃	416	400	400	444	504
Ammonia as N	0.2	<0.2	0.2	<0.2	<0.2
Nitrate as N	1.4	1.6	2.1	0.8	1.0
Chloride as Cl	55	100	74	29	24
Sulphate as SO₄	665	1489	1220	442	286
Fluoride as F	0.3	0.2	0.2	0.2	0.2
Total hardness as CaCO₃	1140	1820	1560	752	652
Calcium hardness as CaCO₃	444	760	656	308	252
Sodium as Na	42	64	59	55	73
Potassium as K	2.4	3.6	2.7	1.3	1.2
Calcium as Ca	178	304	262	123	101
Magnesium as Mg	167	254	217	107	96
Aluminium as Al	11	11	14	4.40	13
Iron as Fe	17	16	18	4.94	42
Manganese as Mn	0.134	0.339	0.362	0.047	0.967
% Balancing	98.6	96.3	97.0	95.6	98.1

ANALYSES in mg/ℓ	SAMPLING SITE: SASOL SECUNDA SAMPLE IDENTIFICATION				
	TPW119	TPW120	TPW125	TPW131	TPW132
SAMPLE NUMBER	7735	7736	7737	7738	7739
pH Value at 25°C	8.1	7.8	7.0	7.2	7.5
Electrical Conductivity in mS/m at 25°C	132	177	233	392	361
Total Dissolved Solids at 180°C	912	1052	1898	3930	3016
Total Alkalinity as CaCO₃	400	1004	328	380	368
Ammonia as N	<0.2	2.9	0.2	<0.2	<0.2
Nitrate as N	0.3	0.2	110	0.4	214
Chloride as Cl	55	35	88	88	129
Sulphate as SO₄	302	34	478	1981	577
Fluoride as F	0.3	0.2	0.3	0.3	0.8
Total hardness as CaCO₃	640	1012	1280	2240	1800
Calcium hardness as CaCO₃	268	320	740	1332	956
Sodium as Na	56	33	63	227	146
Potassium as K	1.8	2.6	1.6	1.1	1.3
Calcium as Ca	107	128	296	533	382
Magnesium as Mg	89	166	130	218	203
Aluminium as Al	20	8.06	10	16	52
Iron as Fe	41	26	17	23	77
Manganese as Mn	0.583	1.86	0.242	0.791	0.334
% Balancing	97.7	99.9	97.5	97.0	95.3

ANALYSES in mg/ℓ	SAMPLING SITE: SASOL SECUNDA SAMPLE IDENTIFICATION				
	TPW133A	Ostrich Dam	V-1	V-2	V-3
SAMPLE NUMBER	7741	7742	7743	7744	7745
pH Value at 25°C	7.4	8.0	8.5	8.0	8.2
Electrical Conductivity in mS/m at 25°C	196	47.0	28.6	163	149
Total Dissolved Solids at 180°C	1282	314	190	1080	1058
Total Alkalinity as CaCO₃	624	184	112	648	316
Ammonia as N	<0.2	<0.2	0.2	<0.2	<0.2
Nitrate as N	7.3<	<0.2	<0.2	<0.2	<0.2
Chloride as Cl	97	5	11	36	116
Sulphate as SO₄	314	61	15	279	333
Fluoride as F	0.6	1.0	0.2	0.3	0.7
Total hardness as CaCO₃	584	212	116	652	488
Calcium hardness as CaCO₃	248	92	76	160	104
Sodium as Na	227	24	14	156	164
Potassium as K	6.8	6.9	3.9	2.8	7.7
Calcium as Ca	99	37	30	64	42
Magnesium as Mg	82	29	10	120	93
Aluminium as Al	13	0.446	3.57	2.52	3.41
Iron as Fe	17	0.550	5.50	2.77	4.22
Manganese as Mn	1.97	0.307	0.209	0.211	0.226
% Balancing	98.7	97.1	97.1	99.7	98.5

ANALYSES in mg/ℓ	SAMPLING SITE: SASOL SECUNDA SAMPLE IDENTIFICATION				
	WK	Q1	EW1	EW3	EW6
SAMPLE NUMBER	7931	7930	7923	7924	7925
pH Value at 25°C	7.9	8.2	7.2	7.6	7.1
Electrical Conductivity in mS/m at 25°C	398	134	87.5	182	147
Total Dissolved Solids at 180°C	4204	936	582	1014	734
Total Alkalinity as CaCO₃	304	600	248	496	508
Ammonia as N	<0.2	<0.2	<0.2	<0.2	<0.2
Nitrate as N	0.6	0.5	9.8	0.2	0.4
Chloride as Cl	179	37	37	70	114
Sulphate as SO₄	2148	156	122	314	43
Fluoride as F	0.2	0.8	0.4	<0.2	<0.2
Total hardness as CaCO₃	2520	640	372	600	692
Calcium hardness as CaCO₃	1140	184	180	116	284
Sodium as Na	168	96	55	205	86
Potassium as K	6.4	24	1.5	8.3	1.2
Calcium as Ca	456	74	72	75	38
Magnesium as Mg	331	109	46	64	87
Aluminium as Al	<0.100	<0.100	<0.100	<0.100	<0.100
Iron as Fe	<0.025	<0.025	<0.025	<0.025	<0.025
Manganese as Mn	<0.025	<0.025	<0.025	<0.025	3.61
% Balancing	98.6	96.8	97.1	99.2	94.6

ANALYSES in mg/ℓ	SAMPLING SITE: SASOL SECUNDA SAMPLE IDENTIFICATION				
	EW7	EW13	E24	WO	SW108
SAMPLE NUMBER	7926	7927	7928	7929	7740
pH Value at 25°C	7.5	7.8	7.8	8.0	7.6
Electrical Conductivity in mS/m at 25°C	165	321	226	295	201
Total Dissolved Solids at 180°C	880	2372	1652	3036	2494
Total Alkalinity as CaCO₃	536	416	484	240	344
Ammonia as N	<0.2	<0.2	<0.2	<0.2	<0.2
Nitrate as N	0.3	9.5	6.0	0.5	0.5
Chloride as Cl	93	190	122	126	60
Sulphate as SO₄	139	1045	531	1425	775
Fluoride as F	<0.2	<0.2	<0.2	<0.2	1.3
Total hardness as CaCO₃	768	1176	968	1752	1124
Calcium hardness as CaCO₃	384	728	364	704	316
Sodium as Na	101	350	185	126	68
Potassium as K	2.7	1.9	13.5	8.3	6.1
Calcium as Ca	64	291	146	282	126
Magnesium as Mg	86	108	115	252	194
Aluminium as Al	<0.100	<0.100	<0.100	<0.100	0.522
Iron as Fe	<0.025	<0.025	<0.025	<0.025	0.144
Manganese as Mn	<0.025	<0.025	<0.025	<0.025	0.179
% Balancing	95.1	96.6	98.9	96.9	98.9

ANALYSES in mg/ℓ	SAMPLING SITE: SASOL SECUNDA SAMPLE IDENTIFICATION				
	E4W	E8W	E10W	E12AW	E12W
SAMPLE NUMBER	7915	7916	7917	7918	7219
pH Value at 25°C	7.3	7.5	7.4	7.4	7.5
Electrical Conductivity in mS/m at 25°C	136	307	413	104	574
Total Dissolved Solids at 180°C	968	2068	3494	560	3432
Total Alkalinity as CaCO₃	252	468	352	360	488
Ammonia as N	<0.2	<0.2	<0.2	<0.2	<0.2
Nitrate as N	0.8	0.2	0.5	0.3	0.6
Chloride as Cl	113	242	364	37	1459
Sulphate as SO₄	354	756	1526	107	279
Fluoride as F	0.4	0.4	<0.2	0.2	0.4
Total hardness as CaCO₃	540	720	1944	488	1152
Calcium hardness as CaCO₃	244	184	774	160	240
Sodium as Na	109	460	334	63	821
Potassium as K	3.4	3.3	2.3	1.2	4.5
Calcium as Ca	98	74	310	80	96
Magnesium as Mg	71	129	281	44	219
Aluminium as Al	<0.100	<0.100	<0.100	<0.100	<0.100
Iron as Fe	<0.025	0.096	<0.025	<0.025	<0.025
Manganese as Mn	<0.025	0.380	<0.025	0.445	<0.025
% Balancing	99.6	96.3	96.0	99.5	98.4

ANALYSES in mg/ℓ	SAMPLING SITE: SASOL SECUNDA SAMPLE IDENTIFICATION				
	E15W	E16W	E19W	ASW 01	ASW 02
SAMPLE NUMBER	7220	7921	7922	8743	8744
pH Value at 25°C	7.8	7.3	7.4	7.2	7.7
Electrical Conductivity in mS/m at 25°C	80.8	120	94.4	180	192
Total Dissolved Solids at 180°C	518	728	494	982	1174
Total Alkalinity as CaCO₃	344	384	424	612	624
Ammonia as N	<0.2	<0.2	<0.2	<0.2	0.6
Nitrate as N	0.2	0.2	0.4	<0.2	<0.2
Chloride as Cl	23	56	24	149	114
Sulphate as SO₄	53	141	<5	139	277
Fluoride as F	2.0	0.6	<0.2	0.3	0.7
Total hardness as CaCO₃	256	492	520	720	680
Calcium hardness as CaCO₃	100	196	88	392	204
Sodium as Na	110	103	46	139	188
Potassium as K	1.5	4.5	4.1	1.2	2.1
Calcium as Ca	34	70	61	157	82
Magnesium as Mg	34	50	54	79	114
Aluminium as Al	<0.100	<0.100	0.125	<0.100	<0.100
Iron as Fe	<0.025	<0.025	0.052	<0.025	<0.025
Manganese as Mn	0.706	0.724	2.76	<0.025	1.17
% Balancing	96.7	99.9	97.8	97.3	99.4



ANALYSES in mg/ℓ	SAMPLING SITE: SASOL SECUNDA SAMPLE IDENTIFICATION				
	ASW6	ASW10	ASW12	ASW13	ASW14
SAMPLE NUMBER	8745	8746	8747	8748	8749
pH Value at 25°C	7.5	7.6	7.4	7.8	7.2
Electrical Conductivity in mS/m at 25°C	137	131	150	186	242
Total Dissolved Solids at 180°C	870	738	718	996	1640
Total Alkalinity as CaCO₃	396	456	548	624	628
Ammonia as N	0.6	0.8	0.8	0.8	<0.2
Nitrate as N	0.2	0.3	0.2	0.4	0.3
Chloride as Cl	72	74	86	78	147
Sulphate as SO₄	278	114	71	171	553
Fluoride as F	0.8	0.5	0.2	0.4	0.2
Total hardness as CaCO₃	580	476	580	360	1280
Calcium hardness as CaCO₃	220	212	84	152	584
Sodium as Na	111	128	118	284	118
Potassium as K	1.9	2.3	4.4	4.9	1.4
Calcium as Ca	88	85	34	61	234
Magnesium as Mg	86	63	76	50	167
Aluminium as Al	<0.100	<0.100	<0.100	<0.100	<0.100
Iron as Fe	0.036	<0.025	<0.025	<0.025	<0.025
Manganese as Mn	2.17	1.04	<0.025	<0.025	<0.025
% Balancing	98.1	94.8	94.2	96.3	96.0

ANALYSES in mg/ℓ	SAMPLING SITE: SASOL SECUNDA SAMPLE IDENTIFICATION				
	ASW18	ASW18	ASW19A	ESW01	SWE02
SAMPLE NUMBER	87507.8	8751	8752	8753	8754
pH Value at 25°C	7.8	7.7	7.2	7.5	7.5
Electrical Conductivity in mS/m at 25°C	118	267	236	472	1047
Total Dissolved Solids at 180°C	440	1882	1232	2290	7363
Total Alkalinity as CaCO₃	300	340	440	484	344
Ammonia as N	0.2	1.8	5.2	2.0	1.0
Nitrate as N	1.0	0.2	0.8	<0.2	0.8
Chloride as Cl	81	223	199	754	1449
Sulphate as SO₄	49	807	281	362	3392
Fluoride as F	0.4	0.4	0.6	0.5	0.6
Total hardness as CaCO₃	316	788	880	888	3240
Calcium hardness as CaCO₃	160	376	428	360	1920
Sodium as Na	89	325	100	514	997
Potassium as K	5.6	5.9	5.7	5.4	7.9
Calcium as Ca	64	151	171	144	768
Magnesium as Mg	37	99	108	127	317
Aluminium as Al	<0.100	<0.100	<0.100	<0.100	0.194
Iron as Fe	<0.025	<0.025	<0.025	<0.025	0.042
Manganese as Mn	0.076	0.228	3.23	0.189	0.766
% Balancing	95.6	99.7	95.5	97.8	95.4

ANALYSES in mg/ℓ	SAMPLING SITE: SASOL SECUNDA SAMPLE IDENTIFICATION				
	SWE03	SWE05	H10W	H25W	H26W
SAMPLE NUMBER	8755	8756	1005	1006	1007
pH Value at 25°C	7.5	7.3	8.3	6.8	6.6
Electrical Conductivity in mS/m at 25°C	345	379	121	4250	954
Total Dissolved Solids at 180°C	1738	3758	774	54984	9442
Total Alkalinity as CaCO₃	392	232	624	80	84
Ammonia as N	19	<0.2	0.2	234	58
Nitrate as N	0.2	30	0.3	7303	823
Chloride as Cl	586	208	12	1302	249
Sulphate as SO₄	175	1959	104	1344	2160
Fluoride as F	0.3	0.3	0.4	0.5	1.7
Total hardness as CaCO₃	784	2440	-	-	-
Calcium hardness as CaCO₃	380	2240	-	-	-
Sodium as Na	280	115	56	903	746
Potassium as K	8.1	5.7	2.0	54	24
Calcium as Ca	152	896	80	5932	818
Magnesium as Mg	97	48	117	3227	505
Aluminium as Al	<0.100	<0.100	<0.100	0.425	<0.100
Iron as Fe	<0.025	0.027	<0.025	0.238	0.033
Manganese as Mn	<0.025	<0.025	<0.025	6.48	0.853
% Balancing	97.8	99.7	96.5	97.4	97.0

ANALYSES in mg/ℓ	SAMPLING SITE: SASOL SECUNDA SAMPLE IDENTIFICATION				
	H27W	H58W	H61W	DD1	DD2
SAMPLE NUMBER	1008	1009	1010	1011	1012
pH Value at 25°C	5.5	7.3	8.4	7.9	8.0
Electrical Conductivity in mS/m at 25°C	5440	96.6	220	196	109
Total Dissolved Solids at 180°C	44206	696	1774	1544	906
Total Alkalinity as CaCO₃	220	360	40	488	140
Ammonia as N	6000	2.8	3.6	1.2	1.0
Nitrate as N	15	1.1	0.9	1.3	0.4
Chloride as Cl	12239	45	146	37	29
Sulphate as SO₄	1431	118	921	735	444
Fluoride as F	14	0.8	2.8	0.7	0.6
Sodium as Na	214	46	250	111	52
Potassium as K	267	4.8	12.4	23	3.0
Calcium as Ca	290	90	176	213	88
Magnesium as Mg	350	56	57	128	73
Aluminium as Al	0.141	<0.100	<0.100	<0.100	<0.100
Iron as Fe	0.079	0.025	0.033	0.33	<0.025
Manganese as Mn	4.88	3.11	1.07	1.07	<0.025
% Balancing	98.9	97.8	99.1	99.1	99.6

ANALYSES in mg/ℓ	SAMPLING SITE: SASOL SECUNDA SAMPLE IDENTIFICATION				
	CAN2	SMX Magazine dam	SMX Bleshoender dam		
SAMPLE NUMBER	1013	1014	1015		
pH Value at 25°C	6.0	7.0	8.8		
Electrical Conductivity in mS/m at 25°C	1166	68.5	290		
Total Dissolved Solids at 180°C	12004	656	2366		
Total Alkalinity as CaCO₃	20	75	220		
Ammonia as N	1.0	0.8	1.0		
Nitrate as N	1787	33	1.9		
Chloride as Cl	309	30	363		
Sulphate as SO₄	716	121	930		
Fluoride as F	0.5	0.4	0.7		
Sodium as Na	267	32	210		
Potassium as K	18	9.2	55		
Calcium as Ca	1460	40	289		
Magnesium as Mg	719	52	156		
Aluminium as Al	<0.100	<0.100	<0.100		
Iron as Fe	0.066	0.028	<0.025		
Manganese as Mn	0.745	0.145	0.059		
% Balancing	97.5	95.2	95.0		



APPENDIX C REPORT ON GROUNDWATER MODELING

RISON GROUNDWATER CONSULTING

GEOHYDROLOGICAL INVESTIGATION:

GROUNDWATER MODELLING AT THE SASOL SECUNDA SITE, SOUTHERN SEEPAGE ZONE

August 2007



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August 2007

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1 Introduction

Rison Groundwater Consulting undertook a groundwater modelling exercise for the Sasol Synfuels site in 2005 (Van Biljon, 2005). During that study the focus was on the following potential contaminant sources:

- Process water dams.
- Salty water dams.
- Ash effluent dams.
- Ash disposal area.
- Black products area.

The current investigation focuses on the southern seepage area and the existing model was upgraded to simulate the impact from this area on the groundwater regime. The model was re-calibrated to include the new data. The description of the methodology is therefore similar to that of the original report and again included for easier reference.

2 Regional Setting

2.1 Locality of the Study Area

SASOL Synfuels is situated just outside the town of Secunda, Mpumalanga Province (Figure 2.1). The study area covers an area of approximately 2 696 hectares.

Apart from SASOL's mining and industrial development the land use in the region is predominantly agriculture. The towns of Secunda and eMbalenhle are located 3km north-east and 1km west of the study area respectively.

2.2 Regional Drainage

The study area is located within the catchment of the Grootspuit and in particular the sub-catchments of the Kleinspruit, Trichardspruit, Klipspruit and the Bossiespruit (Figure 2.2).

