APPENDIX B
Laboratory Test Results

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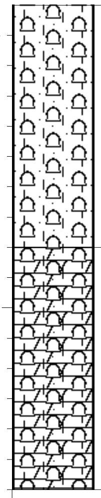
WP RSA
Amesfontein Solar (CSP)

HOLE No: **IP1**
Sheet 1 of 1

JOB NUMBER: 11-863

Scale
1:25



0.00

Dark translucent grey slightly weathered angular to boulder sized hard rock CHERT in a matrix of a slightly moist orange brown medium dense intact silty sandy GRAVEL. Transported.

0.80

Dry light grey and dark grey dense friable calciferous silty sandy GRAVEL. Gravel generally fine (light grey) and occasionally coarse (dark grey) angular tightly packed CHERT and DOLOMITE GRAVEL. Residual chert / dolomite.

1.60

NOTES

1) Refusal on soft rock.

2) No groundwater seepage.

3) No sidewall collapse.

4) No samples taken.

5) Abundant chert gravel on surface area.

6) Final depth 1.60m.

CONTRACTOR :
MACHINE :
DRILLED BY :
PROFILED BY : SH

INCLINATION :
DIAM :
DATE : 23/01/2012
DATE : 23/01/2012

ELEVATION :
X-COORD :
Y-COORD :

HOLE No: **IP1**

TYPE SET BY : AM
SETUP FILE : MSJA4.SET

DATE : 02/02/12 16:35
TEXT : ..\11-863\Logs\Dothead.doc

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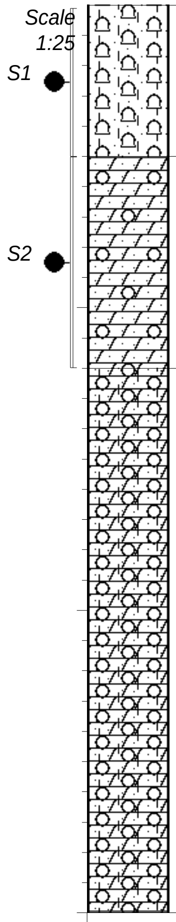
HOLE No: **IP2**
Sheet 1 of 1

JOB NUMBER: 11-863

Scale 1:25



0.00	Dark translucent grey slightly weathered angular to boulder sized hard rock CHERT in a matrix of a slightly moist orange brown medium dense intact silty sandy GRAVEL. Transported.
0.50	Dark grey slightly weathered tabular closely to medium jointed hard rock DOLOMITE in a matrix of dry off white and pinkish brown loose intact calciferous gravelly SAND. Residual.
1.20	Slightly moist pinkish brown dense reworked calciferous gravelly silty SAND. Gravel generally fine to medium occasionally coarse to cobble angular hard rock dolomite and soft rock ferruginised gravel. Residual.
3.00	

NOTES

1) No refusal on dense material.

2) No groundwater seepage.

3) No sidewall collapse.

4) Samples taken :
S1 0.01--0.50m (1 x Small)
S2 0.50--1.20m (1 x Small)

5) Final depth 3.00m.

CONTRACTOR :
MACHINE :
DRILLED BY :
PROFILED BY : SH
INCLINATION :
DIAM :
DATE : 23/01/2012
DATE : 23/01/2012
ELEVATION :
X-COORD :
Y-COORD :

HOLE No: **IP2**

TYPE SET BY : AM
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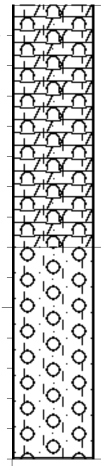
HOLE No: **IP3**
Sheet 1 of 1

JOB NUMBER: 11-863

Scale
1:25



0.00	Slightly moist orange brown loose intact silty sandy GRAVEL. Gravel generally fine to medium and occasionally coarse to cobble subrounded (fine to medium) to angular (coarse and cobble) abundant tightly packed hard rock CHERT and DOLOMITE fragments. Transported.
0.80	Slightly moist yellowish brown becoming off-white speckled and mottled dark grey (dolomite) dense calciferous moderately cemented friable silty sandy GRAVEL. Non-indurated Calcrete.
1.50	

NOTES

1) Refusal on medium hard to hard rock calcrete.