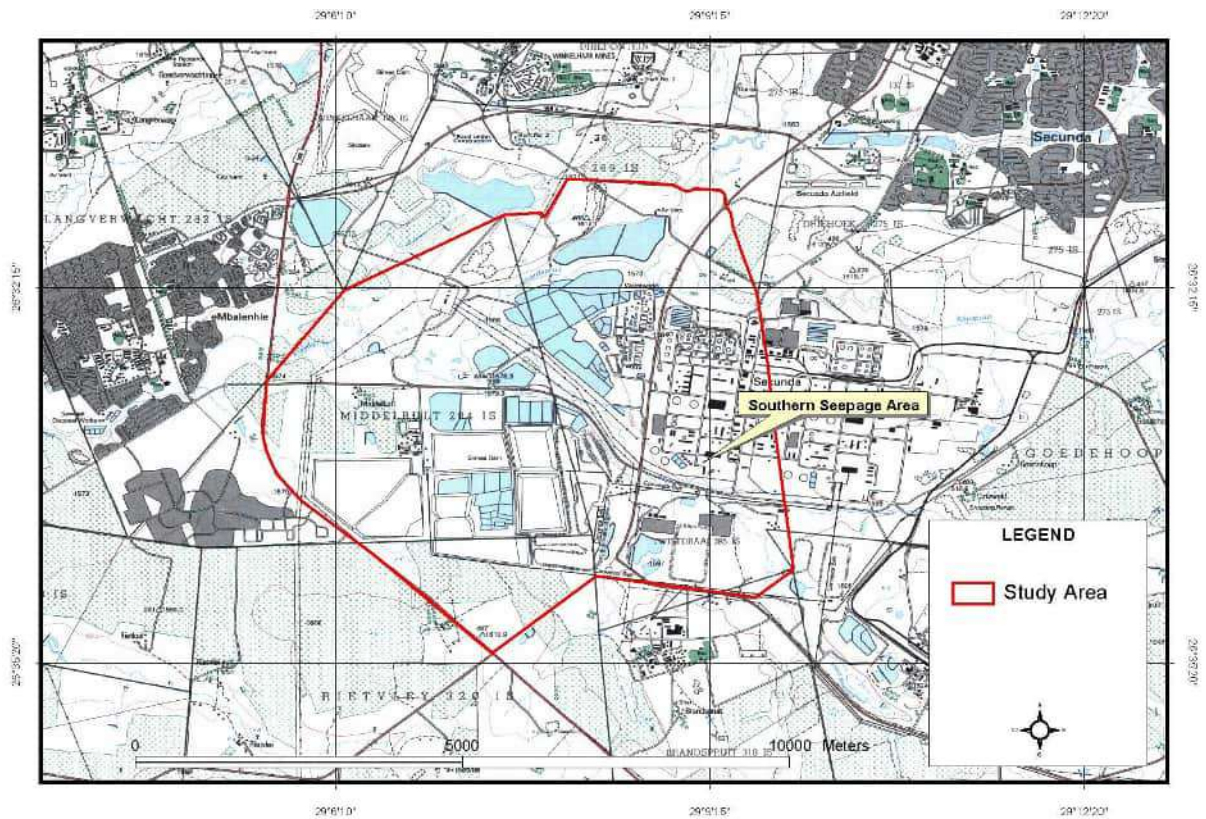


Figure 2.1: Locality of the Southern Seepage Area

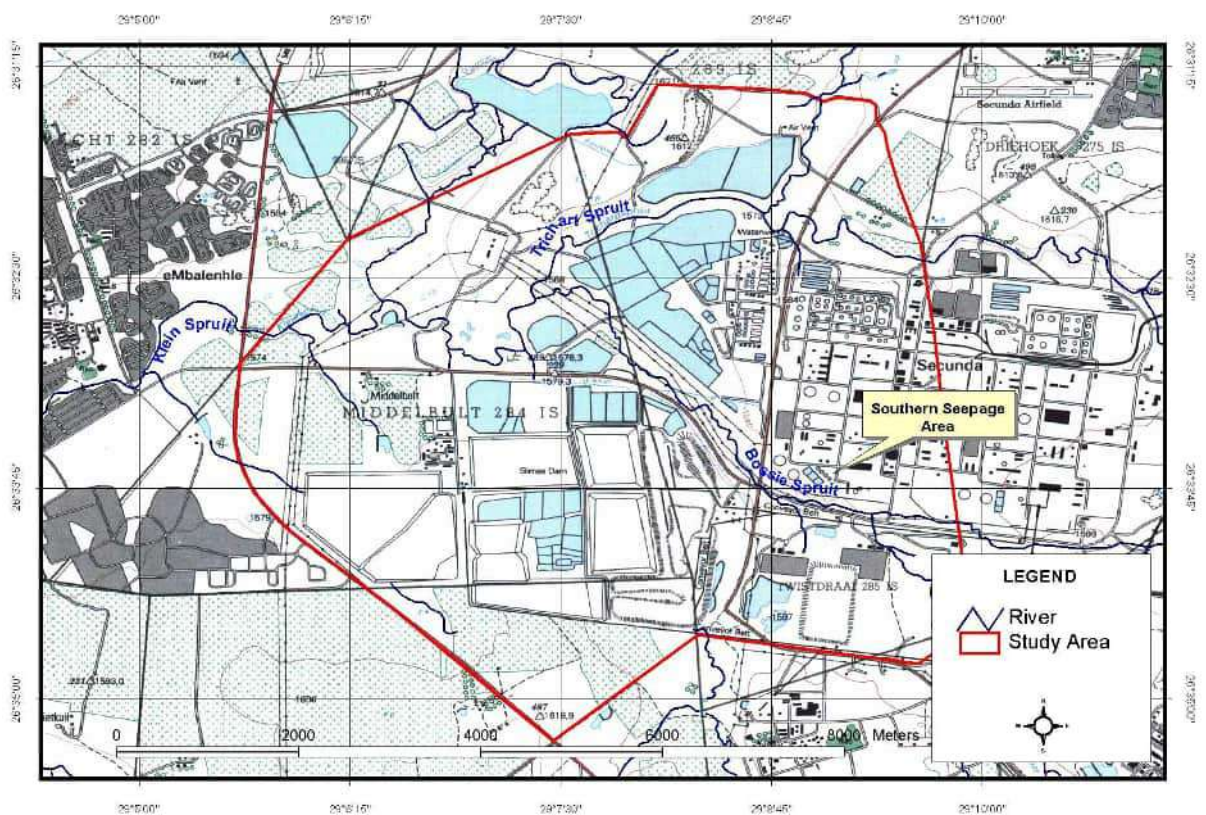


Figure 2.2: Surface Drainage from the SASOL Synfuels Site

2.3 Surface Topography

The elevation of the study area varies between 1580metres above mean sea level (m amsl) and 1620m amsl (Figure 2.3). The potential contaminant sources are primarily located close to the surface streams at elevations between 1580m amsl and 1600m amsl.

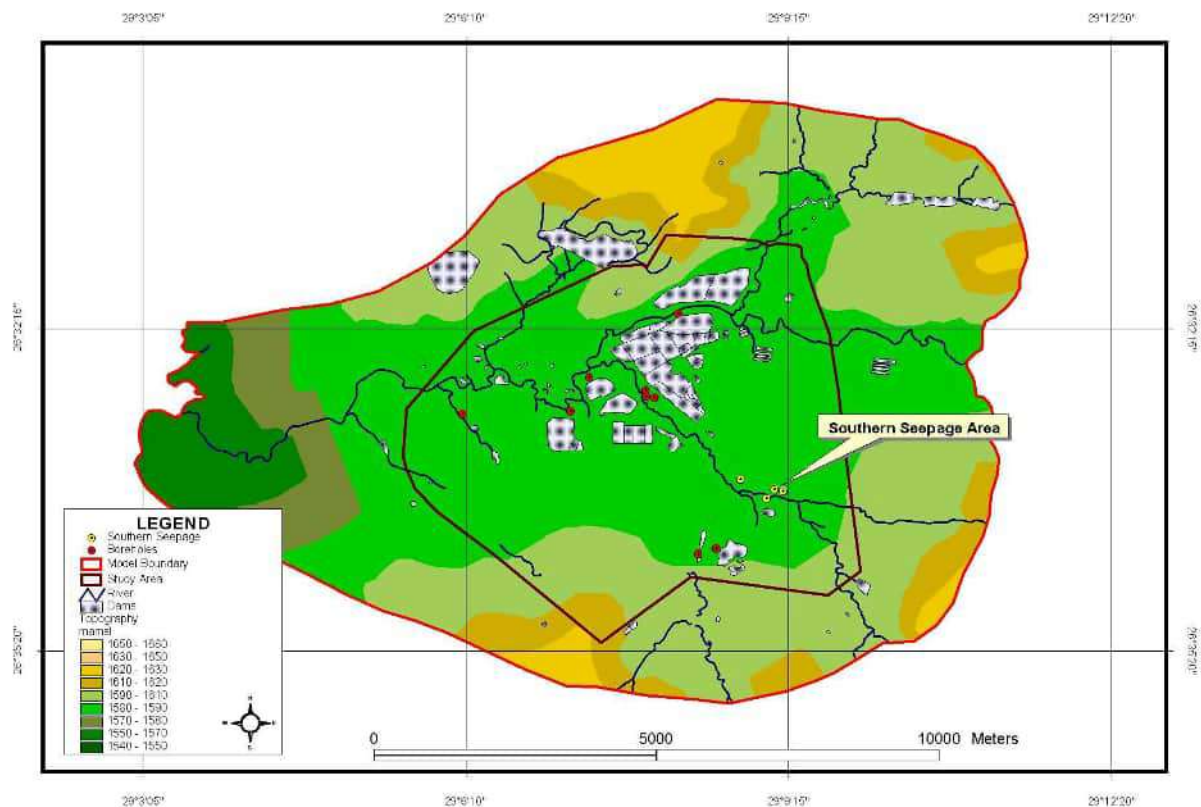


Figure 2.3: Topography of the Study Area

2.4 Rainfall

The annual average rainfall is 710mm (SA Weather Service). Recharge to the aquifers is primarily from rainfall and is a component that has been incorporated into the groundwater model. The regional groundwater recharge is estimated at 3% of the MAP.

3 Geology and Geohydrology of the Study Area

3.1 Geological Setting

Sediments of the Vryheid Formation of the Ecca Group underlie the study area (Figure 3.1). The Vryheid Formation (Ecca Group) mainly comprises mudstone, siltstone and fine- to coarse-grained sandstone (pebbly in places). Large sections of the study area are underlain by alluvium, especially along the river floodplains, as well as dolerite sills. Both these lithologies influences groundwater flow and hence contaminant migration.

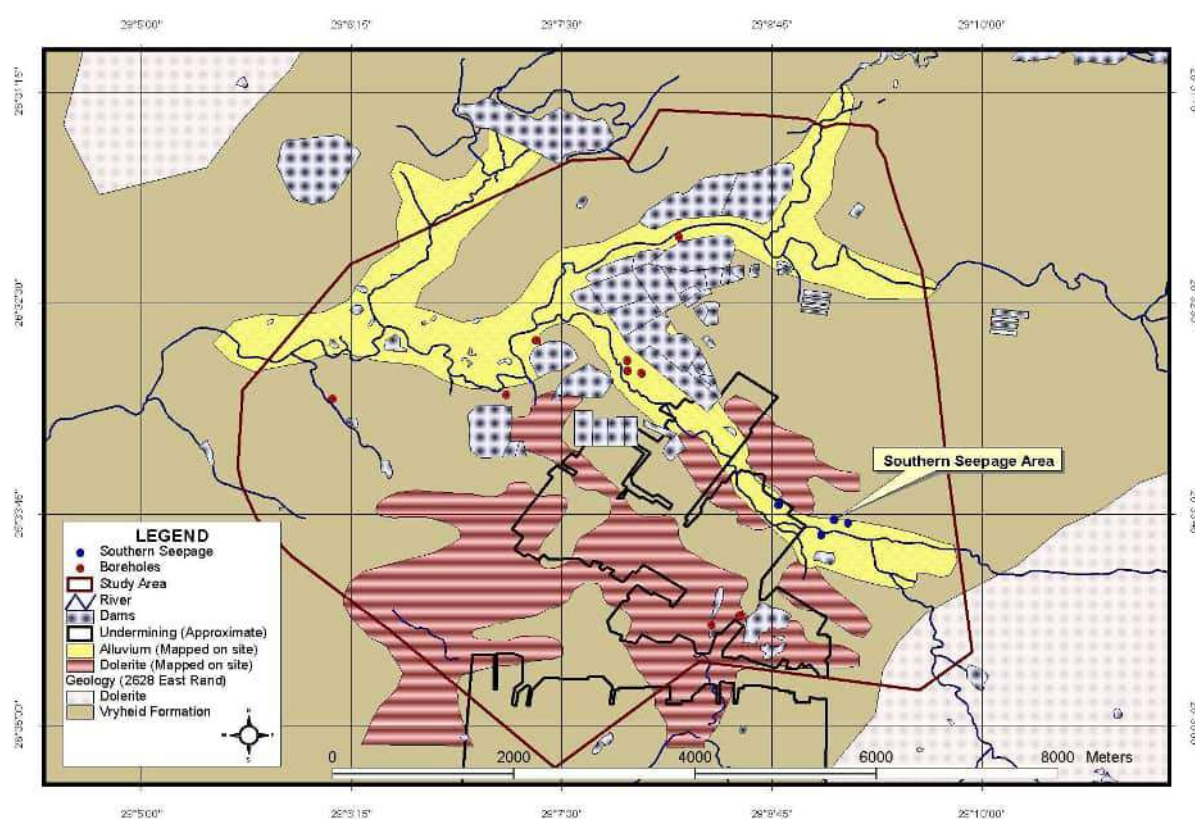


Figure 3.1: Regional Geology

Typically the different lithofacies of the Karoo Basin are mainly arranged in upward-coarsening deltaic cycles (up to 80m thick in the southeast). Linear coastline cycles are, however, fairly common particularly in the thin northwestern part of the basin. A relatively thin fluvial interval (60 m thick) which grades distally into deltaic deposits towards the southwest and south occurs approximately in the middle of the formation in the east and northeast. Fining-upward fluvial cycles, of which up to six are present in the east, are typically sheet-like in geometry, although some form valley-fill

deposits. They comprise coarse-grained to pebbly, immature sandstones - with an abrupt upward transition into fine-grained sediments and coal seams.

Dolerite intrusions represent the roots of the volcanic system and are presumed to be of the same age as the extrusive lavas (Fitch and Miller, 1984). The level of erosion that affected the Main Karoo Basin has revealed the deep portions of the intrusive system, which displays a high degree of tectonic complexity. The Karoo dolerite, which includes a wide range of petrological facies, consists of an interconnected network of dykes and sills and it is nearly impossible to single out any particular intrusive or tectonic event. It would, however, appear that a very large number of fractures were intruded simultaneously by magma and that the dolerite intrusive network acted as a shallow stockwork-like reservoir.

Based on recent drilling the local geology is characterised by the following lithologies:

0m – 5m: Hillwash and Alluvium: The alluvium generally consists of a grey to black, shattered fissured and slickensided silty clay, sandy clay or clayey silt. The alluvial deposits are generally 1m in thickness along tributary streams and might be up to 5m in thickness along the flood plains of the Trichardtspruit. Occasional calcrete concretions might be present. The alluvium is potentially highly active and compressible (WMB, 1999).

5m – 15m: Siltstone: The residual siltstone and mudrock typically consists of grey fissured and slickensided silty clay and numerous calcrete nodules. The mudrock is frequently reworked and relict rock structures might not be visible (WMB, 1999). The siltstone is carbonaceous in places.

15m – 30m: Sandstone: The residual sandstone consists of pale brown to off-white medium dense slightly silty medium sand and clayey sand. The sandstone is often micaceous and varies from fine to medium grained.

The above stratigraphic description is typically an upwards fining sequence and the siltstone and sandstone shows variable degrees of weathering. A dolerite sill has intruded large parts of the study area and occurs at variable horizons. As a rule of thumb the formations overlying the sills are more extensively weathered than those underlying the sill.

According to recent drilling as well as the Wates, Meiring & Barnard (WMB, 1999) report and with reference to Figure 3.1 the following geological conditions are encountered within the various sections of the study area.

Process Water Dams: The process water dams are largely underlain by alluvium, siltstone and shale. The alluvium occurs along the northern, western and southern parts of the process water dams and the siltstone and shale underlies the central and eastern parts of the dam. The southern, western and northern portions of the dam are located within the floodplain area of the Trichardt- and Bossiespruits.

Salty Water Dams: The salty water dams are largely underlain by alluvium, siltstone and shale. The alluvium occurs along the northern, western and southern parts of the salty water dams and the siltstone and shale underlies the central and eastern parts of the dams. The southern, western and northern portions of the dam are located within the floodplain area of the Trichardt- and Bossiespruits.

Ash Effluent Dams: The Botha and Van Niekerk Dams are entirely underlain by alluvium. Both are largely located on the Trichardt and Bossiespruit floodplains.

Ash Disposal Area: The coarse ash dump is underlain by dolerite, sandstone, siltstone and alluvium. The southern portions of the dump are underlain by dolerite, the central parts by sandstone and the northern part by siltstone. Alluvium bisects the ash dump. The southern portion of the coarse ash dump is underlain by a fault zone, which forms part of a graben structure with an east-west turning southwest-northeast strike at the region of the coarse ash dump.

Black Products Area: The Black Products Area is mainly underlain by dolerite. The north-western part of the area is underlain by sandstone. The southern portion of the Black Products Area is underlain by a fault zone, which forms part of a graben structure with an east-west orientation.

Southern Seepage Area: This area is underlain by alluvium, alternating siltstone and sandstone as well as carbonaceous siltstone. Groundwater seepage will flow predominantly through the alluvium that forms the floodplain of the Bossiespruit.

3.2 Geohydrological Setting and Conceptual Groundwater Model

3.2.1 General

This section outlines the general hydrological characteristics of the various lithostratigraphic units, related more to the processes of sedimentation and diagenesis (i.e. the primary hydraulic properties). These properties are more important when considering the longer-term sustainable utilisation of the Karoo aquifers (storativity), rather than individual borehole yields.

Data from all available boreholes and auger holes in the vicinity of the study area were used in the geohydrological assessment. The locations of these boreholes are shown as Figure 3.2.

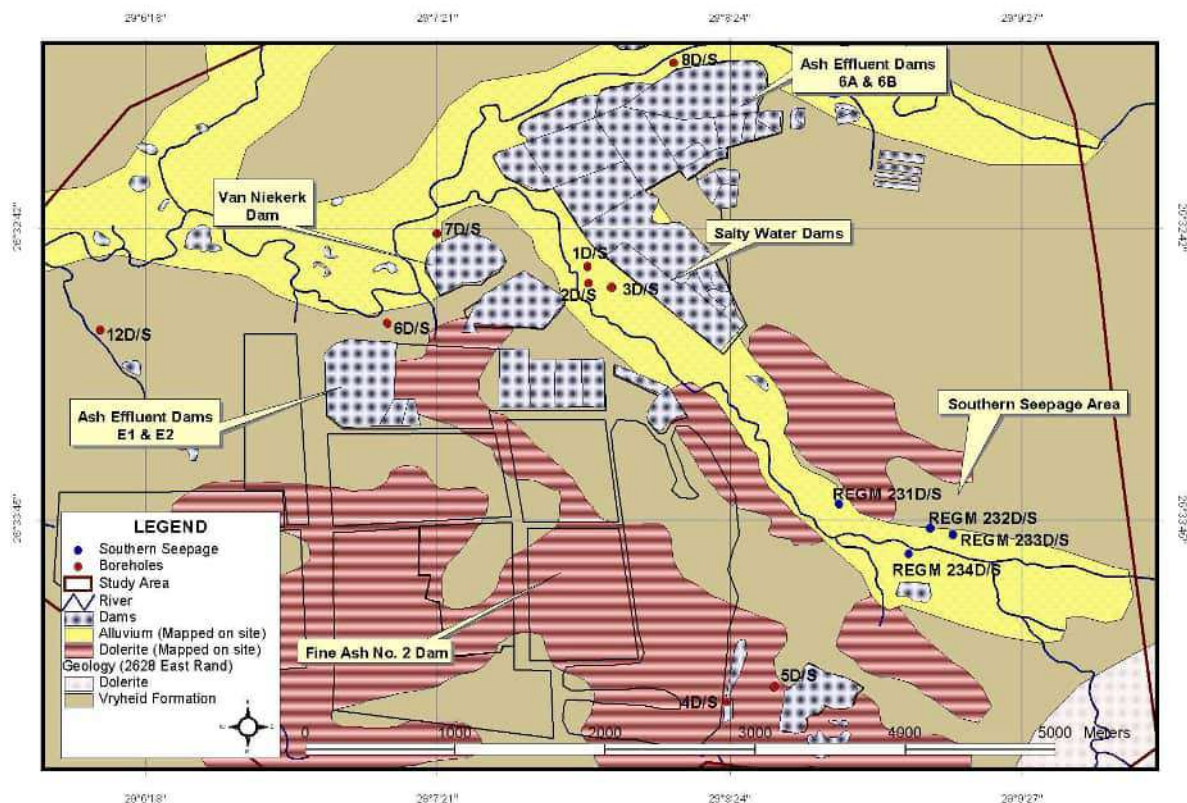


Figure 3.2: Borehole Locality Map

3.2.2 Unsaturated Zone

The depth to groundwater within the study area is in certain areas less than 1m and several boreholes are artesian. This very shallow unsaturated zone does not allow

for much retention time of contaminants before it reaches the groundwater table. The shallow depth to groundwater limits any attenuation of the contaminant migration before the shallow aquifer becomes contaminated.

3.2.3 Weathered Aquifer

The aquifer mostly affected by this contamination is the weathered formations referred to as the weathered aquifer. This shallow aquifer is located within the weathered profile where the depth to groundwater ranges from 1.43m to 3.55m below surface. The average hydraulic conductivity (permeability) of the weathered aquifer ranges from 0.063m/day to 0.138 m/day. The vertical permeability is in the order of 0.001 m/day to 0.00010m/day, which is sufficiently low to confine the groundwater in the underlying fractured rock aquifer.

Regionally the groundwater gradients within the weathered aquifer mimic the topography (Figure 3.3).

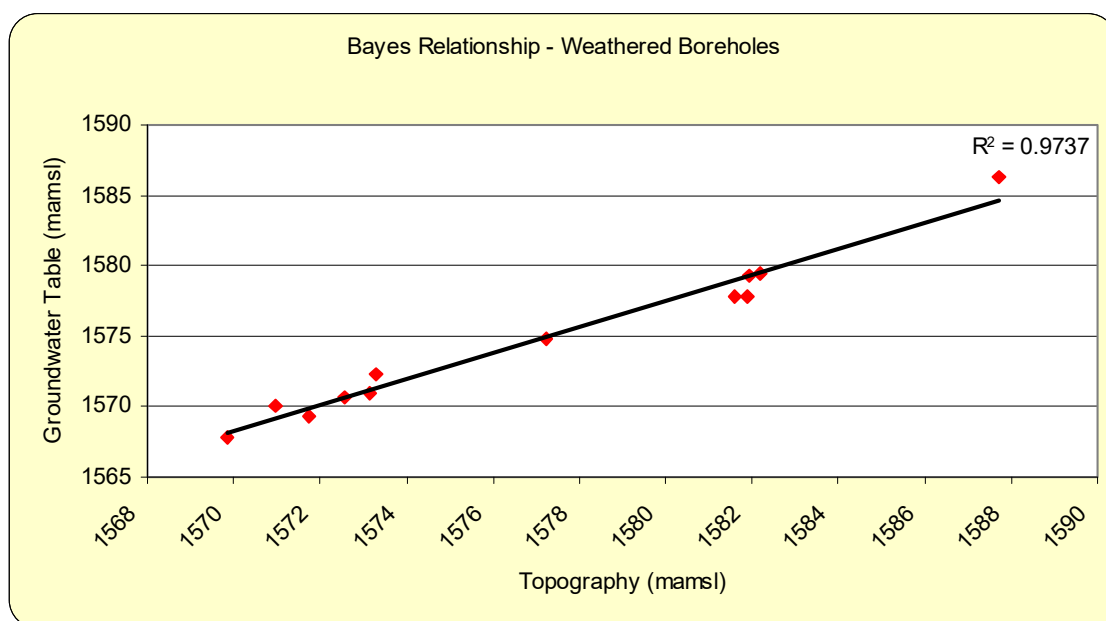


Figure 3.3: Correlation Between Topography and Groundwater Table – Weathered Aquifer

Due to the 99% correlation between topography and the groundwater table, known as the Bayesian Relationship, the regional groundwater gradient can be interpolated

using measured groundwater levels and the regional topography. The interpolated regional groundwater table is shown later in the report.