2) No groundwater seepage.

3) No sidewall collapse.

4) No samples taken.

5) Final depth 1.50m.

CONTRACTOR :
MACHINE :
DRILLED BY :
PROFILED BY : SH

INCLINATION :
DIAM :
DATE : 23/01/2012
DATE : 23/01/2012

ELEVATION :
X-COORD :
Y-COORD :

HOLE No: **IP3**

TYPE SET BY : AM
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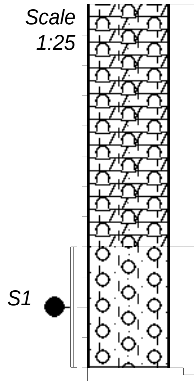
HOLE No: **IP4**
Sheet 1 of 1

JOB NUMBER: 11-863

Scale
1:25



0.00

Slightly moist orange brown loose intact silty sandy GRAVEL. Gravel generally fine to medium and occasionally coarse to cobble subrounded (fine to medium) to angular (coarse and cobble) abundant tightly packed hard rock CHERT and DOLOMITE fragments. Transported.

0.80

Slightly moist yellowish brown becoming off-white speckled and mottled dark grey (dolomite) dense calciferous moderately cemented friable silty sandy GRAVEL. Non-indurated Calcrete.

1.20

NOTES

1) Refusal on well cemented medium hard to hard rock calcrete.

2) No groundwater seepage.

3) No sidewall collapse.

4) Samples taken :
S1 0.80--1.20m (1 x Small)

5) Final depth 1.20m.

CONTRACTOR :
MACHINE :
DRILLED BY :
PROFILED BY : SH
TYPE SET BY : AM
SETUP FILE : MSJA4.SET

INCLINATION :
DIAM :
DATE : 23/01/2012
DATE : 23/01/2012
DATE : 02/02/12 16:35
TEXT : ..\11-863\Logs\Dothead.doc

ELEVATION :
X-COORD :
Y-COORD :

HOLE No: **IP4**

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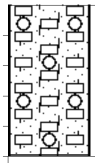
HOLE No: **IP5**
Sheet 1 of 1

JOB NUMBER: 11-863

Scale
1:25



0.00

Dry white indurated fragments of hard rock CALCRETE in a matrix of slightly moist medium brown loose intact gravelly silty SAND of Aeolian origin.

0.50

NOTES

1) Refusal on hard rock hardpan calcrete.

2) No groundwater seepage.

3) No sidewall collapse.

4) No samples taken.

5) Final depth 0.50m.

CONTRACTOR :
MACHINE :
DRILLED BY :
PROFILED BY : SH

INCLINATION :
DIAM :
DATE : 23/01/2012
DATE : 23/01/2012

ELEVATION :
X-COORD :
Y-COORD :

HOLE No: **IP5**

TYPE SET BY : AM
SETUP FILE : MSJA4.SET

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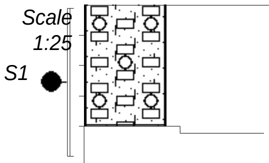
HOLE No: **IP6**
Sheet 1 of 1

JOB NUMBER: 11-863

Scale 1:25



0.00

Dry white indurated fragments of hard rock CALCRETE in a matrix of slightly moist medium brown loose intact gravelly silty SAND of Aeolian origin.

0.40

NOTES

1) Refusal on hard rock hardpan calcrete.

2) No groundwater seepage.

3) No sidewall collapse.

4) Samples taken :
S1 0.01--0.50m (1 x Small)

5) Final depth 0.40m.

CONTRACTOR :
MACHINE :
DRILLED BY :
PROFILED BY : SH

INCLINATION :
DIAM :
DATE : 23/01/2012
DATE : 23/01/2012

ELEVATION :
X-COORD :
Y-COORD :

HOLE No: **IP6**

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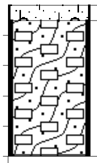
HOLE No: **IP12**
Sheet 1 of 1

JOB NUMBER: 11-863

Scale
1:25



0.00	Slightly moist orange brown loose intact slightly fine gravelly silty SAND. Aeolian.
0.05	Off-white indurated well cemented fractured tabular medium hard to hard rock HARDPAN CALCRETE with remnants of QUARTZITE host rock.
0.50	

NOTES

1) Refusal on medium hard to hard rock hardpan calcrete.

2) No groundwater seepage.

3) No sidewall collapse.

4) No samples taken.

5) Abundant calcrete at surface.

6) Final depth 0.50m.

CONTRACTOR :
MACHINE :
DRILLED BY :
PROFILED BY : SH

INCLINATION :
DIAM :
DATE : 23/01/2012
DATE : 23/01/2012

ELEVATION :
X-COORD :
Y-COORD :

HOLE No: **IP12**

TYPE SET BY : AM
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HOLE No: **IP13**
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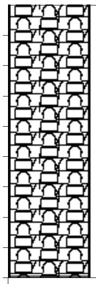
JOB NUMBER: 11-863

Scale
1:25



0.00

Slightly moist orange brown medium dense friable silty sandy GRAVEL. Gravel generally fine to medium and occasionally coarse to cobble angular to subangular abundant tightly packed hard rock CHERT, DOLOMITE and CALCRETE fragments. Transported.

0.90

NOTES

1) Refusal on hard rock calcrete.

2) No groundwater seepage.

3) No sidewall collapse.

4) No samples taken.

5) Final depth 0.90m.

CONTRACTOR :
MACHINE :
DRILLED BY :
PROFILED BY : SH

INCLINATION :
DIAM :
DATE : 23/01/2012
DATE : 23/01/2012

ELEVATION :
X-COORD :
Y-COORD :

HOLE No: **IP13**

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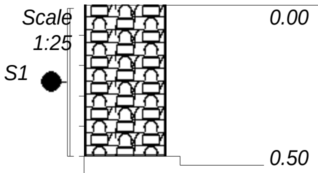
HOLE No: **IP14**
Sheet 1 of 1

JOB NUMBER: 11-863



Slightly moist orange brown medium dense friable silty sandy GRAVEL. Gravel generally fine to medium and occasionally coarse to cobble angular to subangular abundant tightly packed hard rock CHERT, DOLOMITE and CALCRETE fragments. Transported.

NOTES

1) Refusal on hard rock hardpan calcrete.

2) No groundwater seepage.

3) No sidewall collapse.

4) Samples taken :
S1 0.01--0.50m (1 x Small)

5) Final depth 0.50m.

CONTRACTOR :
MACHINE :
DRILLED BY :
PROFILED BY : SH

INCLINATION :
DIAM :
DATE : 23/01/2012
DATE : 23/01/2012

ELEVATION :
X-COORD :
Y-COORD :

HOLE No: **IP14**

TYPE SET BY : AM
SETUP FILE : MSJA4.SET

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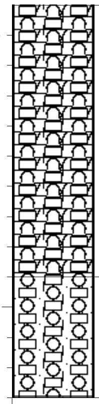
HOLE No: **IP15**
Sheet 1 of 1

JOB NUMBER: 11-863

Scale
1:25



0.00	Slightly moist orange brown medium dense friable silty sandy GRAVEL. Gravel generally fine to medium and occasionally coarse to cobble angular to subangular abundant tightly packed hard rock CHERT, DOLOMITE and CALCRETE fragments. Transported.
0.90	Dry greyish white medium dense calciferous silty sandy GRAVEL. Non-indurated Calcrete.
1.30	

NOTES

1) Refusal on hardpan CALCRETE.