3.2.4 Fractured Aquifer

The primary porosity of the Vryheid Formation is very low. Any water bearing capacity is therefore associated with secondary joints, bedding planes and faults. For this reason, the horizontal permeability of the Karoo strata is generally orders of magnitude greater than the vertical permeability. The contact zones of dolerite intrusions are characterised by cooling joints and fractures, which are considered the primary source of groundwater flow within the deeper formations. Within the study area, however, the dolerite sill is thought to act as a confining layer and that the underlying sandstone formations act as the primary aquifer in the deeper horizons.

The average hydraulic conductivity (permeability) of the fractured rock aquifer varies from 0.024m/day to 0.037m/day. This variation is attributed to the lithological variations and the dolerite intrusions found within the site.

The depth to groundwater in this aquifer ranges from 0m (artesian) to 23.34m below surface. The fact that some deeper boreholes are artesian is indicative that the fractured aquifer is confined in places. The variation in groundwater levels is attributed to the undermining in the area, of which the exact extent is uncertain (Figure 3.4). Although the aquifer is not completely dewatered it appears that some water is seeping into the underlying workings, causing localized dewatering cones. The low aquifer parameters will result in localized, but steep dewatering cones.

A very poor correlation between the topography and the groundwater table is observed if the “dewatered” boreholes are included (Figure 3.5). If these boreholes are excluded the fractured groundwater gradient also show a good correlation with the topography (Figure 3.6). In the vicinity of the southern seepage area it appears if boreholes REGM231D and REGM234D are affected by the undermining.

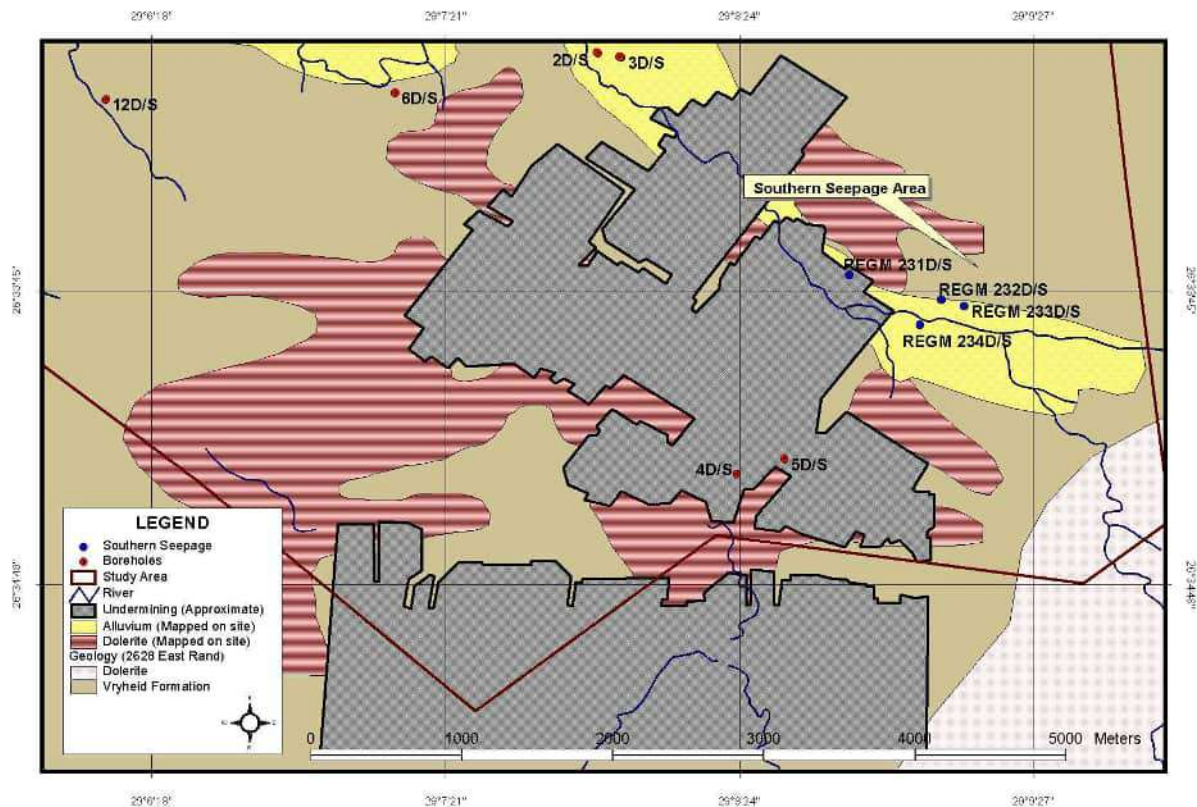


Figure 3.4: Approximate Extent of Undermining in the Study Area

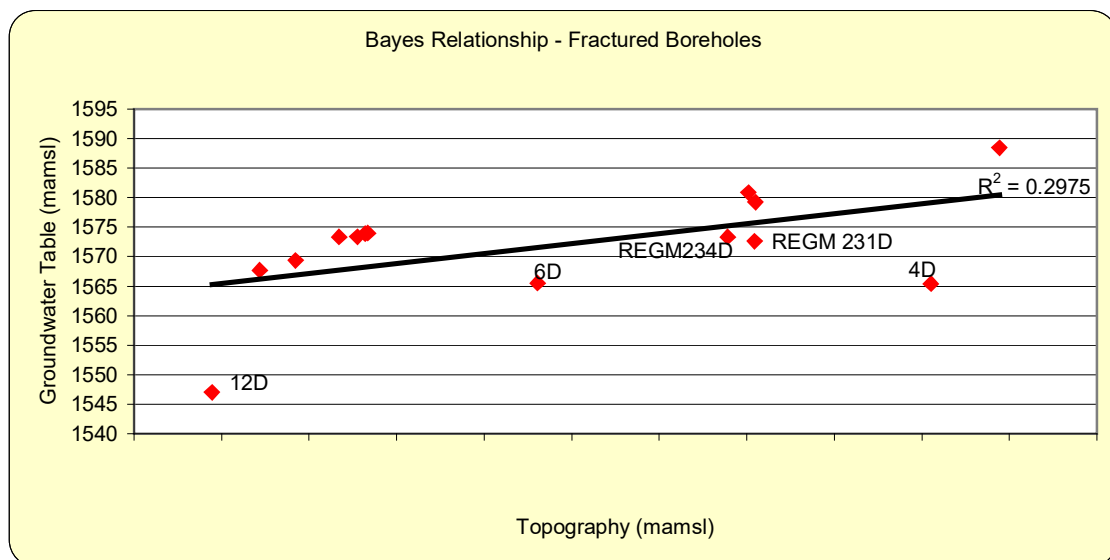


Figure 3.5: Correlation Between Topography and Groundwater Table – Fractured Aquifer (All Boreholes)

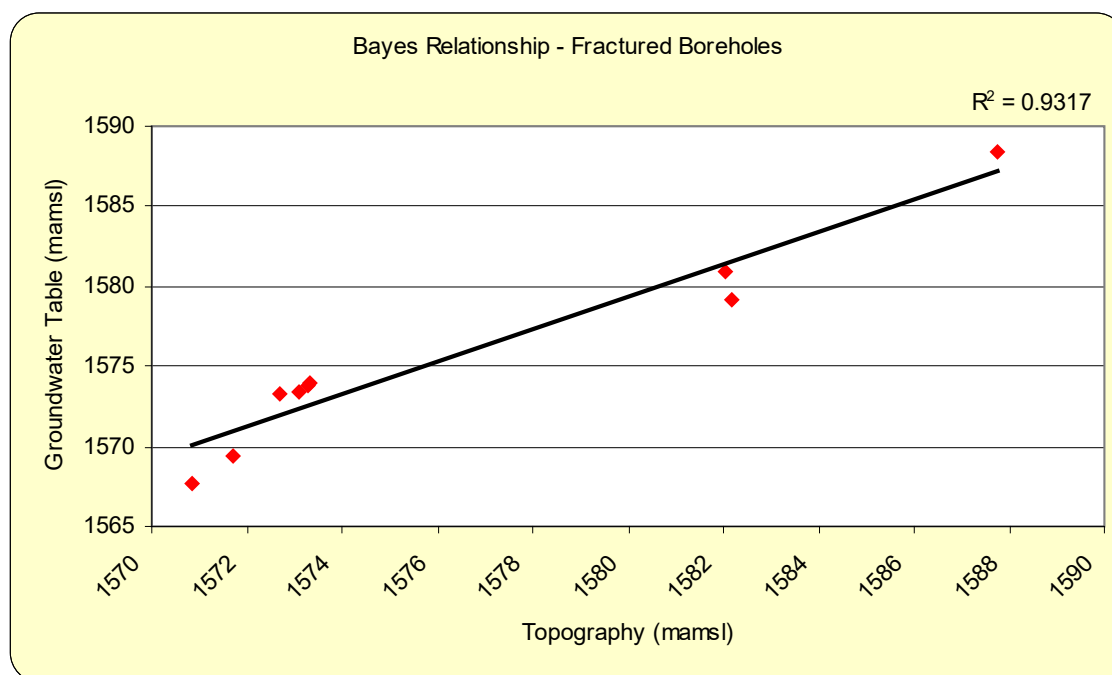


Figure 3.6: Correlation Between Topography and Groundwater Table – Fractured Aquifer (Excluding Dewatered Boreholes)

3.2.5 Groundwater Gradients and Flow Directions

The groundwater table governs water flow and the groundwater levels within the boreholes were measured as a first step to determine the groundwater flow directions. The groundwater levels in the newly drilled as well as some of the older boreholes were measured to interpolate the regional groundwater table.

The interpolated groundwater table is shown on Figure 3.7. Regionally the groundwater flow is towards the north-west, similar to that of the surface water. Local variations do, however, occur and are generally towards the surface streams. The groundwater gradient is relatively flat at 1.3%.

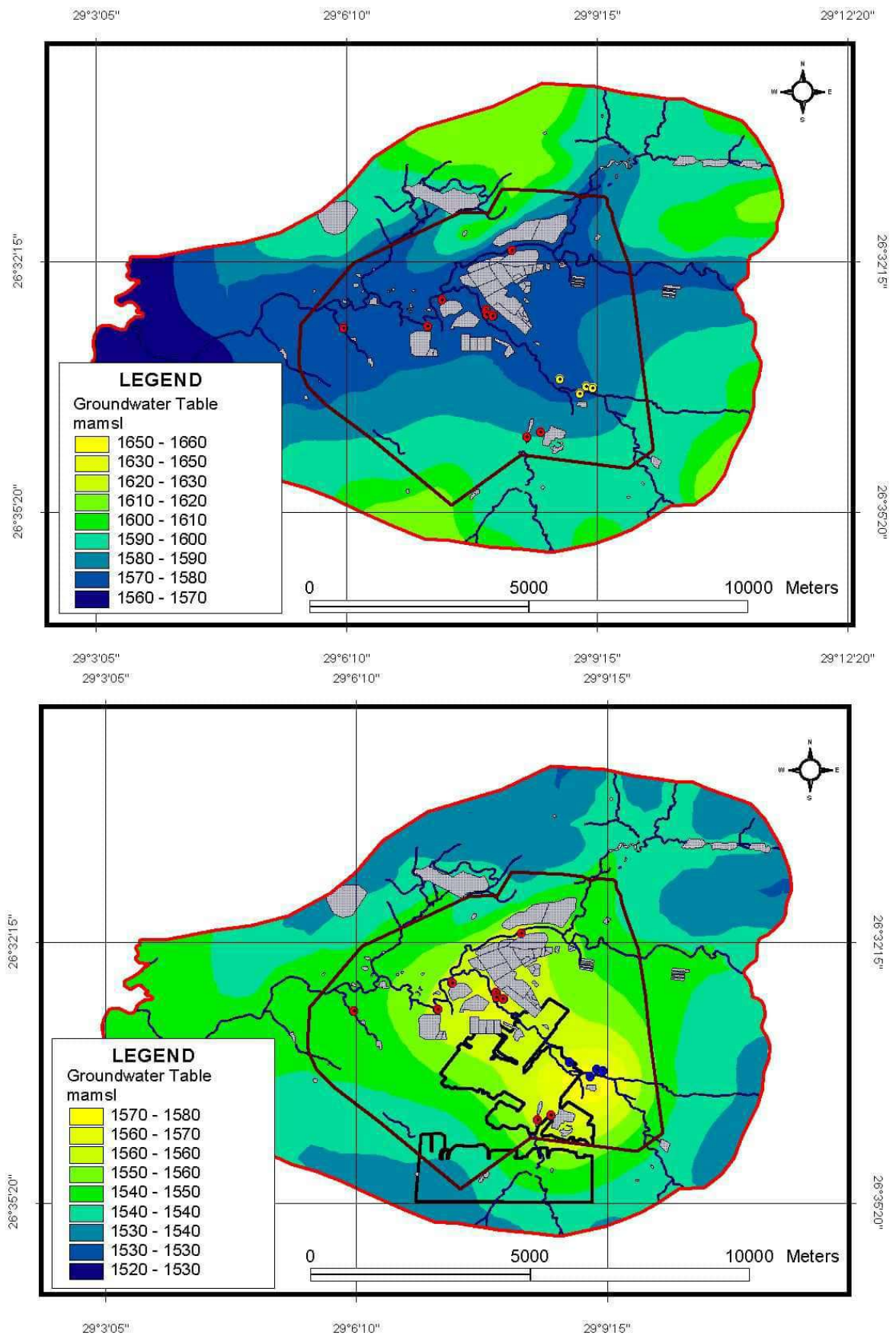


Figure 3.7: Regional Groundwater Gradients

3.2.6 Hydraulic Tests and Aquifer Parameters

Aquifer tests were performed on all the newly drilled boreholes within the study area, mainly to determine the hydraulic parameters of the aquifers. This data is essential for the flow and mass transport modelling.

3.2.6.1 Aquifer Transmissivity (T)

Aquifer transmissivity is defined as *“the rate of flow under a unit hydraulic gradient through a cross-section of unit width over the full saturated thickness of the aquifer”*. Transmissivity is the product of the average hydraulic conductivity and the saturated thickness of the aquifer. Transmissivity is expressed in metres squared per day (m^2/day).

Estimates of the transmissivity of the aquifer were obtained from the results of constant discharge as well as recovery tests conducted during the field exploration programme. Aquifer tests were analysed using different methods of evaluation suitable for the specific criteria of the tests. Table 2.1 provides the results obtained from the aquifer tests conducted on the tested boreholes. The detailed data interpretation for the southern seepage area is attached as Appendix 1.

3.2.6.2 Hydraulic Conductivity (K)

Hydraulic conductivity is defined as *“the volume of water that will move through a porous medium in unit time under a unit hydraulic gradient through a unit area measured at right angles to the direction of flow. It is normally expressed in metres per day (m/day)”*.

Estimates of the hydraulic conductivity of the aquifer can be obtained from the relationship $T = KD$ where D = aquifer thickness (m). Using aquifer thickness of about 8m (weathered aquifer) and 22m (fractured aquifer) the average hydraulic conductivity values are of 0.128m/day and 0.038m/day respectively. The calculated T and K values were used as the starting aquifer parameters in the groundwater model.

Table 3.1: Aquifer Transmissivity

Weathered Aquifer		
Borehole ID	Calculated Transmissivity (m²/day)	
	Constant Rate Test	Recovery Test
1S	0.68	0.23
2S	0.50	0.41
3S	2.19	1.37
5S	0.46	0.25
6S	0.76	-
7S	0.48	0.36
8S	5.61	0.96
12S	0.42	0.96
BH 231S	0.62	0.38
BH232S	0.42	0.13
BH233S	0.50	0.31
BH234S	0.54	0.15
Average	1.10	0.50
Fractured Aquifer		
Borehole ID	Calculated Transmissivity (m²/day)	
	Constant Rate Test	Recovery Test
1D	2.45	3.11
2D	0.56	0.42
3M	0.41	0.19
3D	0.80	0.67
4D	0.53	3.67
5D	0.25	0.028
6D	0.38	0.80
7D	0.25	0.24
8D	0.20	0.095
12D	0.57	0.86
BH 231D	0.18	0.22
BH232D	0.20	0.11
BH233D	0.20	0.35
BH234D	0.23	0.75
Average	0.52	0.82

3.2.6.3 Aquifer Storativity

The Storativity (S) (also referred to as Specific Yield) of a saturated confined aquifer is *“the volume of water released from storage per unit surface area of the aquifer per unit decline in the component of hydraulic head normal to that surface”*. Storativity is a dimensionless quantity.

The following definition also apply:

Storage Coefficient: *Specific storage (S_o) times aquifer thickness (B). The volume of water an aquifer release from or takes into storage per unit surface area of the aquifer per unit change in head.*

Groundwater is stored within the pores of the host rock, but igneous rocks such as the dolerite intrusions exhibit no primary porosity characteristics. Secondary porosity is present as a result of the weathering and fracturing processes the rocks underwent. The weathering also increased the primary porosity of the sedimentary rock overlying the dolerite.

4 Groundwater Flow Model

4.1 Conceptual Model of the Aquifer System

The first step in the procedure of modelling is the construction of a conceptual model of the problem and the relevant aquifer domain. The conceptual model consists of a set of assumptions that reduce the real problem and the real domain to simplified versions that are acceptable in view of the objectives of the modelling and of the associated management problem.

As described previously rocks of the Karoo Supergroup cover the area under investigation. The formations consist mainly of alluvium, weathered and fractured siltstone, sandstone and dolerite. Two distinct aquifers, a shallow weathered aquifer and a deeper fractured aquifer, were identified. These aquifers may in certain areas be hydraulically connected.

Due to the two aquifers the groundwater model consists of two layers. The first modelling layer represents the weathered zone of the aquifer. The second modelling layer represents the fractured horizon of the aquifer. The average thickness as obtained from borehole logs for these zones were assigned in the model. On average a thickness of 8 m and 22 m were assigned to layers 1 and 2 respectively for a total aquifer thickness of 30m.

4.2 Model Domain and Boundary Conditions

The study area is located within the catchment of the Grootspuit and the Trichardspruit, Klipspruit and Bossiespruit catchments were included in the modelling domain (Figure 4.1).