2) No groundwater seepage.

3) No sidewall collapse.

4) No samples taken.

5) Final depth 1.30m.

CONTRACTOR :
MACHINE :
DRILLED BY :
PROFILED BY : SH

INCLINATION :
DIAM :
DATE : 23/01/2012
DATE : 23/01/2012

ELEVATION :
X-COORD :
Y-COORD :

HOLE No: **IP15**

TYPE SET BY : AM
SETUP FILE : MSJA4.SET

DATE : 02/02/12 16:35
TEXT : ..\11-863\Logs\Dothead.doc

WP RSA
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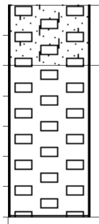
HOLE No: **IP16**
Sheet 1 of 1

JOB NUMBER: 11-863

Scale
1:25



0.00	Dry white indurated hard rock CALCRETE fragments in a matrix of dry medium brown loose intact silty SAND of Aeolian origin.
0.20	Dry white medium dense moderately cemented non-indurated CALCRETE.
0.70	

NOTES

1) Refusal on hard rock hardpan calcrete.

2) No groundwater seepage.

3) No sidewall collapse.

4) No samples taken.

5) Abundant calcrete at surface.

6) Final depth 0.70m.

CONTRACTOR :
MACHINE :
DRILLED BY :
PROFILED BY : SH

INCLINATION :
DIAM :
DATE : 23/01/2012
DATE : 23/01/2012

ELEVATION :
X-COORD :
Y-COORD :

HOLE No: **IP16**

TYPE SET BY : AM
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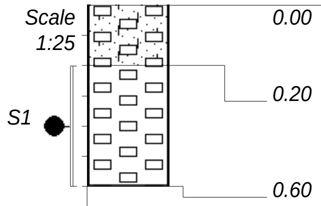
HOLE No: **IP17**
Sheet 1 of 1

JOB NUMBER: 11-863



Dry white indurated hard rock CALCRETE fragments in a matrix of dry medium brown loose intact silty SAND of Aeolian origin.

Dry white medium dense moderately cemented non-indurated CALCRETE.

NOTES

1) Refusal on hard rock hardpan calcrete.

2) No groundwater seepage.

3) No sidewall collapse.

4) Samples taken :
S1 0.20--0.60m (1 x Small)

5) Final depth 0.60m.

CONTRACTOR :
MACHINE :
DRILLED BY :
PROFILED BY : SH

INCLINATION :
DIAM :
DATE : 23/01/2012
DATE : 23/01/2012

ELEVATION :
X-COORD :
Y-COORD :

HOLE No: **IP17**

TYPE SET BY : AM
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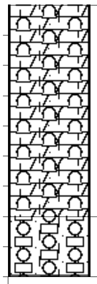
HOLE No: **IP20**
Sheet 1 of 1

JOB NUMBER: 11-863

Scale
1:25



0.00	Slightly moist orange brown loose intact silty sandy GRAVEL. Gravel generally fine to medium and occasionally coarse to cobble subrounded (fine to medium) to angular (coarse and cobble) abundant tightly packed hard rock CHERT and DOLOMITE fragments. Transported.
0.70	Dry light grey dense calciferous silty sandy GRAVEL. Non-indurated Calcrete.
0.90	

NOTES

1) Refusal on hard rock CALCRETE.

2) No groundwater seepage.

3) No sidewall collapse.

4) No samples taken.

5) Final depth 0.90m.

CONTRACTOR :
MACHINE :
DRILLED BY :
PROFILED BY : SH

INCLINATION :
DIAM :
DATE : 23/01/2012
DATE : 23/01/2012

ELEVATION :
X-COORD :
Y-COORD :

HOLE No: **IP20**

TYPE SET BY : AM
SETUP FILE : MSJA4.SET

DATE : 02/02/12 16:35
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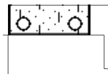
HOLE No: **IP21**
Sheet 1 of 1

JOB NUMBER: 11-863

Scale 1:25



0.00 – *0.10*	Dry orange brown loose intact gravelly silty SAND. Aeolian.