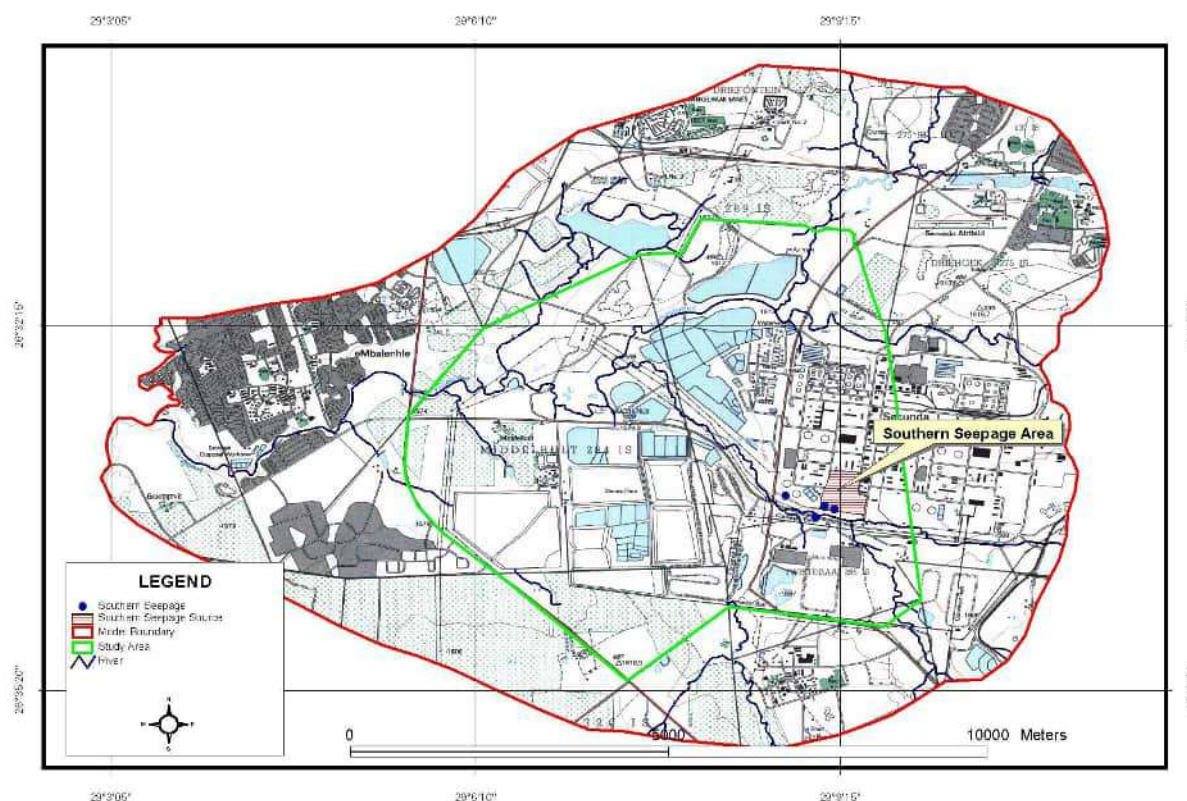


Figure 4.1: Model Domain

Boundary conditions express the way the considered domain interacts with its environment. In other words, they express the conditions of known water flux, or known variables, such as piezometric head. Different boundary conditions result in different solutions hence the importance of stating the correct boundary conditions. Boundary conditions in a groundwater flow model can be specified either as:

- Dirichlet Type (or constant head) boundary conditions.
- Neuman Type (or specified flux) boundary conditions.
- A mixture of the above.

A significant correlation between groundwater level elevations and topography was obtained (see Figures 3.3 and 3.6). It can therefore be postulated that the position of

groundwater inflow and outflow from the area will correspond to the position of surface inflow and outflow from the area, with the exception of some seepage into the underlying mined out areas. Constant head boundary conditions were therefore specified along all surface streams to simulate outflow (Figure 4.2). No-flow boundary conditions, an end member of the Neuman Type, were specified elsewhere.

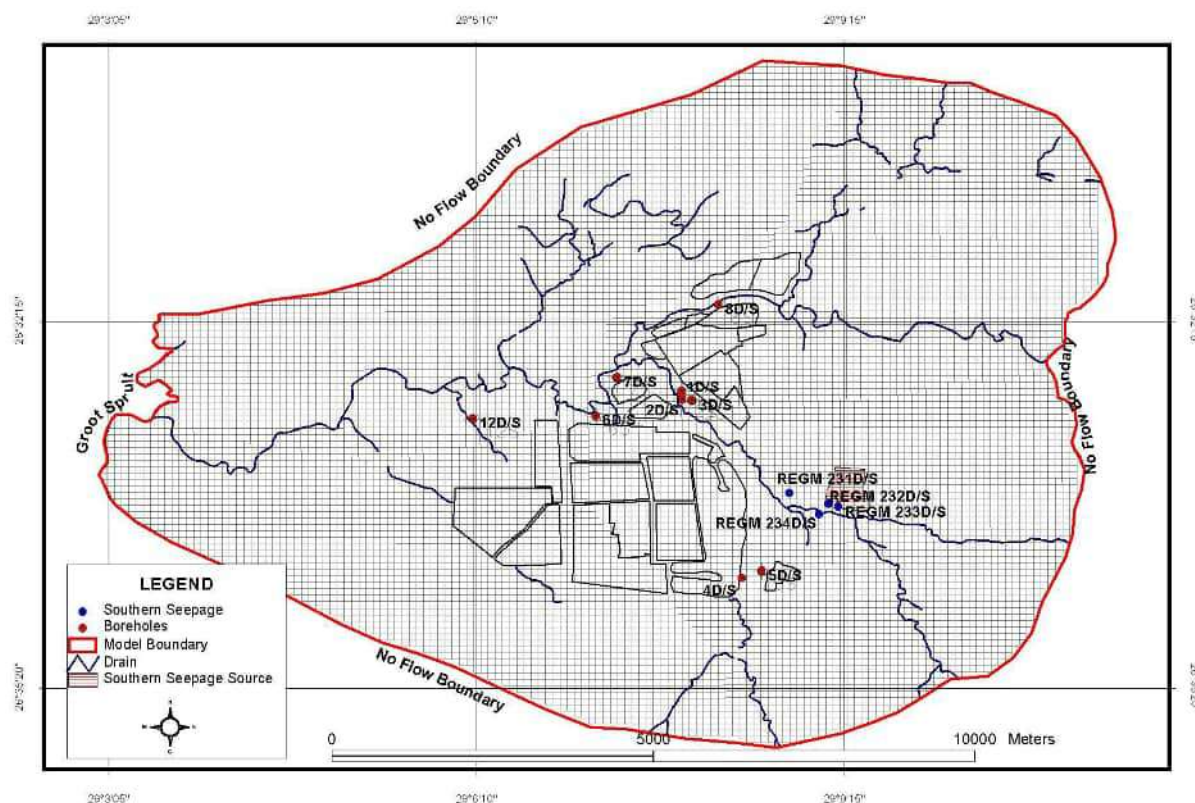


Figure 4.2: Model Boundary Conditions

4.3 Numerical Groundwater Flow Model

A steady state groundwater flow model for the study area was constructed to simulate undisturbed groundwater flow conditions. These conditions serve as starting heads for the transient simulations of groundwater flow where the effect of seepage from the contaminant sources were taken into consideration.

A dynamic flow model using the modelling package MODFLOW was constructed for the study area.

The groundwater model used in this modelling study is based on three-dimensional groundwater flow and may be described by the following equation:

$$\frac{\partial}{\partial x} (K_x \frac{\partial h}{\partial x}) + \frac{\partial}{\partial y} (K_y \frac{\partial h}{\partial y}) + \frac{\partial}{\partial z} (K_z \frac{\partial h}{\partial z}) \pm W = S \frac{\partial h}{\partial t} \quad (1)$$

where

h	=	hydraulic head [L]
K _x , K _y , K _z	=	Hydraulic Conductivity [L/T]
S	=	storage coefficient
t	=	time [T]
W	=	source (recharge) or sink (pumping) per unit area [L/T]
x, y, z	=	spatial co-ordinates [L]

4.4 Initial Aquifer Parameters

4.4.1 Initial Head Conditions

The initial head conditions specified in the model were interpolated from the measured groundwater levels (see Figure 3.7) and extrapolated to the nodes in the model (both layers).

4.4.2 Storage Coefficient

A storage coefficient of 0.0001 was estimated for both the weathered and fractured aquifers.

4.4.3 Hydraulic Conductivity and Transmissivity

Estimates of the hydraulic conductivity (K) and transmissivity (T) of the aquifers were obtained from the results of constant rate discharge tests and water level recovery tests (Table 3.1). The average calculated transmissivity values are 1.02m²/day and 0.83m²/day for the weathered and fractured aquifers respectively.

Based on an average weathered aquifer (Layer 1) thickness of 8m the following calibrated transmissivity (T) and hydraulic conductivity (K) values were applied to the model.

- T value range: 0.36m²/day – 3.29m²/day.
- K value range: 0.045m/day – 0.66m/day.

Based on an average fractured aquifer (Layer 2) thickness of 22m the following calibrated transmissivity (T) and hydraulic conductivity (K) values were applied to the model.

- T value range: 0.14m²/day – 2.78m²/day.
- K value range: 0.006m/day – 0.116m/day.

Three major permeability zones, represented by the hydraulic conductivity (Figure 4.3) and which are justifiable from the field data, were incorporated into the model to achieve the required calibration. The three zones correspond to the underlying geology, but a more permeable zone was included in the fractured aquifer at the edge of the mined-out area.

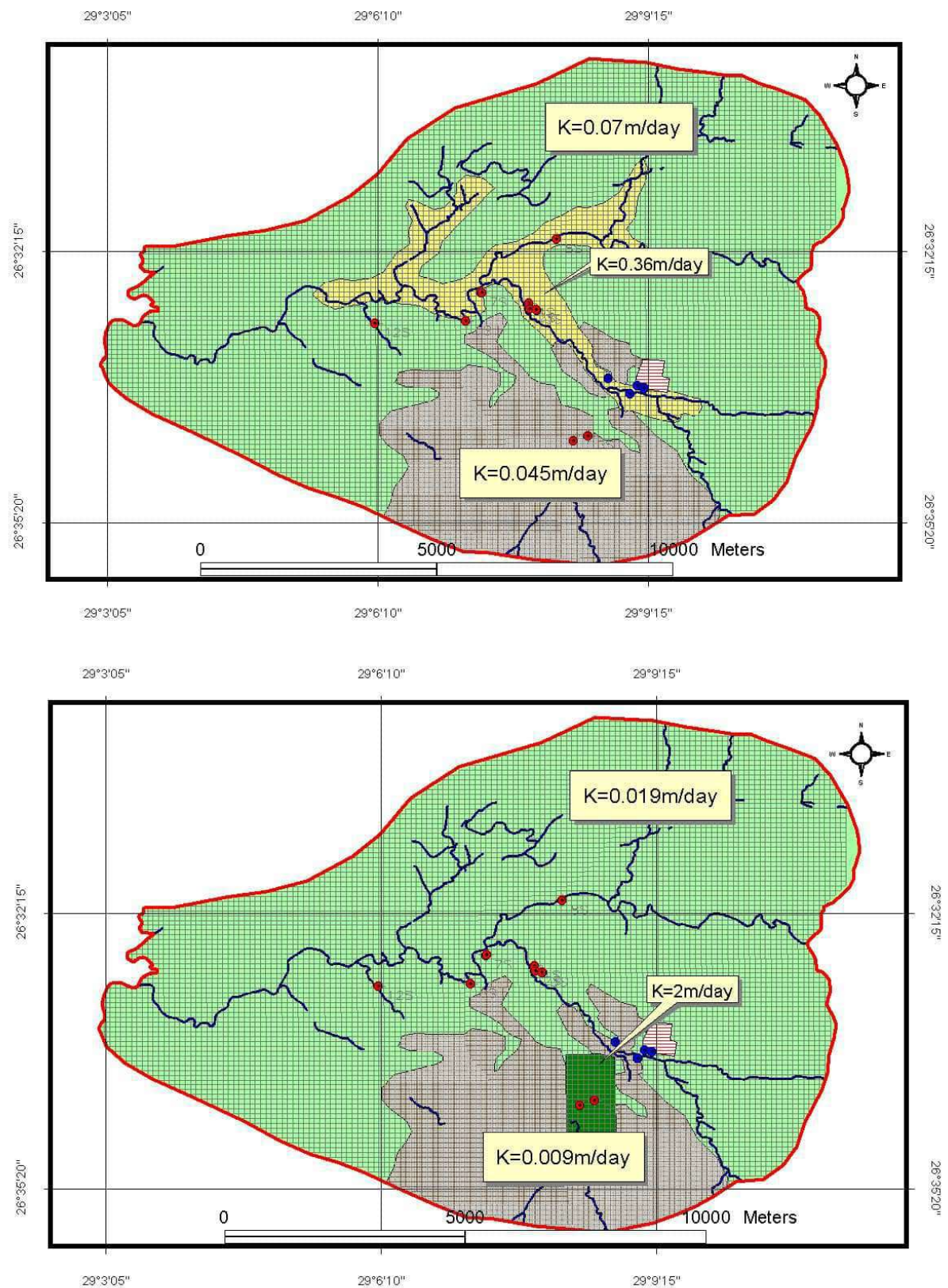


Figure 4.3: Calibrated Hydraulic Conductivity Values

4.4.4 Recharge

Groundwater recharge may be defined as the downward percolation of water or soil moisture, which eventually reaches the groundwater table, thereby forming an additional source to an already existing groundwater reservoir. Recharge from rainfall is a highly complex process in which numerous factors and their interaction play a role.

The more important aspects affecting recharge from rainfall according to Vegter (1995) are:

- The amount, type, intensity, duration and temporal distribution of rainfall.
- Climate: potential evaporation.
- Surface slope and type of vegetation cover: storm runoff, interception and transpiration losses.
- Infiltration capacity of the materials at the surface be it rock or soil and subsoil; the presence of so-called macropores and fractured rock is of major importance; capillary movement.
- The moisture retention capacity of the aeration or unsaturated zone and temporal fluctuations of moisture.

The annual average rainfall is 710mm. The regional groundwater recharge is estimated at 3% of the MAP, but due to the presence of a shallow dolerite sill in certain areas a recharge rate of 2% of the MAP is estimated for areas underlain by dolerite. The alluvium was assigned a slightly higher recharge rate of 5%. The same zones illustrated in Figure 4.3 also applies to the recharge zones, but is only applicable to Layer 1. Recharge to Layer 2 occurs as a result of the vertical permeability, which for this model were estimated at 0.001 m/day.

Some dewatering and increased flow appears to be evident in the vicinity of boreholes 4D, 6D, 12D, REGM231D and REGM234D. This is attributed to undermining, although the exact extent of the undermining is not clear.

Groundwater fluxes from the investigated water impoundments within the study area were calculated, based on the dimensions of these dams and the calculated aquifer

parameters. A summary of the seepage rates to the aquifer system is presented in Table 4.1.

Table 4.1: Calculated Seepage to Aquifer System

Site	Area	Seepage rate
	(m ²)	(m ³ /day)
Ash Effluent Dams 6A & 6B	238 613	139
Salty Water Dam No 6	69 117	40
Van Niekerk Dam	128 232	75
Ash Effluent Dams E1 & E2	542 520	316
Ash Dams	2 248 671	250
Southern Seepage Area	335 102	37

Note: The Ash Dams and Southern Seepage areas are dry facilities and the seepage rate was based on a 5% recharge rate.

4.5 Groundwater Flow Model Calibration

The groundwater flow calibration is measured by the difference between the observed and simulated groundwater levels. Successful calibration is therefore achieved when there is reasonable correlation between:

- The simulated and observed groundwater elevations.
- The interpolated and simulated groundwater gradients.

Table 4.2 and 4.3 shows the difference between the measured and observed groundwater levels for the weathered and fractured aquifers respectively as well as the correlation between the observed and measured groundwater levels for the weathered and fractured aquifers.

A reasonable correlation of 99% was achieved for both the weathered and fractured aquifers. The calibration of the model was accomplished by altering the recharge from rainfall and hydraulic conductivity until a reasonable resemblance between the measured piezometric levels and the simulated piezometric levels were obtained. The calibrated groundwater level contours are presented in Figure 4.4.

Table 4.2: Observed vs Simulated Groundwater Levels – Weathered Aquifer

Borehole	Observed Groundwater Level (m amsl)	Simulated Groundwater Level (m amsl)	Difference (m)
1S	1570.65	1570.88	-0.23
2S	1570.99	1571.49	-0.50
3S	1572.34	1571.98	0.36
5S	1586.32	1585.90	0.42
6S	1574.86	1575.22	-0.36
7S	1570.08	1571.23	-1.15
8S	1569.30	1569.55	-0.25
12S	1567.81	1567.12	0.69
REGM 231S	1577.8	1577.21	0.59
REGM 232S	1579.42	1579.30	0.12
REGM 233S	1579.35	1579.67	-0.32
REGM 234S	1577.86	1577.44	0.42

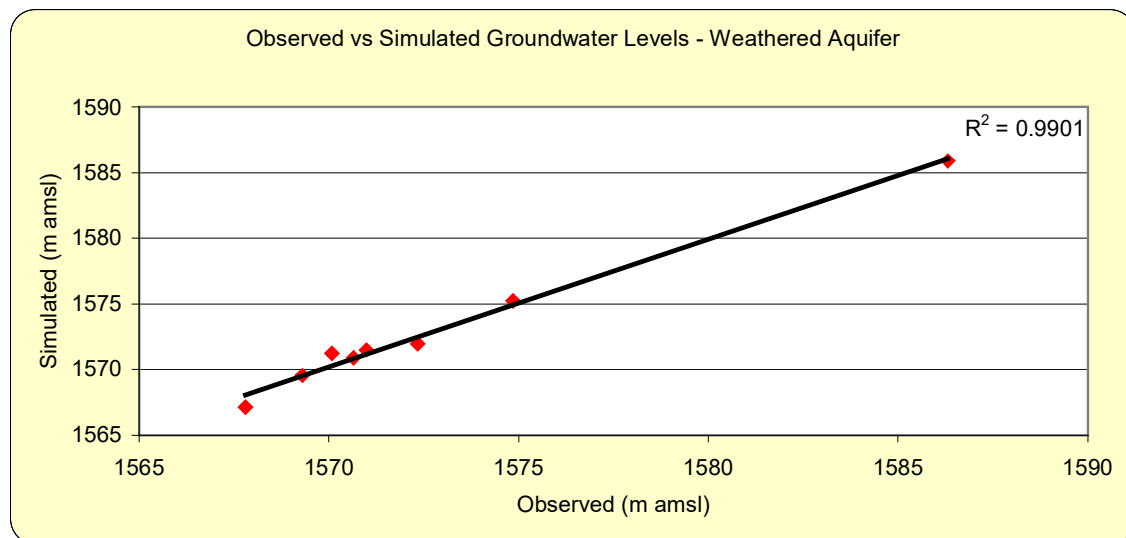
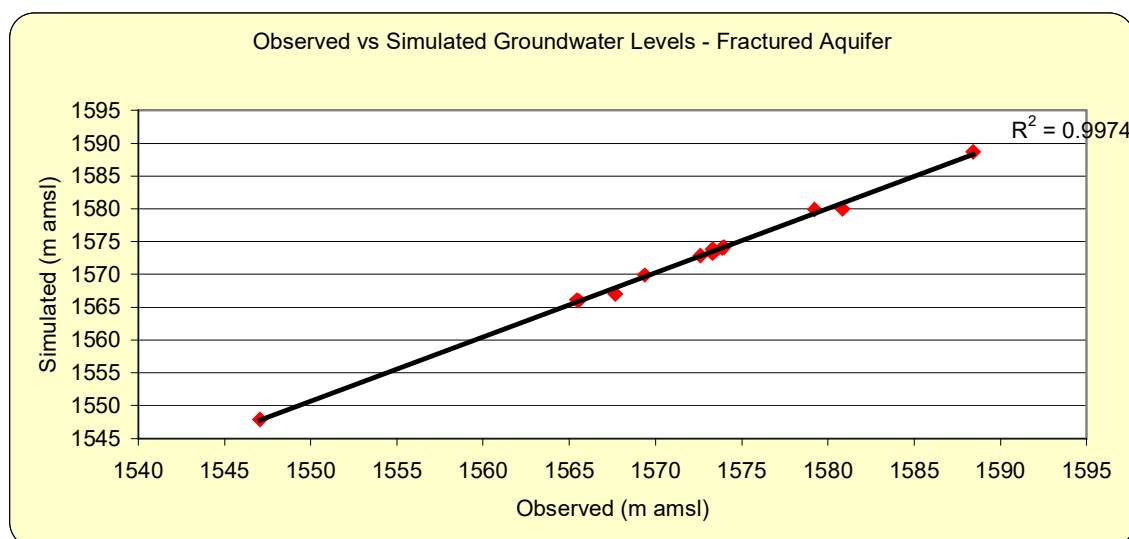


Table 4.3: Observed vs Simulated Groundwater Levels – Fractured Aquifer

Borehole	Observed Groundwater Level (m amsl)	Simulated Groundwater Level (m amsl)	Difference (m)
1D	1573.32	1573.20	0.12
2D	1573.38	1573.68	-0.30
3D	1573.96	1574.12	-0.16
3M	1573.86	1574.05	-0.19
4D	1565.42	1566.10	-0.68
5D	1588.42	1588.67	-0.25
6D	1565.55	1566.02	-0.47
7D	1567.68	1567.00	0.68
8D	1569.38	1569.90	-0.52
12D	1547.06	1547.88	-0.82
REGM 231D	1572.61	1572.90	-0.29
REGM 232D	1579.22	1579.89	-0.67
REGM 233D	1580.85	1579.95	0.90
REGM 234D	1573.3	1573.90	-0.60



4.6 Groundwater Flow Patterns

The groundwater flow patterns, based on the calibrated groundwater flow model are presented as Figure 4.5. Contaminant transport simulations utilise the groundwater flow velocities and direction as key model inputs.