NOTES

1) Refusal on hard rock HARDPAN CALCRETE.

2) No groundwater seepage.

3) No sidewall collapse.

4) No samples taken.

5) Final depth 0.10m.

CONTRACTOR :
MACHINE :
DRILLED BY :
PROFILED BY : SH

INCLINATION :
DIAM :
DATE : 23/01/2012
DATE : 23/01/2012

ELEVATION :
X-COORD :
Y-COORD :

HOLE No: **IP21**

TYPE SET BY : AM
SETUP FILE : MSJA4.SET

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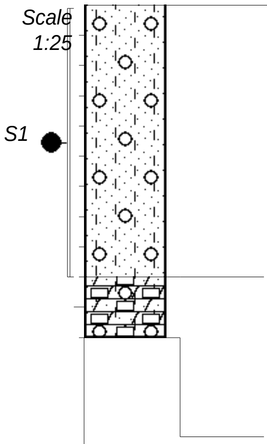
HOLE No: **IP22**
Sheet 1 of 1

JOB NUMBER: 11-863



0.00

Slightly moist orange brown loose intact slightly gravelly silty SAND. Transported.

0.90

Dry white dense to very dense powdery moderately cemented silty gravelly SAND. Non-indurated Calcrete. Gravel generally well cemented calcrete fragments and fine to coarse angular hard rock DOLOMITE fragments.

1.10

NOTES

1) Refusal on dolomite bedrock.

2) No groundwater seepage.

3) No sidewall collapse.

4) Samples taken :
S1 0.01--0.90m (1 x Small)

5) Final depth 1.10m.

CONTRACTOR :
MACHINE :
DRILLED BY :
PROFILED BY : SH

TYPE SET BY : AM
SETUP FILE : MSJA4.SET

INCLINATION :
DIAM :
DATE : 23/01/2012
DATE : 23/01/2012

DATE : 02/02/12 16:35
TEXT : ..\11-863\Logs\Dothead.doc

ELEVATION :
X-COORD :
Y-COORD :

HOLE No: **IP22**

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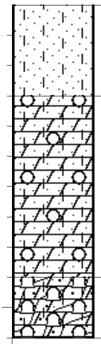
HOLE No: **IP23**
Sheet 1 of 1

JOB NUMBER: 11-863

Scale
1:25



0.00	Slightly moist orange brown loose intact silty fine SAND. Transported.
0.30	Slightly moist orange brown loose intact gravelly silty SAND. Gravel generally fine subangular abundant unweathered hard rock DOLOMITE fragments. Transported.
0.90	Slightly moist yellowish brown to off white medium dense calciferous silty sandy GRAVEL. Gravel generally fine to medium sub-angular abundant hard rock CHERT, QUARTZITE and DOLOMITE fragments. Residual Dolomite.
1.10	

NOTES

1) Refusal on apparent dolomite bedrock.

2) No groundwater seepage.

3) No sidewall collapse.

4) No samples taken.

5) Bedrock in undulating.

6) Final depth 1.10m.

CONTRACTOR :
MACHINE :
DRILLED BY :
PROFILED BY : SH

INCLINATION :
DIAM :
DATE : 23/01/2012
DATE : 23/01/2012

ELEVATION :
X-COORD :
Y-COORD :

HOLE No: **IP23**

TYPE SET BY : AM
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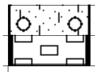
HOLE No: **IP24**
Sheet 1 of 1

JOB NUMBER: 11-863

Scale
1:25



0.00	Dry orange brown loose intact gravelly silty SAND. Aeolian.
0.10	White indurated well cemented fractured tabular hard rock HARDPAN CALCRETE.
0.20	

NOTES

1) Refusal on hard rock hardpan CALCRETE.