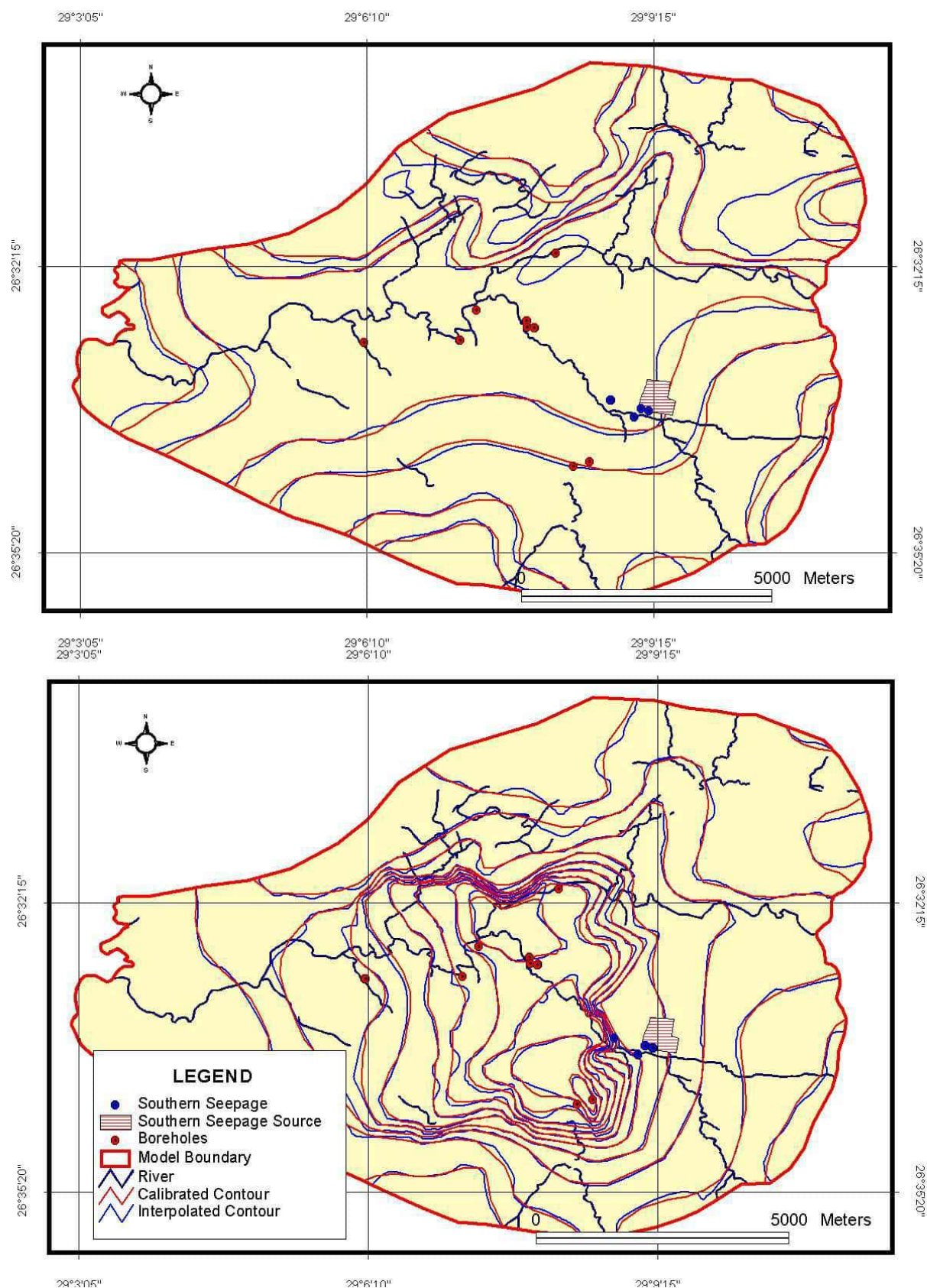
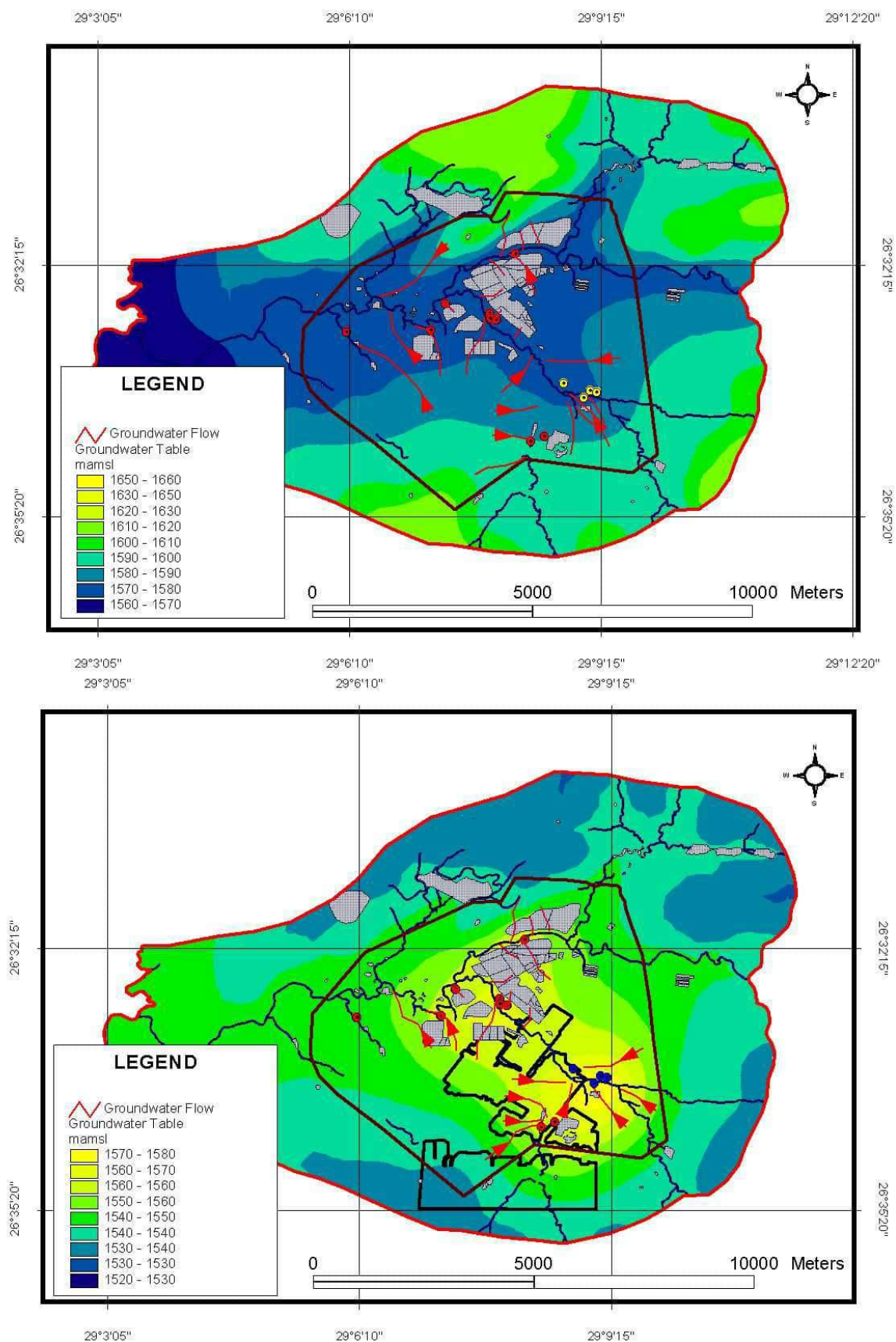


Figure 4.4: Calibrated Groundwater Contours

**Figure 4.5: Groundwater Flow Patterns**

5 CONTAMINANT TRANSPORT MODEL

5.1 Introduction

The evaluation and cleanup of contaminated land is one of the highest priority environmental issues in the western world. Because concerns with groundwater contamination figure prominently in these cleanup operations, a dramatic increase in transport modelling activities has occurred in the last decade. The frequent discoveries of groundwater contamination highlight the need to understand the transport behaviour of contaminants. A groundwater contamination plume generally contains numerous contaminants. Each contaminant within the plume may migrate differently, and some will react with each other. In transport predictions one normally concentrates on the contaminant that is considered the most significant for the investigated transport problem. In this study the potential migration of chloride (Cl) was investigated.

The processes controlling contaminant migration in groundwater is briefly discussed in the following section.

5.2 Processes Controlling Contaminant Transport

Transport through a porous medium is mainly controlled by the following two processes:

- Advection.
- Hydrodynamic dispersion.

For clarity these processes will be discussed briefly.

5.2.1 Advection

Advection is the component of contaminant movement described by Darcy's Law. If uniform flow at a velocity (V) takes place in the aquifer, Darcy's law calculates the distance (x) over which a labelled water particle migrates over a time period t as $x = Vt$.

5.2.2 Hydrodynamic Dispersion

Hydrodynamic dispersion comprises two processes:

- Mechanical dispersion and
- Molecular diffusion.

Mechanical dispersion is the process whereby the initially close group of labelled particles is spread in a longitudinal as well as in a transverse direction. This is caused by the velocity distribution (as a result of varying microscopic streamlines) that develops at the microscopic level of flow around the grain particles of the porous medium. Although this spreading is both in the longitudinal and transversal direction of flow, it is primarily in the former direction. Very little spreading can be caused in the transversal direction by velocity variations alone.

Molecular diffusion mainly causes transversal spreading, by the random movement of the molecules in the fluid from higher contaminant concentrations to lower ones. It is thus clear that if $V = 0$, the contaminant is transported by molecular diffusion only or in other words the higher the velocity of the groundwater the less the relative effect of molecular diffusion on the transportation of a labelled particle.

In addition to advection, mechanical dispersion and molecular diffusion, several other phenomena may affect the concentration distribution of a contaminant as it moves through a porous medium. The contaminant may interact with the solid surface of the porous matrix in the form of adsorption of contaminant particles on the solid surface, deposition, solution of the solid matrix and ion exchange. All these phenomena cause changes in the concentration of a contaminant in a flowing fluid.

5.3 Mass Balance Equation

The mass balance equation (Bear and Verruijt, 1992) (equation of *hydrodynamic dispersion* or the *advection-dispersion* equation) of a pollutant (contaminant) is expressed as:

$$\frac{\partial n c}{\partial t} = - \Delta \cdot \mathbf{q} c_{c, \text{total}} - f + n p l' - P c + R c \quad (3)$$

where:

n_c	= mass of pollutant per unit volume of porous medium;
n	= porosity of saturated zone;
c	= concentration of pollutant (mass of pollutant per unit volume of liquid (water));
$\Delta \bullet q_{c, \text{ total}}$	= excess of inflow of a considered pollutant over outflow, per unit volume of porous medium, per unit time;
f	= quantity of pollutant leaving the water (through adsorption, ion exchange etc.);
$n p \Gamma$	= mass of pollutant added to the water (or leaving it) as a result of chemical interactions among species inside the water, or by various decay phenomena;
Γ	= rate at which the mass of a pollutant is added to the water per unit mass of fluid;
p	= density of pollutant;
P_c	= total quantity of pollutant withdrawn (pumped) per unit volume of porous medium per unit time;
R_c	= total quantity of pollutant added (artificial recharge) per unit volume of porous medium per unit time.

Elevated chloride levels are used in this investigation as an indicator of contamination in order to simplify the groundwater flow modelling exercise. Chloride is considered to be a conservative tracer and migrates at the same rate as groundwater. In the case of this investigation it is therefore assumed that no decay or retardation of chloride is taking place in the aquifer. Contaminant migration is therefore attributable only to advection and hydrodynamic dispersion. This will provide a worst-case scenario in terms of travel distance of contaminants.

5.4 Numerical Mass Transport Model

MT3D is a groundwater modelling code, which was designed to interface with MODFLOW. This package was used to undertake the contaminant transport modelling. Input required in the software is:

- Input concentrations of contaminants.
- Longitudinal dispersivities.

- Transversal dispersivities.

5.4.1 Longitudinal and Transversal Dispersivities

A longitudinal dispersivity value of 25m was calibrated for the simulations. Bear and Verruijt (1992) estimated the average transversal dispersivity to be 10 to 20 times smaller than the longitudinal dispersivity. An average value of 2.5 m was selected for this parameter during the simulations.

5.4.2 Input Sources

During the previous investigation five contaminant sources were investigated. These were:

- Ash effluent dams 6A and 6B.
- Salty water dams.
- Van Niekerk Dam.
- Ash effluent dams E1 and E2.
- Fine and Coarse ash dams.

The current investigation, however, only focuses on the seepage area in the vicinity of the SCS W PC Dam. The localities of all the sources in relation to each other are shown as Figure 5.1. The potential sources were included during the calibration process of the mass transport model in order to simulate the observed chloride concentrations in the boreholes.

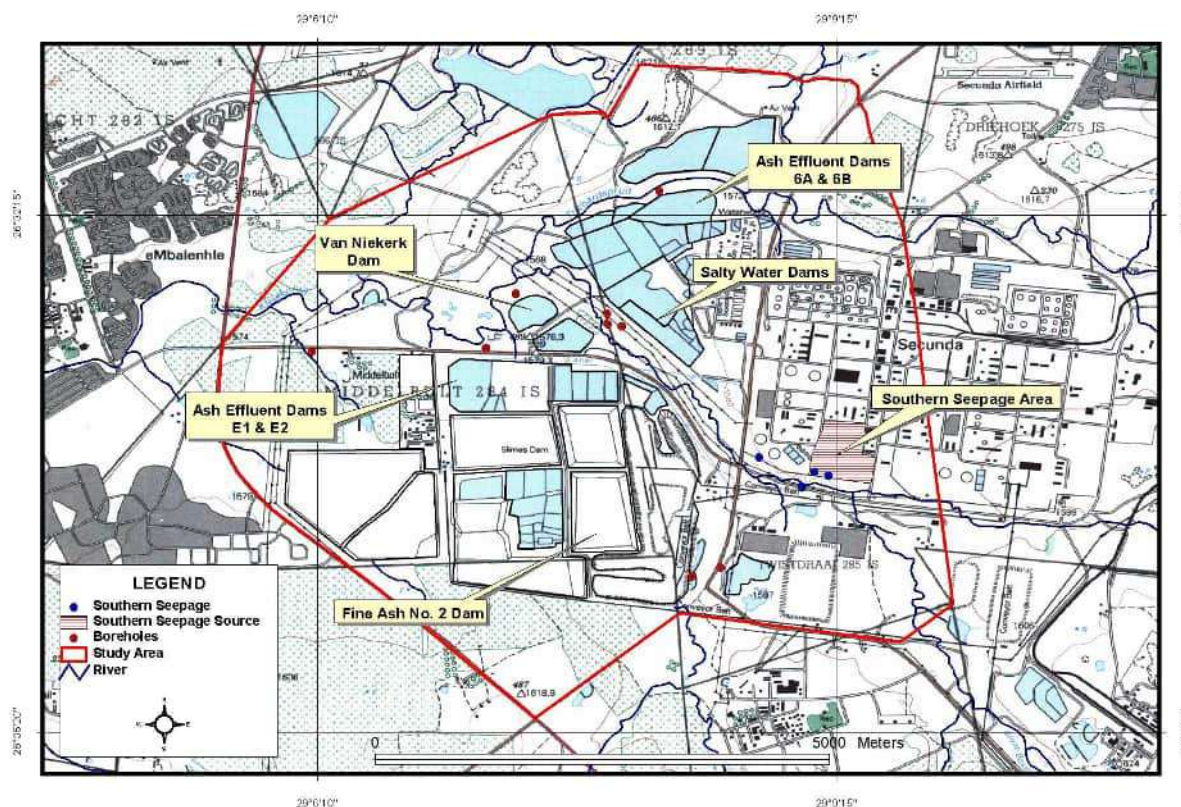


Figure 5.1: Contaminant Sources Included in the Mass Transport Model

5.5 Mass Transport Model Calibration

The calibration for chloride achieved a 99% correlation in the weathered aquifer and a 96% correlation in the fractured aquifer. The source concentration in the SCS WPC Dam was based on sampling conducted by Jones & Wagener. Boreholes REGM231S and REGM231D were excluded from the calibration. The contamination in these boreholes are not believed to be derived from the southern seepage zone.

The comparison and correlation between the observed and simulated chloride concentrations are presented as Tables 5.1 and 5.2 for the weathered and fractured aquifers respectively.

Table 5.1: Observed vs Simulated Chloride Concentrations – Weathered Aquifer

Borehole	Observed Cl Concentration (mg/l)	Simulated Cl Concentration (mg/l)	Difference (mg/l)
1S	1262	1065	-197
2S	300	346	46
3S	12035	12108	73
5S	147	176	29
6S	411	393	-18
7S	1761	1753	-8
8S	283	673	390
AH01	1675	1788	113
AH02	1991	2030	39
AH03	2069	1961	-108
AH04	2424	2159	-265
AH05	2010	2269	259
AH06	1912	1831	-81
AH07	1616	1433	-183
AH08	453	362	-91
AH09	296	396	100
AH10	384	451	67
AH11	966	658	-308
AH12	1540	1755	215
AH13	5440	5000	-440
AH14	3523	3324	-199
AH15	641	624	-17
AH16	641	671	30
AH17	653	667	14
AH18	641	617	-24
AH19	345	658	313
AH20	601	678	77
AH21	552	685	133
AH22	877	984	107
AH23	946	983	37
AH24	986	955	-31
REGM139s	646	650	4
REGM232s	68	80	12
REGM233s	222	201	-21

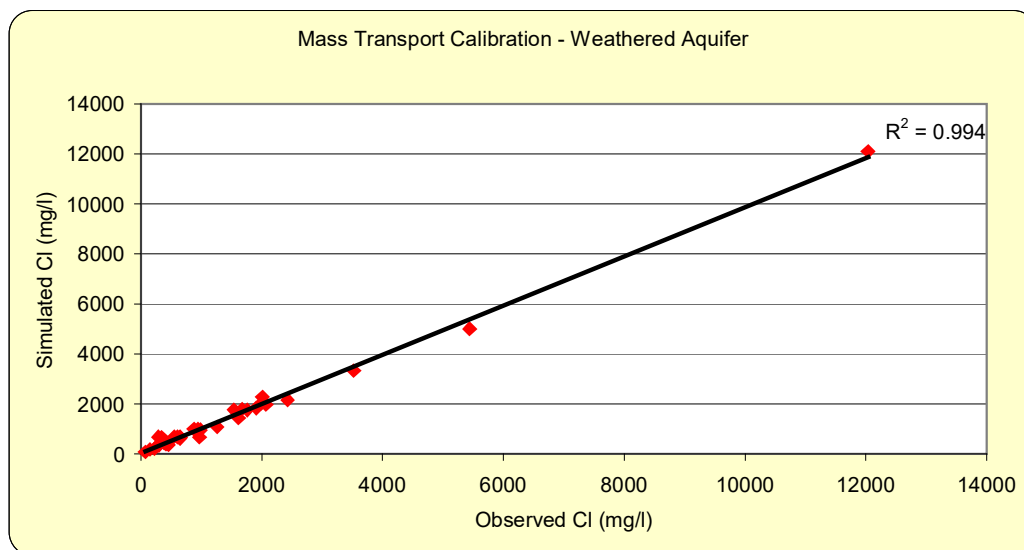
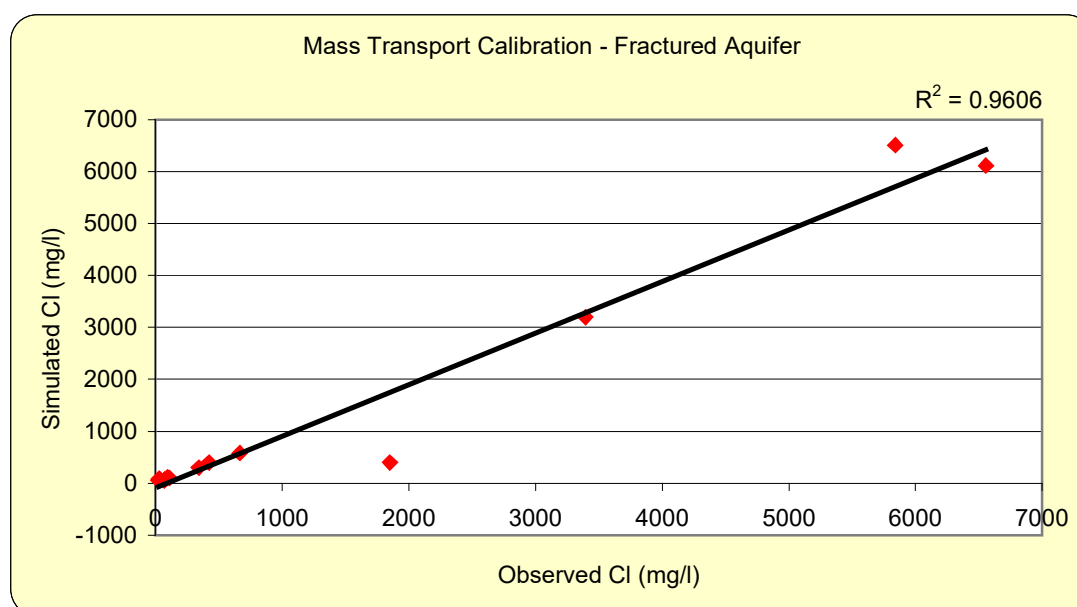


Table 5.2: Observed vs Simulated Chloride Concentrations – Fractured Aquifer

Borehole	Observed Cl Concentration (mg/l)	Simulated Cl Concentration (mg/l)	Difference (mg/l)
1D	3395	3198	-197
2D	6555	6112	-443
3D	5841	6509	668
4D	665	578	-87
5D	28	78	50
6D	76	79	3
7D	421	398	-23
8D	94	118	24
REGM139d	342	301	-41
REGM123	70	53	-17
REGM126	1849	398	-1451
REGM136	23	56	33
REGM232d	31	88	57
REGM233d	112	98	-14



5.6 Groundwater Contaminant Plumes and Impact to the Environment

The current chloride plume from the southern seepage area is compared to the simulated 50-year plume, which is presented as Figures 5.2 and 5.3 for the weathered and fractured aquifers respectively. These simulations assumed a do – nothing scenario.