2) No groundwater seepage.

3) No sidewall collapse.

4) No samples taken.

5) Final depth 0.20m.

CONTRACTOR :
MACHINE :
DRILLED BY :
PROFILED BY : SH

INCLINATION :
DIAM :
DATE : 23/01/2012
DATE : 23/01/2012

ELEVATION :
X-COORD :
Y-COORD :

HOLE No: **IP24**

TYPE SET BY : AM
SETUP FILE : MSJA4.SET

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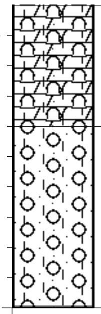
Amesfontein Solar (CSP)

HOLE No: **IP25**
Sheet 1 of 1

JOB NUMBER: 11-863

Scale
1:25



0.00	Slightly moist orange brown loose intact silty sandy GRAVEL. Gravel generally fine to medium sub-angular abundant hard rock DOLOMITE and CHERT fragments. Transported.
0.40	Slightly moist yellowish brown becoming off-white speckled and mottled dark grey (dolomite) dense calciferous moderately cemented friable silty sandy GRAVEL. Non-indurated Calcrete.
1.00	

NOTES

1) Refusal on hard rock HARDPAN CALCRETE.

2) No groundwater seepage.

3) No sidewall collapse.

4) No samples taken.

5) Final depth 1.0m.

CONTRACTOR :
MACHINE :
DRILLED BY :
PROFILED BY : SH

TYPE SET BY : AM
SETUP FILE : MSJA4.SET

INCLINATION :
DIAM :
DATE : 23/01/2012
DATE : 23/01/2012

DATE : 02/02/12 16:35
TEXT : ..\11-863\Logs\Dothead.doc

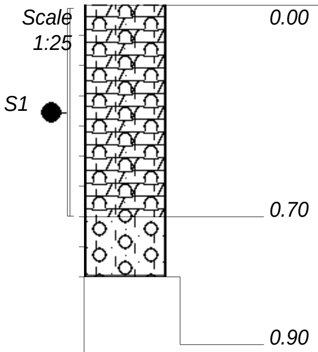
ELEVATION :
X-COORD :
Y-COORD :

HOLE No: **IP25**

WP RSA
Amesfontein Solar (CSP)

HOLE No: **IP26**
Sheet 1 of 1

JOB NUMBER: 11-863



Slightly moist orange brown loose intact silty sandy GRAVEL. Gravel generally fine to medium sub-angular abundant hard rock DOLOMITE and CHERT fragments. Transported.

Slightly moist yellowish brown becoming off-white speckled and mottled dark grey (dolomite) dense calciferous moderately cemented friable silty sandy GRAVEL. Non-indurated Calcrete.

NOTES

1) Refusal on hard rock HARDPAN CALCRETE.

2) No groundwater seepage.

3) No sidewall collapse.

4) Samples taken :
S1 0.01--0.70m (1 x Small)

5) Final depth 0.90m.

CONTRACTOR :
MACHINE :
DRILLED BY :
PROFILED BY : SH
TYPE SET BY : AM
SETUP FILE : MSJA4.SET

INCLINATION :
DIAM :
DATE : 23/01/2012
DATE : 23/01/2012
DATE : 02/02/12 16:35
TEXT : ..\11-863\Logs\Dothead.doc

ELEVATION :
X-COORD :
Y-COORD :

HOLE No: **IP26**

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WP RSA
Amesfontein Solar (CSP)

HOLE No: **IP27**
Sheet 1 of 1

JOB NUMBER: 11-863

Scale
1:25

0.00	White indurated hard rock CALCRETE fragments in a matrix of dry medium brown loose intact slightly gravelly silty SAND of Aeolian origin.
0.20	

NOTES

1) Refusal on hard rock HARDPAN CALCRETE.