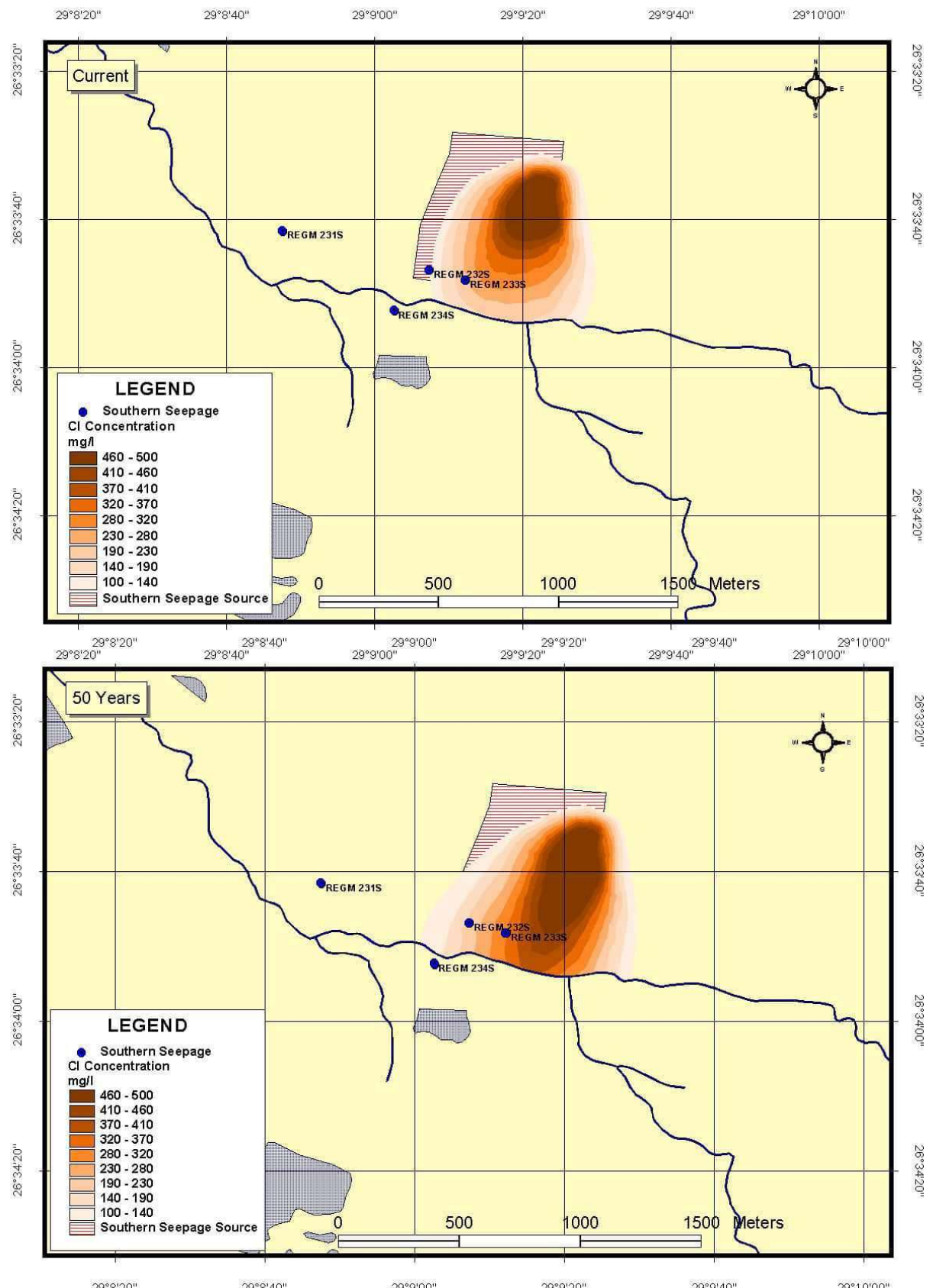


Figure 5.2: Calibrated and Simulated Chloride Plumes – Weathered Aquifer

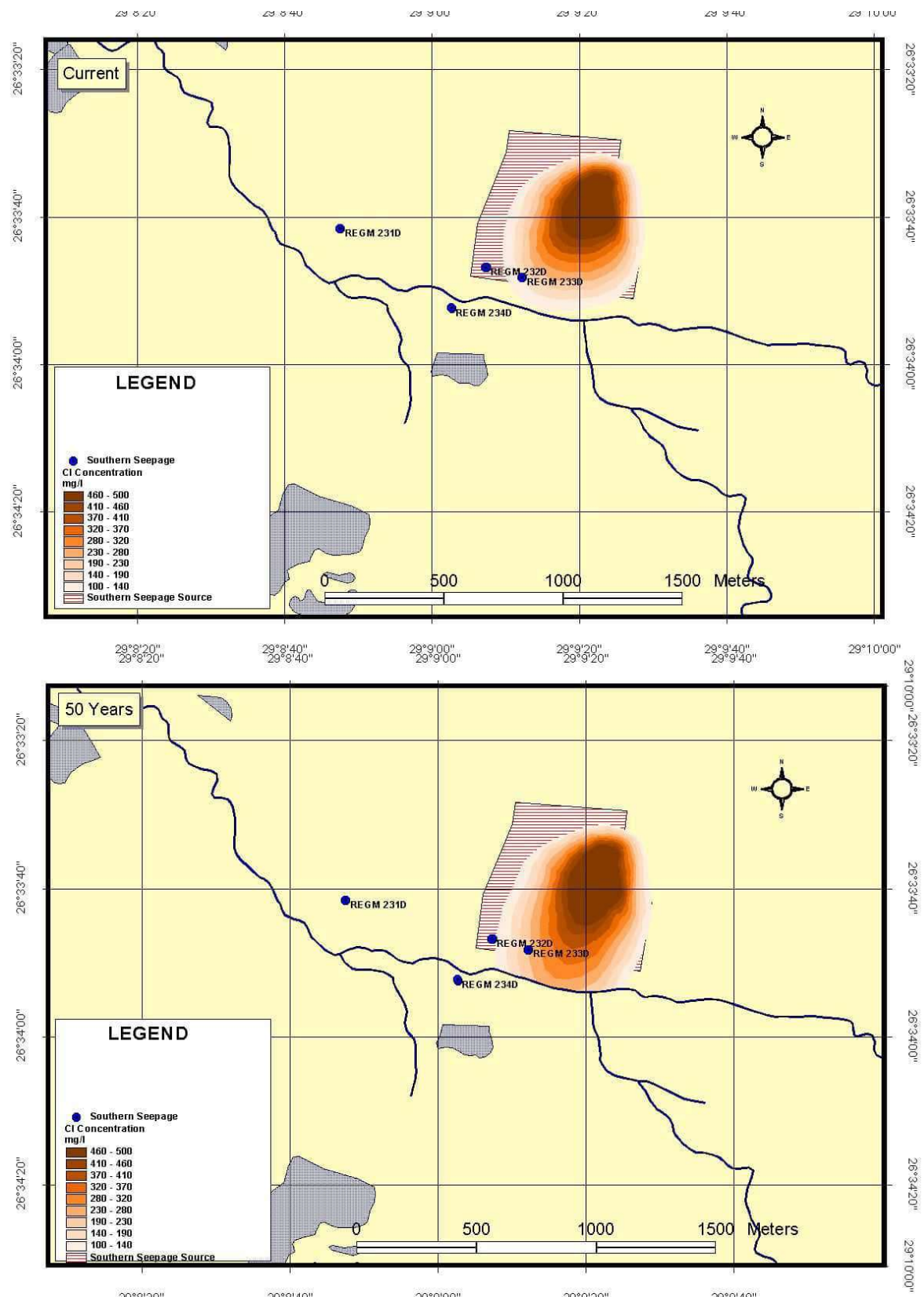


Figure 5.3: Calibrated and Simulated Chloride Plumes – Fractured Aquifer

Impact to the environment is in the form of seepage to the surface streams. The chloride mass loads from the various sources to the nearby streams are presented in Table 5.3.

Table 5.3: Chloride Mass Loads to Surface Streams

Source	Affected Stream	Chloride Load per day to Aquifer	Chloride Load Released into Aquifer System over 50 Year Period	Chloride Load Reporting to Stream over 50 Year Period	Chloride Load Remaining in Aquifer System after 50 Year Period
		(kg/d)	(tonnes)	(tonnes)	(tonnes)
Ash Effluent Dams 6A and 6B	Trichardspruit	149.76	2 695.68	2 393.76	301.92
Salty Water Dams	Bossiespruit	10 183.68	183 306.24	126 010.21	57 296.03
Van Niekerk Dam	Kleinspruit	3 839.04	69 102.72	61 473.78	7 628.94
Ash Effluent Dams E1 & E2	Kleinspruit	276.48	4 976.64	3 318.80	1 657.84
Ash Dams	Brandspruit	564.02	10 152.36	7 480.25	2 672.11
Southern Seepage Area	Bossiespruit	68.36	1 230.48	498.45	732.03

The chloride mass load from the southern seepage area to the Bossiespruit is graphically shown as Figure 5.4.

The total salt load reporting to the surface streams from the sources investigated is summarised in Table 5.4.

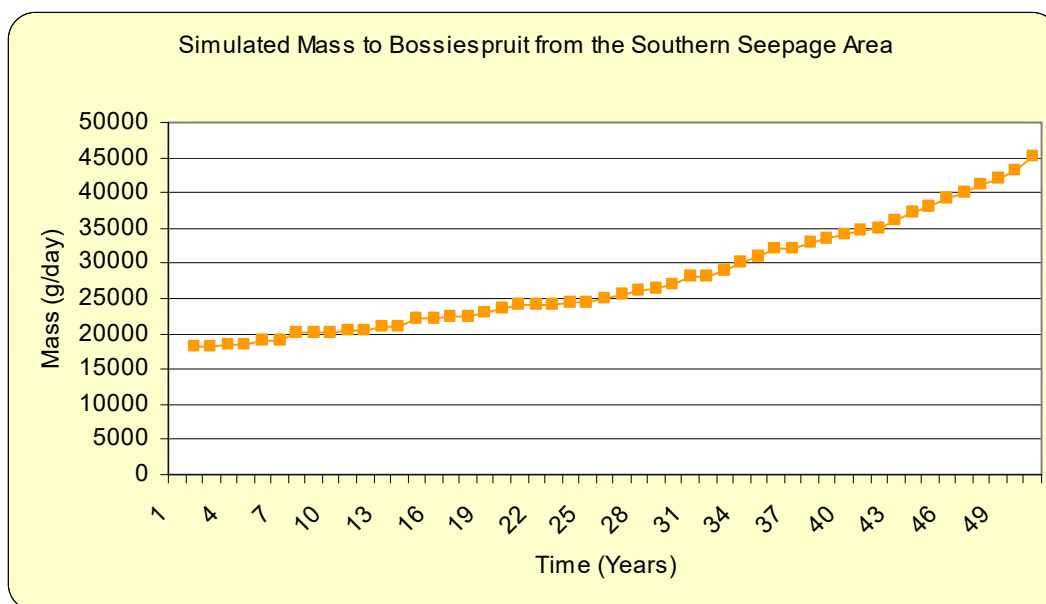


Figure 5.4: Chloride Load to Bossiespruit

Table 5.4: Calculated Total Salt Load to Streams

Source	Affected Stream	Salt Load Currently Reporting to Stream	Maximum Salt Load to Report to Stream when Steady State is Reached
		(tons/day)	(tons/day)
Ash Effluent Dams 6A and 6B	Trichardspruit	3.56	8.01
Salty Water Dams	Bossiespruit	0.42	33.95
Van Niekerk Dam	Kleinspruit	3.07	19.2
Ash Effluent Dams E1 & E2	Kleinspruit	7.39	14.79
Ash Dams	Brandspruit	2.55	4.34
Southern Seepage Area	Bossiespruit	0.55	1.36
Total Salt Load to Streams		17.54	81.64

5.7 Recommended Remedial Action

The most severe environmental impact occurs as a result of seepage to the surface stream. Due to the relative shallow nature of this weathered aquifer the recommended remedial option will be cut-off trenches at positions indicated on Figure 5.5 to intercept the seepage. The calculated volumes of seepage that will be reporting to the various trenches is summarised in Table 5.5.

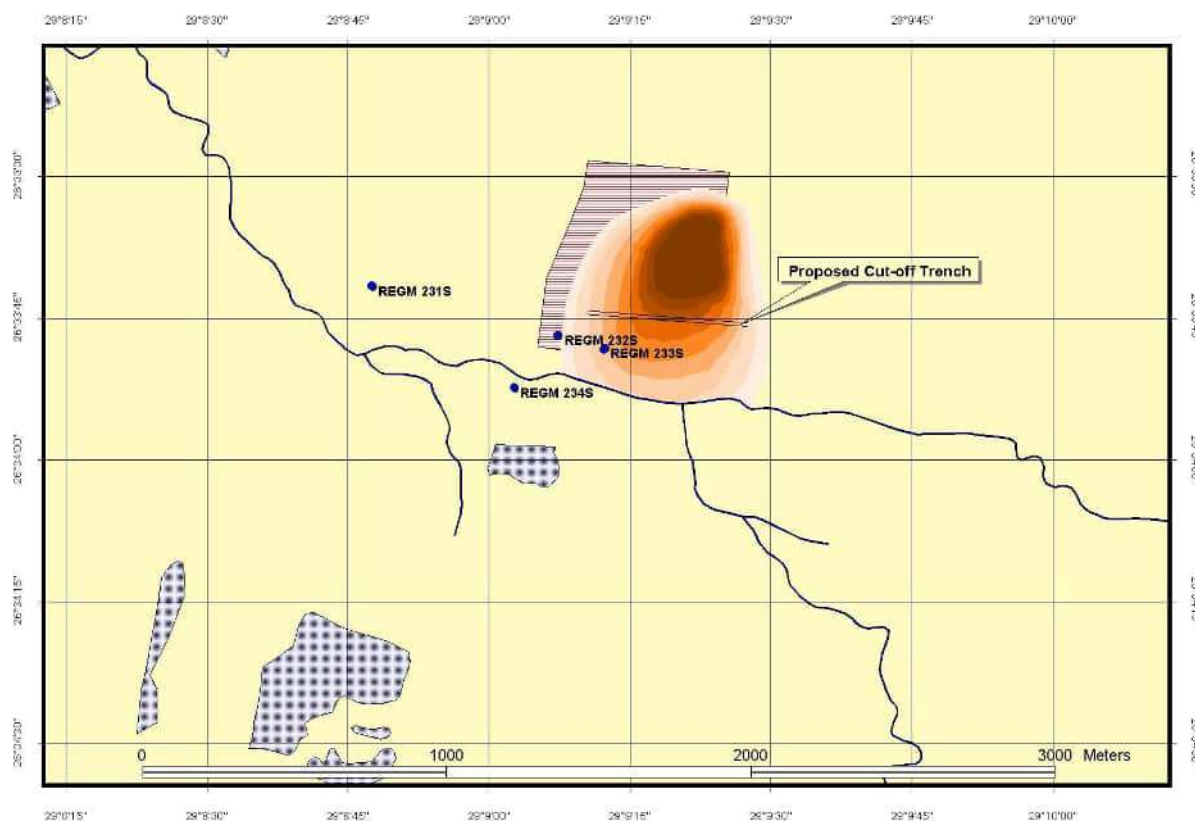


Figure 5.5: Recommended Locality of Cut-off Trench

Table 5.5: Calculated Seepage Rates to Cut-off Trenches

Site	Length (m)	Depth (m)	Seepage Rate (m³/day)
Ash Effluent Dams 6A and 6B	750	8	108.00
Salty Water Dams	200	8	34.56
Van Niekerk Dam	500	8	288.00
Ash Effluent Dams E1 & E2	320	8	92.16
Fine Ash Dam 2	640	8	110.59
Southern Seepage Area	500	8	86.40

6 Conclusions and Recommendations

During a previous study Rison Groundwater Consulting constructed a groundwater model for the Sasol Synfuels site. During that study the focus was on the following potential contaminant sources:

- Process water dams.
- Salty water dams.
- Ash effluent dams.
- Ash disposal area.
- Black products area.

The current investigation focused on the southern seepage area and the existing model was upgraded to simulate the impact from this area on the groundwater regime. The model was re-calibrated to include the new data.

The following are the major conclusions and recommendations derived from this investigation:

- The study area is located within the Grootspuit catchment and drainage occurs primarily towards the north-west.
- SASOL Synfuels is located on the siltstone and sandstone formations of the Karoo Supergroup, specifically the Eccu Group. These formations are not known to contain economic aquifers, but groundwater does contribute to stream flow and in some instances high yielding boreholes have been recorded. The latter is often associated with the intrusions of dolerite dykes and sills and subsequent fracturing of the host rock. Another important feature on the site is the presence of alluvium, which influences groundwater flow.
- There are two aquifers underlying the site.
 - A shallow, weathered aquifer that consists of siltstone, alluvium residual sandstone and weathered dolerite. The most consistent water strike is located at the fresh bedrock / weathering interface. The average depth of weathering is approximately 8m below surface. Groundwater table elevations vary between 1.43m and 3.55m below surface. Groundwater flow from this aquifer discharges into surface streams particularly where the fresh bedrock is close to surface.
 - A deeper aquifer where fracture flow dominate within the fractured sandstone and dolerite formations. The primary porosity of the Vryheid Formation is generally very low. Any water bearing capacity is therefore associated with secondary joints, bedding planes and faults. For this reason, the horizontal permeability of the Karoo strata is generally orders of magnitude greater than the vertical permeability. The contact zones of dolerite intrusions are characterised by cooling joints and fractures, which are considered the primary source of groundwater flow within the deeper formations. At the SASOL site, however, the dolerite sill appears to act as a confining barrier between the overlying weathered siltstone and the underlying fractured sandstone. Within the study area the sandstone is considered the more prominent aquifer. The depth to groundwater in this aquifer ranges from 0m (artesian) to 23.34m below surface. The fact that some deeper boreholes are artesian is indicative that the fractured aquifer is confined in places. The variation in groundwater levels is

attributed to the undermining in the area, of which the exact extent is uncertain. Although the aquifer is not completely dewatered it appears that some water is seeping into the underlying workings, causing localized dewatering cones. The low aquifer parameters will result in localized, but steep dewatering cones.

- A good correlation between the topography and the measured groundwater levels in the weathered aquifer has been observed, suggesting that the groundwater flow patterns are similar to that of the surface water flow. When assessing the water levels in the deep boreholes the same good correlation is not observed. This is as a result of boreholes 4D, 6D and 12D, REGM231D and REGM234D (southern seepage area) which are thought to leak into the underlying mine workings. If these boreholes are excluded a good correlation with the topography is again noticed.
- Groundwater gradients in the vicinity of the investigated areas are generally very shallow and averages 1.3%. Regionally the groundwater flow is towards the north-west, similar to that of the surface water, but local variations do, however, occur and are generally towards the surface streams.
- Aquifer tests were performed on the newly drilled boreholes to determine the aquifer parameters in both the weathered and fractured aquifers. These tests formed the basis for the construction of a numerical groundwater model.
- The modelling software MODFLOW was used to construct a two-layered, three-dimensional numerical groundwater model. The two layers are to account for the weathered and fractured zones of the aquifer. The important parameters regarding the model construction are listed below:
 - The modelling area includes both the Klipspruit and Bossiespruit catchments.
 - All surface streams were assigned constant head boundaries. These boundaries were restraint to only remove water from the system. No-flow conditions were assigned to the model boundaries.