2) No groundwater seepage.

3) No sidewall collapse.

4) No samples taken.

5) Final depth 0.20m.

CONTRACTOR :
MACHINE :
DRILLED BY :
PROFILED BY : SH
TYPE SET BY : AM
SETUP FILE : MSJA4.SET

INCLINATION :
DIAM :
DATE : 23/01/2012
DATE : 23/01/2012
DATE : 02/02/12 16:35
TEXT : ..\11-863\Logs\Dothead.doc

ELEVATION :
X-COORD :
Y-COORD :

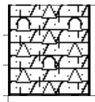
HOLE No: **IP27**

WP RSA
Amesfontein Solar (CSP)

HOLE No: **IP28**
Sheet 1 of 1

JOB NUMBER: 11-863

Scale
1:25



0.00

Slightly moist orange brown loose intact gravelly silty SAND. Gravel generally fine to medium sub-rounded abundant hard rock CHERT and DOLOMITE fragments. Transported.

0.30

NOTES

1) Refusal on hard rock hardpan calcrete.

2) No groundwater seepage.

3) No sidewall collapse.

4) No samples taken.

5) Final depth 0.30m.

CONTRACTOR :
MACHINE :
DRILLED BY :
PROFILED BY : SH

TYPE SET BY : AM
SETUP FILE : MSJA4.SET

INCLINATION :
DIAM :
DATE : 23/01/2012
DATE : 23/01/2012

DATE : 02/02/12 16:35
TEXT : ..\11-863\Logs\Dothead.doc

ELEVATION :
X-COORD :
Y-COORD :

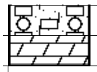
HOLE No: **IP28**

WP RSA
Amesfontein Solar (CSP)

HOLE No: **IP29**
Sheet 1 of 1

JOB NUMBER: 11-863

Scale
1:25



0.00

White indurated hard rock CALCRETE fragments in a matrix of dry medium brown loose intact slightly gravelly silty SAND of Aeolian origin.

0.10

Light grey slightly weathered thinly to medium bedded closely to moderately jointed hard rock CALCIFEROUS DOLOMITE.

0.20

NOTES

1) Refusal on hard rock calcreteous DOLOMITE BEDROCK.

2) No groundwater seepage.

3) No sidewall collapse.

4) No samples taken.

5) Final depth 0.20m.

CONTRACTOR :
MACHINE :
DRILLED BY :
PROFILED BY : SH

INCLINATION :
DIAM :
DATE : 23/01/2012
DATE : 23/01/2012

ELEVATION :
X-COORD :
Y-COORD :

HOLE No: **IP29**

TYPE SET BY : AM
SETUP FILE : MSJA4.SET

DATE : 02/02/12 16:35
TEXT : ..\11-863\Logs\Dothead.doc

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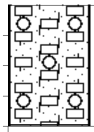
HOLE No: **IP30**
Sheet 1 of 1

JOB NUMBER: 11-863

Scale
1:25



0.00

White indurated hard rock CALCRETE fragments in a matrix of dry medium brown loose intact slightly gravelly silty SAND of Aeolian origin.

0.40

NOTES

1) Refusal on hard rock hardpan CALCRETE.

2) No groundwater seepage.

3) No sidewall collapse.

4) Final depth 0.40m.

CONTRACTOR :
MACHINE :
DRILLED BY :
PROFILED BY : SH

TYPE SET BY : AM
SETUP FILE : MSJA4.SET

INCLINATION :
DIAM :
DATE : 23/01/2012
DATE : 23/01/2012

DATE : 02/02/12 16:35
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ELEVATION :
X-COORD :
Y-COORD :

HOLE No: **IP30**

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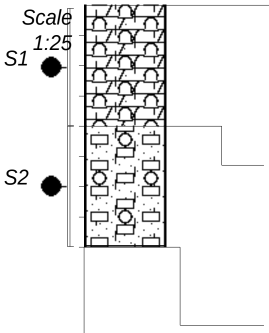
HOLE No: **IP31**
Sheet 1 of 1

JOB NUMBER: 11-863



0.00

Slightly moist orange brown loose intact silty sandy GRAVEL. Gravel generally fine to medium and occasionally coarse to cobble subrounded (fine to medium) to angular (coarse and cobble) abundant tightly packed hard rock CHERT and DOLOMITE fragments. Transported.