- o The interpolated groundwater levels, based on the measured groundwater levels and the topography, were used as the initial hydraulic heads.
 - o A storage coefficient of 0.0001 was assigned to both Layers 1 and 2.
 - o Hydraulic conductivity values in the weathered aquifer (Layer 1) varied between 0.045m/day and 0.178m/day. Hydraulic conductivity values in the fractured aquifer (Layer 2) varied between 0.006m/day and 0.116m/day.
 - o Transmissivity values in the weathered aquifer (Layer 1) varied between 0.36m²/day and 3.29m²/day. Transmissivity values in the fractured aquifer (Layer 2) varied between 0.14m²/day and 2.78m²/day.
 - o Recharge is applied to Layer 1 only and was regionally estimated at 3% of the MAP. Recharge from the investigated contaminant sources was also included.
- o The groundwater flow model was calibrated for observed water levels and interpolated groundwater gradients. A 99% calibration was achieved for both aquifers.
- o Once the groundwater flow model was calibrated the MODFLOW software was used to approximate the advection and dispersion equation and to provide numerical solutions for the concentration values in the aquifer in time and space (mass transport model). Elevated chloride levels were used in the investigation as an indicator of contamination in order to simplify the groundwater flow modelling exercise. Chloride is considered to be a conservative tracer and migrates at the same rate as groundwater. In the case of this investigation it is therefore assumed that no decay or retardation of chloride is taking place in the aquifer.
- o The mass transport model was calibrated according to the measured chloride concentrations of the boreholes on site. A 99% and 96% calibration was achieved for the weathered and fractured aquifers respectively.

- o The original field investigations conducted by Jones & Wagener identified the following sources as impacting on the environment and sources that needs to be addressed during remediation of the area:
 - o Ash effluent dams 6A and 6B.
 - o Salty water dams.
 - o Van Niekerk Dam.
 - o Ash effluent dams E1 and E2.
 - o Fine ash dam 2.
 - o In addition to the abovementioned sources the southern seepage area also contribute to contamination and was included in the follow-up investigation.

The impact from the latter source was modelled during the current investigation.

- Once calibrated the mass transport model was used to simulate the migration of the contaminant plumes over a 50-year period. This simulation indicated that the migration of contaminants is relatively slow and although the contamination in all instances are migrating towards surface streams steady state conditions have not been reached and the full impact has therefore not yet manifested in the streams. The chloride loads to the Bossiespruit was calculated and it is estimated that 1 230.48 tonnes will be released from the southern seepage area into the aquifer system over a 50-year period.
- The recommended remedial option is, as was the case at the other contaminant points, the construction of a cut-off trench down-gradient from the source to intercept contaminated groundwater. This trench is estimated to be 500m in length and will intercept 86.4 m³/day of contaminated water.
- Groundwater monitoring must continue to assess the movement of the plume and to improve the understanding of the flow patterns. The exact source of groundwater contamination in the southern seepage area is still unclear and must be further investigated. Due to the low aquifer parameters and slow movement of the water bi-annual sampling is recommended at the end of the dry and wet seasons.

7 References

Bear, J. and Verruijt, A., (1992). Modelling Groundwater Flow and Pollution. D. Reidel publishing Company.

Van Biljon, M (2005). Groundwater Modelling at the Sasol Synfuels Site, Secunda. Report prepared for Jones & Wagner Consulting Civil Engineers.

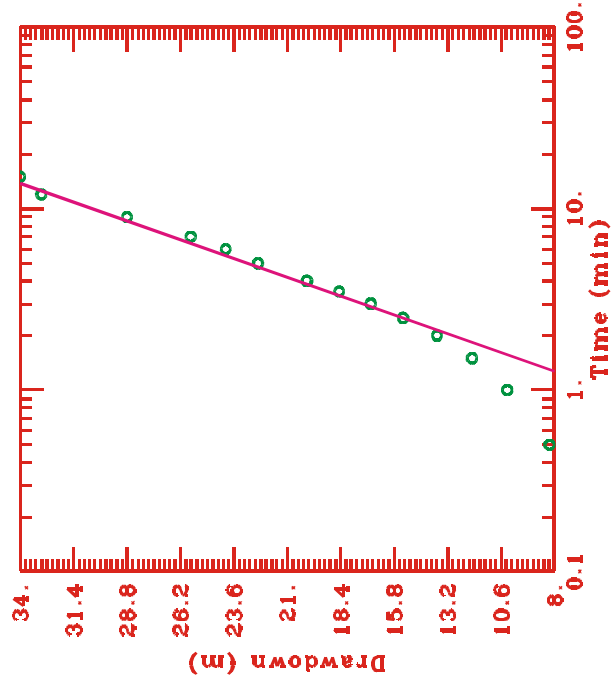
Vegter, J.R., (1995). An Explanation of a set of National Groundwater Maps. Water Research Commission Report No. TT74/95.

Wates, Meiring and Barnard (1999). Integrated Water Management Plan for the SASOL Secunda Industrial and Mining Complex.

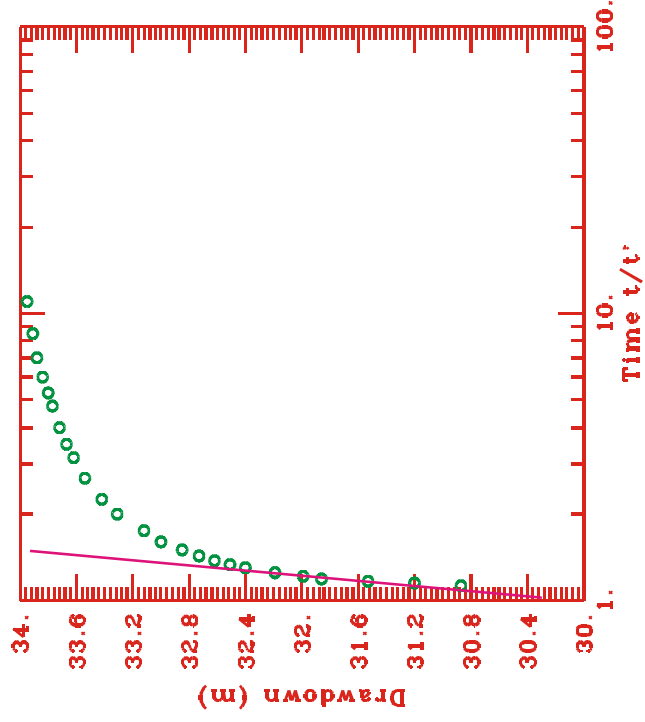
APPENDIX 1

PUMP TEST RESULTS

Constant Rate Test



Recovery Test



SASOL SYNFUELS

Pump Test Interpretation

Borehole Data

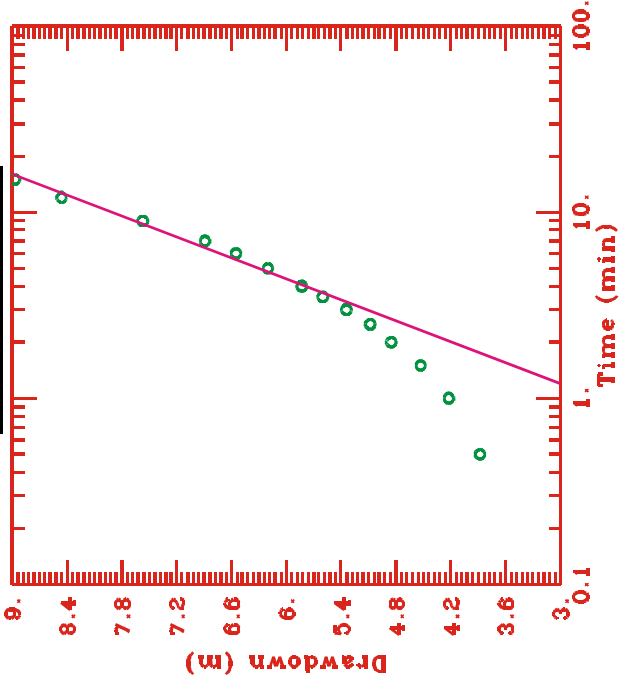
BHID: REGM 231D
BH Depth: 35.85m
SWL: 8.8m
Test Date: 11/06/07
Test Duration: 15 min
Recovery: 120 min
Pump Rate: 0.28 l/s

Result

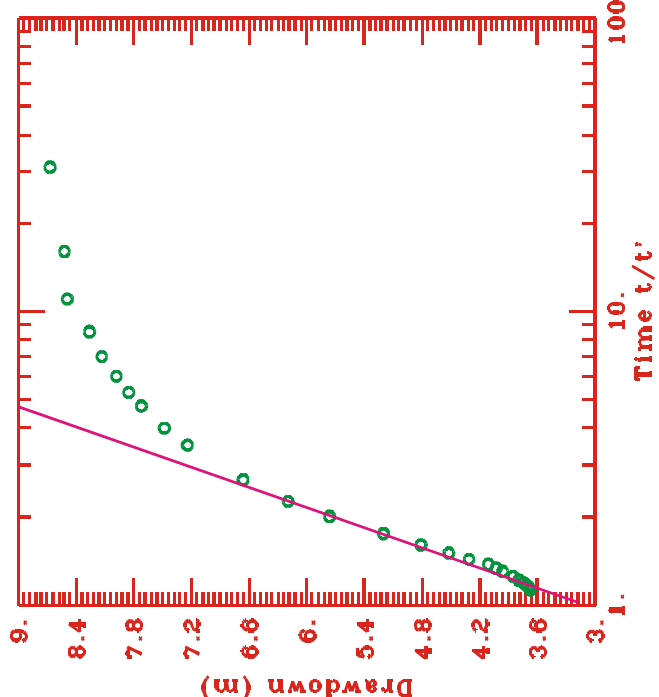
Transmissivity
CR Test: 0.18 m²/day
Rec Test: 0.22 m²/day



Constant Rate Test



Recovery Test



SASOL SYNFUELS

Pump Test
Interpretation

Borehole Data

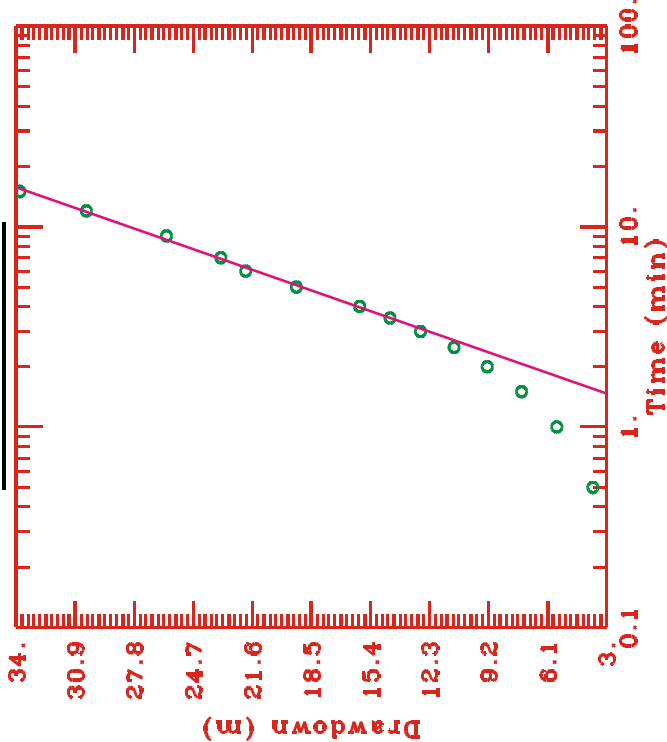
BHID: REGM 231S
BH Depth: 10.14m
SWL: 3.55m
Test Date: 11/06/07
Test Duration: 15 min
Recovery: 120 min
Pump Rate: 0.21 l/s

Result

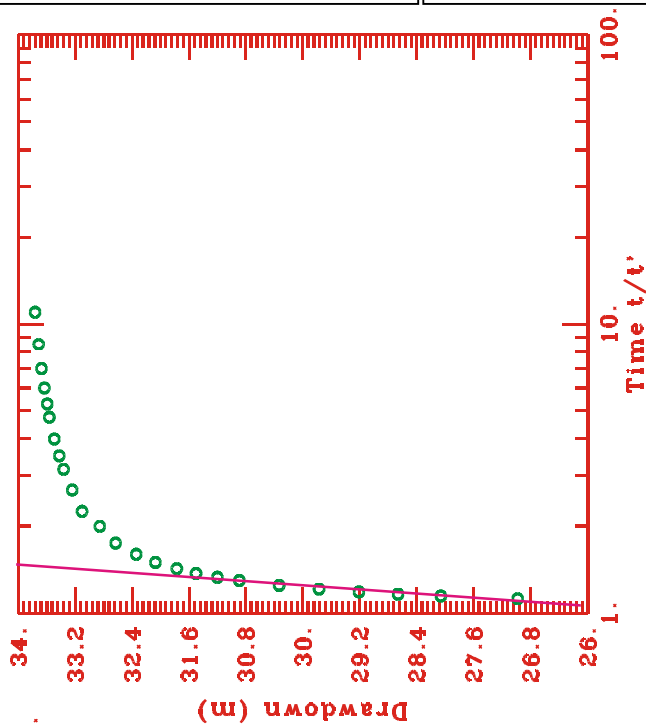
Transmissivity
CR Test: 0.62 m²/day
Rec Test: 0.38 m²/day



Constant Rate Test



Recovery Test



SASOL SYNFUELS

**Pump Test
Interpretation**

Borehole Data

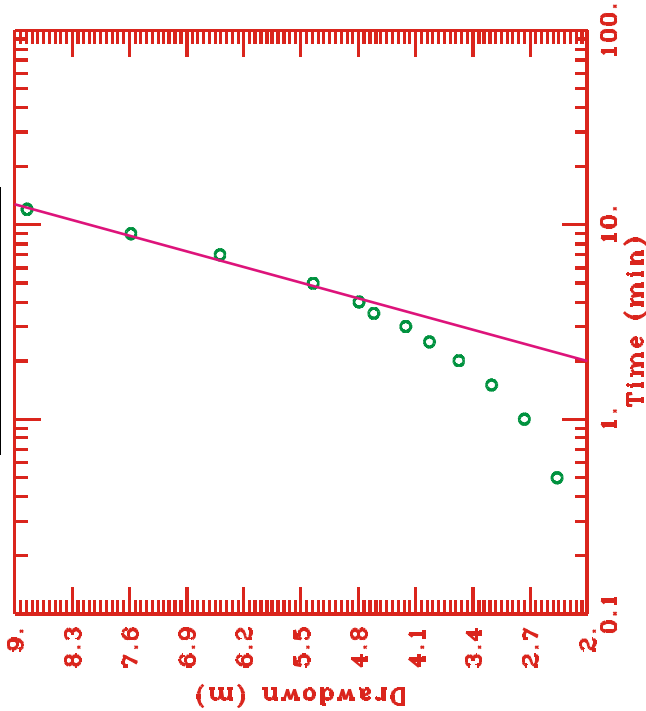
BHID: REGM 232D
BH Depth: 35.75m
SWL: 2.47m
Test Date: 11/06/07
Test Duration: 15 min
Recovery: 120 min
Pump Rate: 0.38 l/s

Result

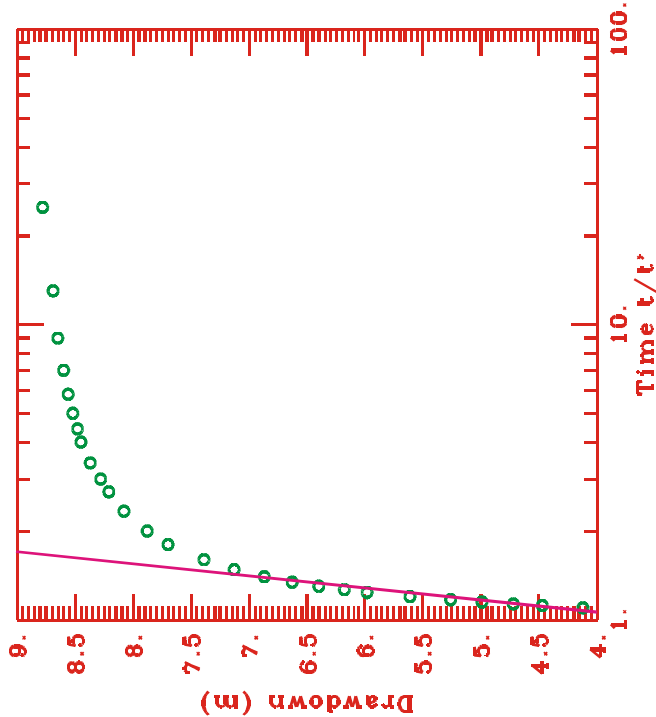
Transmissivity
CR Test: 0.20 m²/day
Rec Test: 0.11 m²/day



Constant Rate Test



Recovery Test



SASOL SYNFUELS

Pump Test
Interpretation

Borehole Data

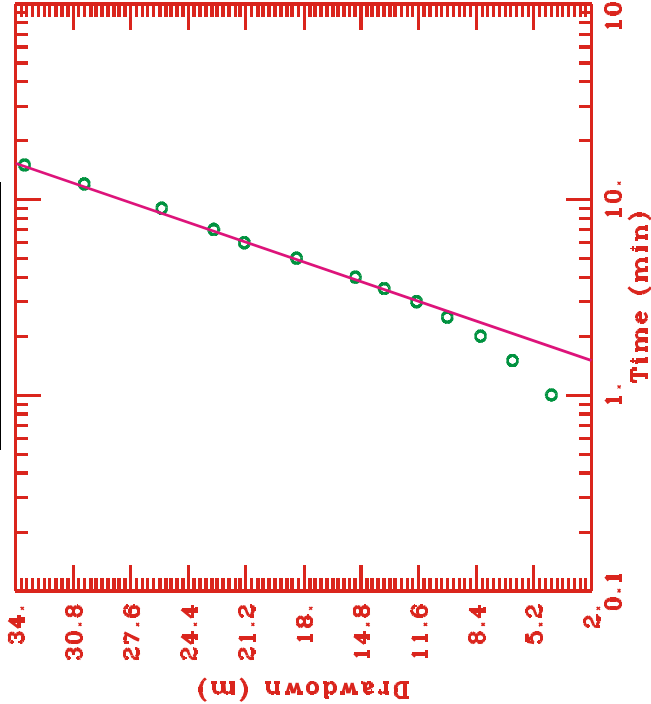
BHID: REGM 232S
BH Depth: 10.15m
SWL: 2.15m
Test Date: 11/06/07
Test Duration: 12 min
Recovery: 120 min
Pump Rate: 0.23 l/s

Result

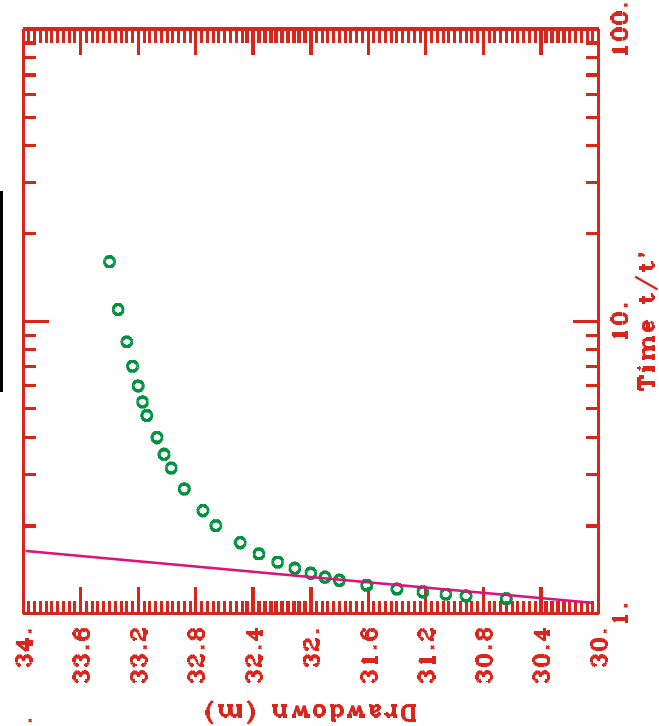
Transmissivity
CR Test: 0.42 m²/day
Rec Test: 0.13 m²/day



Constant Rate Test



Recovery Test



SASOL SYNFUELS

Pump Test
Interpretation

Borehole Data

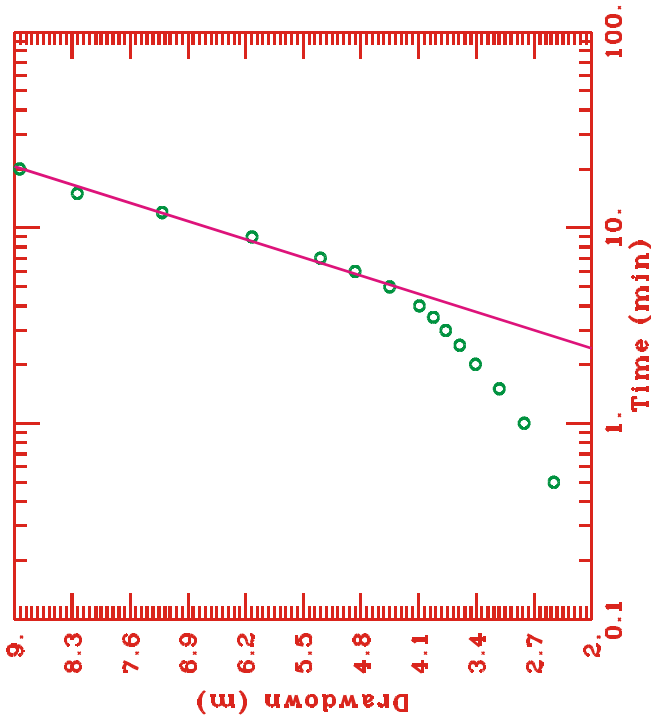
BHID: REGM 233D
BH Depth: 35.77m
SWL: 0.61m
Test Date: 12/06/07
Test Duration: 15 min
Recovery: 120 min
Pump Rate: 0.40 l/s

Result

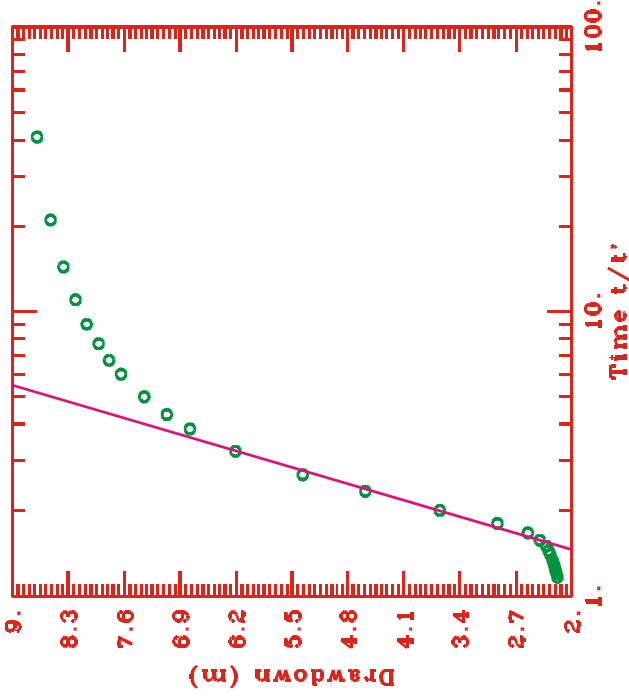
Transmissivity
CR Test: 0.20 m²/day
Rec Test: 0.35 m²/day



Constant Rate Test



Recovery Test



SASOL SYNFUELS

Pump Test
Interpretation

Borehole Data

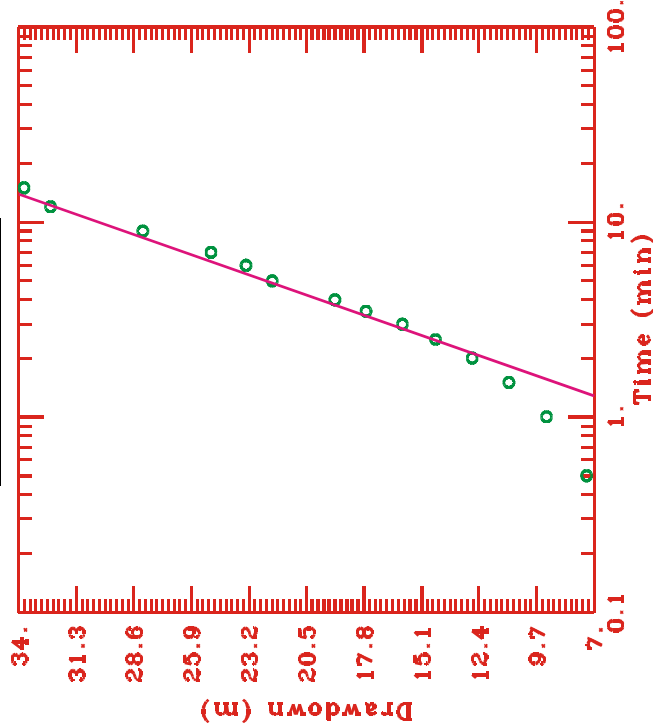
BHID: REGM 233S
BH Depth: 10.16m
SWL: 2.10m
Test Date: 12/06/07
Test Duration: 20 min
Recovery: 120 min
Pump Rate: 0.24 l/s

Result

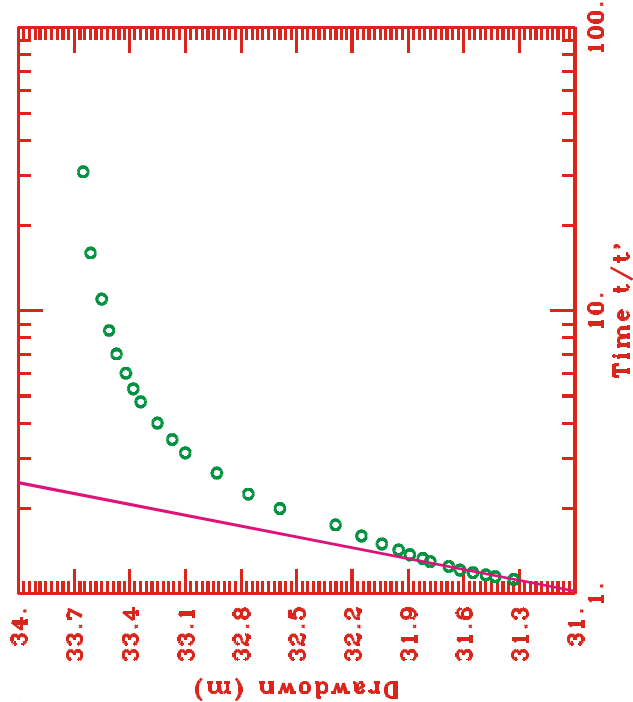
Transmissivity
CR Test: 0.50 m²/day
Rec Test: 0.31 m²/day



Constant Rate Test



Recovery Test



SASOL SYNFUELS

Pump Test
Interpretation

Borehole Data

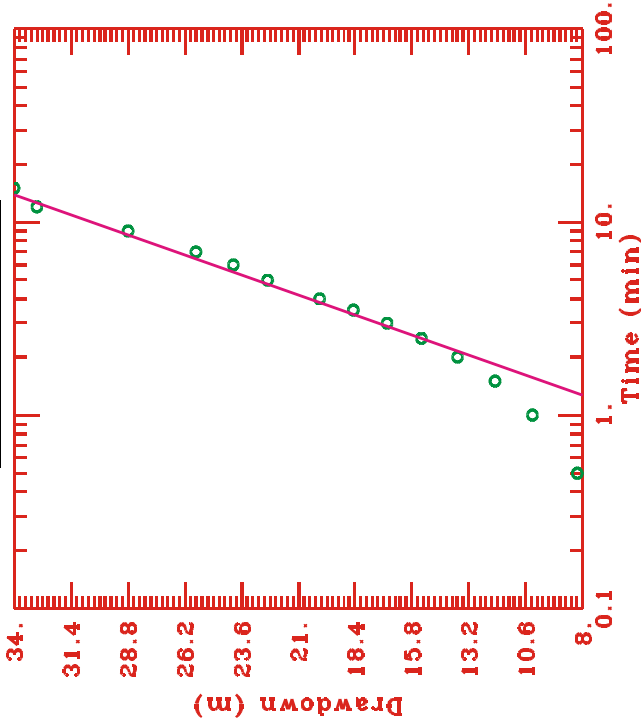
BHID: REGM 234D
BH Depth: 35.54m
SWL: 7.81m
Test Date: 12/06/07
Test Duration: 15 min
Recovery: 120 min
Pump Rate: 0.37 l/s

Result

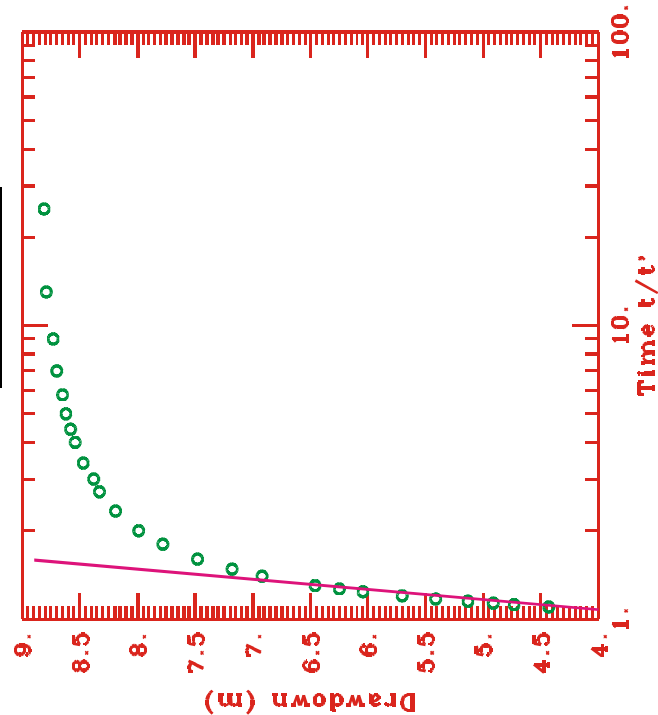
Transmissivity
CR Test: 0.23 m²/day
Rec Test: 0.75 m²/day



Constant Rate Test



Recovery Test



SASOL SYNFUELS

Pump Test
Interpretation

Borehole Data

BHID: REGM 234S
BH Depth: 9.85m
SWL: 3.16m
Test Date: 12/06/07
Test Duration: 12 min
Recovery: 120 min
Pump Rate: 0.23 l/s

Result

Transmissivity
CR Test: 0.54 m²/day
Rec Test: 0.15 m²/day



APPENDIX D STREAM SURVEY DATA AND PLOTS

Low flow stream survey

Coordinates		Conductivity	Measurement in main stream
Y	X	($\mu\text{S/cm}$)	
-19,572	2,940,939	195.5	
-19,564	2,940,893	724	
-19,538	2,940,915	208.5	X
-19,326	2,940,535	268	X
-19,302	2,940,610	235	
-19,153	2,940,451	228.9	X
-18,986	2,940,311	234	X
-19,588	2,939,709	5400	
-19,057	2,939,362	7620	X
-20,613	2,937,990	10180	
-20,847	2,938,107	7690	
-20,819	2,938,245	9210	
-20,714	2,939,331	9420	
-18,830	2,940,305	6900	
-18,972	2,940,593	7090	
-18,565	2,940,421	6480	
-17,931	2,940,481	7090	
-18,410	2,939,747	328.9	X
-18,624	2,940,122	308.4	X
-18,734	2,940,046	378.9	X
-18,775	2,940,013	420.4	X
-18,613	2,939,931	362.3	X
-18,943	2,940,275	232	X
-18,095	2,939,733	402	X
-17,578	2,939,773	384.1	X
-17,137	2,939,756	397.2	X
-17,108	2,939,741	397.4	X
-16,585	2,939,644	417.9	X
-16,343	2,939,533	426.9	X
-15,967	2,939,293	347	X
-15,930	2,939,361	379.9	
-15,930	2,939,365	419.8	X
-15,463	2,939,320	2100	X
-15,505	2,939,263	429.5	X
-15,281	2,939,331	486.2	X
-15,224	2,939,307	487.5	
-15,062	2,939,196	245.8	X
-14,690	2,939,193	511	X
-14,985	2,939,253	495.8	X
-15,463	2,939,320	512	X
-15,736	2,939,294	2035	
-15,463	2,939,482	665	X
-15,554	2,939,610	1929	X
-15,621	2,939,710	1891	X
-15,758	2,939,749	1823	X
-15,798	2,939,856	1962	X



Coordinates		Conductivity	Measurement in
Y	X	($\mu\text{S/cm}$)	main stream
-16,139	2,940,813	1942	X
-16,162	2,940,813	2690	X
-16,156	2,940,659	728	
-16,101	2,940,628	2623	X
-16,161	2,940,562	2684	X
-16,388	2,940,985	2830	X
-16,451	2,940,948	2441	X
-16,364	2,941,068	12200	



High flow stream survey

Coordinates		Conductivity ($\mu\text{S/cm}$)			Measurement in main stream
Y	X	17-Jan-07	18-Jan-07	19-Jan-07	
19,966	2,943,123	1520			X
19,660	2,943,674	228	334		X
19,532	2,943,638	787	791		X
19,530	2,943,598	1043			X
19,555	2,943,572	261			X
19,474	2,943,541	894			X
19,494	2,943,488	302			X
19,451	2,943,471	290			X
19,097	2,943,266	427	454		X
19,081	2,943,265	450			X
19,078	2,943,252	852	1109		X
19,049	2,943,231	1256	1223		X
18,984	2,943,383		277		X
18,924	2,943,289	1072	509		X
18,696	2,943,142	672			X
18,429	2,943,180	534			X
18,308	2,943,081	646			X
18,164	2,943,047	841			X
16,909	2,941,990	838	792		X
16,819	2,941,925		1072		X
16,939	2,941,522		4600		X
16,358	2,941,122		1640		X
16,344	2,941,050		1595		X
16,100	2,940,900		1342		X
16,130	2,940,724		1310		X
16,230	2,940,596		1243		X
15,759	2,939,857		1111		X
15,533	2,939,664		1195		X
15,427	2,939,575		1150		X
15,463	2,939,320		1190	1195	X
19,244	2,943,223	1151			
18,763	2,942,514	923			
17,624	2,942,393	4750			
17,504	2,942,331	35300			
16,715	2,941,466	18900			
17,393	2,941,440	54200			
16,904	2,941,398	35500			
16,548	2,941,204	18900			
16,671	2,941,145	9500			
16,554	2,941,127	5200			
16,163	2,940,853	745			
19,492	2,940,957		444		X
19,301	2,940,588		534		X
19,097	2,940,533		678		X
18,962	2,940,381		683		X
18,384	2,939,796		1525		X
18,063	2,939,795		1228	1190	X
17,559	2,939,825			869	X



Coordinates		Conductivity ($\mu\text{S/cm}$)			Measurement in main stream
Y	X	17-Jan-07	18-Jan-07	19-Jan-07	
17,102	2,939,813			877	X
17,005	2,939,847			914	X
16,554	2,939,726			953	X
16,547	2,939,709			1019	X
16,922	2,939,830			947	X
16,622	2,939,752			946	X
16,365	2,939,582			1050	X
16,290	2,939,585			420	X
15,892	2,939,419			490	X
15,702	2,939,379			525	X
15,469	2,939,319			531	X
15,281	2,939,331		526	531	X
15,189	2,939,363			541	X
14,763	2,939,234			558	X
14,652	2,939,225			559	X
14,567	2,939,173			561	X
14,427	2,939,089			575	X
14,445	2,939,092			572	X
19,210	2,941,402			428	
18,970	2,940,408			486	
17,739	2,939,767			1198	
17,105	2,939,788			4560	
17,005	2,939,806			10730	
16,405	2,939,728			955	
16,329	2,939,549			2200	
16,318	2,939,579			409	
15,894	2,939,406			609	
15,944	2,939,334			985	
15,024	2,939,261			280	
14,445	2,939,092			820	
14,446	2,939,087			1573	



LF110 (10080)
LF114 (7330)
LF12 (9210)

Legend

- LF58 measurements in main stream
- LF58 measurements in stream

Notes

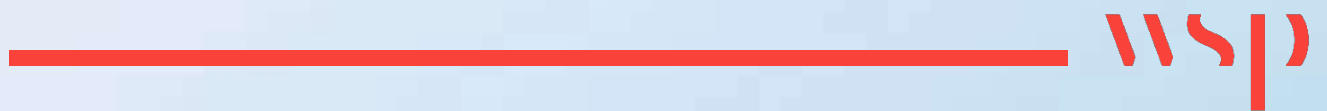
1. Google background image is only approximate, please refer to co-ordinate list in report JWS9 /07 /A839 Appendix D for accurate data.

Co-ordinate System: WGS 84		Projection: WG29	
Pr Eng	Client	Scale	Drawing No
Jones & Wagener Consulting Engineers	SASOL - SYNFUELS	1 : 10 000	A839-00-002
99 Brown Road P.O. Box 1134 Kroonstad 2128			
Tel. (011) 518-0200 Fax. (011) 518-0201 e-mail: jones@jones.co.za			
Designed	Checked	Approved	Revision
KRIEK	RUST	RUST	A
2.04.2008	2.04.2008	2.04.2008	

Reference Drawings / Verwysingskeiens	Rev.	Revision / Hersiening	Notes	Date	Approved
	A	ISSUED WITH REPORT JWS9/07/A839	SK	24.2008	RUST
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Appendix C

IMPACT ASSESSMENT METHODOLOGY





IMPACT ASSESSMENT METHODOLOGY

SCOPING PHASE

REPORTING REQUIREMENTS

- Project Description
- Legislative Context (as applicable)
- Assumptions and limitations
- Description of Baseline Environment
- Site Sensitivity Verification – including sensitivity mapping
- Identification and high-level screening of impacts and mitigation measures
- Plan of Study for EIA

Ensure that all reports fulfil the requirements of the relevant Protocols.

HIGH-LEVEL SCREENING OF IMPACTS AND MITIGATION

Appendix 2 of GNR 982, as amended, requires the identification of the significance of potential impacts during scoping. To this end, an impact screening tool has been used in the scoping phase. The screening tool is based on two criteria, namely probability; and, consequence (**Table 0-3**), where the latter is based on general consideration to the intensity, extent, and duration.

The scales and descriptors used for scoring probability and consequence are detailed in **Table 0-3** and **Table 0-2** respectively.

Table 0-1: Probability Scores and Descriptors

SCORE	DESCRIPTOR
4	Definite: The impact will occur regardless of any prevention measures
3	Highly Probable: It is most likely that the impact will occur
2	Probable: There is a good possibility that the impact will occur
1	Improbable: The possibility of the impact occurring is very low

Table 0-2: Consequence Score Descriptions

SCORE	NEGATIVE	POSITIVE
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4	Very severe: An irreversible and permanent change to the affected system(s) or party(ies) which cannot be mitigated.	Very beneficial: A permanent and very substantial benefit to the affected system(s) or party(ies), with no real alternative to achieving this benefit.
3	Severe: A long term impacts on the affected system(s) or party(ies) that could be mitigated. However, this mitigation would be difficult, expensive or time consuming or some combination of these.	Beneficial: A long term impact and substantial benefit to the affected system(s) or party(ies). Alternative ways of achieving this benefit would be difficult, expensive or time consuming, or some combination of these.
2	Moderately severe: A medium to long term impacts on the affected system(s) or party (ies) that could be mitigated.	Moderately beneficial: A medium to long term impact of real benefit to the affected system(s) or party(ies). Other ways of optimising the beneficial effects are equally difficult, expensive and time consuming (or some combination of these), as achieving them in this way.
1	Negligible: A short to medium term impacts on the affected system(s) or party(ies). Mitigation is very easy, cheap, less time consuming or not necessary.	Negligible: A short to medium term impact and negligible benefit to the affected system(s) or party(ies). Other ways of optimising the beneficial effects are easier, cheaper and quicker, or some combination of these.

Table 0-3: Significance Screening Tool

CONSEQUENCE SCALE

PROBABILITY SCALE		1	2	3	4
	1	Very Low	Very Low	Low	Medium
	2	Very Low	Low	Medium	Medium
	3	Low	Medium	Medium	High
	4	Medium	Medium	High	High

The nature of the impact must be characterised as to whether the impact is deemed to be positive (+ve) (i.e. beneficial) or negative (-ve) (i.e. harmful) to the receiving environment/receptor. For ease of reference, a colour reference system (**Table 0-4**) has been applied according to the nature and significance of the identified impacts.

Table 0-4: Impact Significance Colour Reference System to Indicate the Nature of the Impact

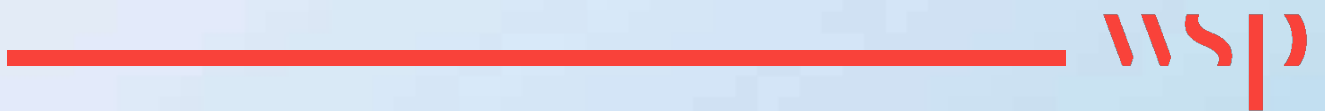
Negative Impacts (-ve)

Positive Impacts (+ve)

Negligible	Negligible
Very Low	Very Low
Low	Low
Medium	Medium
High	High

Appendix D

DOCUMENT LIMITATIONS





DOCUMENT LIMITATIONS

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