0.40

Dry white dense to very dense calciferous gravelly silty SAND. Gravel generally fine to coarse and occasionally cobble angular abundant moderately to well cemented medium hard to hard rock CALCRETE fragments. Non-indurated Calcrete.

0.80

NOTES

1) Refusal on hard rock CALCRETE.

2) No groundwater seepage.

3) No sidewall collapse.

4) Samples taken :
S1 0.01--0.40m (1 x Small)
S2 0.40--0.80m (1 x Small)

5) Final depth 0.80m.

CONTRACTOR :
MACHINE :
DRILLED BY :
PROFILED BY : SH

INCLINATION :
DIAM :
DATE : 23/01/2012
DATE : 23/01/2012

ELEVATION :
X-COORD :
Y-COORD :

HOLE No: **IP31**

TYPE SET BY : AM
SETUP FILE : MSJA4.SET

DATE : 02/02/12 16:35
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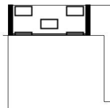
HOLE No: **IP32**
Sheet 1 of 1

JOB NUMBER: 11-863

Scale
1:25



0.00

White well cemented hard rock HARDPAN CALCRETE with a thin aeolian soil cover.

0.10

NOTES

1) Refusal on hard rock HARDPAN CALCRETE.

2) No groundwater seepage.

3) No sidewall collapse.

4) No samples taken.

5) Final depth 0.10m.

CONTRACTOR :
MACHINE :
DRILLED BY :
PROFILED BY : SH
TYPE SET BY : AM
SETUP FILE : MSJA4.SET

INCLINATION :
DIAM :
DATE : 23/01/2012
DATE : 23/01/2012
DATE : 02/02/12 16:35
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ELEVATION :
X-COORD :
Y-COORD :

HOLE No: **IP32**

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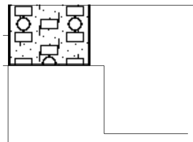
HOLE No: **IP33**
Sheet 1 of 1

JOB NUMBER: 11-863

Scale
1:25



0.00	White indurated hard rock CALCRETE fragments in a matrix of slightly moist greyish medium brown loose intact gravelly silty SAND of aeolian origin.
0.20	

NOTES

1) Refusal on hard rock HARDPAN CALCRETE.

2) No groundwater seepage.

3) No sidewall collapse.

4) No samples taken.

5) Final depth 0.20m.

CONTRACTOR :
MACHINE :
DRILLED BY :
PROFILED BY : SH
TYPE SET BY : AM
SETUP FILE : MSJA4.SET

INCLINATION :
DIAM :
DATE : 23/01/2012
DATE : 23/01/2012
DATE : 02/02/12 16:35
TEXT : ..\11-863\Logs\Dothead.doc

ELEVATION :
X-COORD :
Y-COORD :

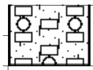
HOLE No: **IP33**

WP RSA
Amesfontein Solar (CSP)

HOLE No: **IP34**
Sheet 1 of 1

JOB NUMBER: 11-863

Scale 1:25



0.00 – *0.20*	White indurated hard rock CALCRETE fragments in a matrix of slightly moist greyish medium brown loose intact gravelly silty SAND of aeolian origin.

NOTES

1) Refusal on hard rock HARDPAN CALCRETE.

2) No groundwater seepage.

3) No sidewall collapse.

4) No samples taken.

5) Final depth 0.20m.

6) Abundant calcrete at surface.

CONTRACTOR :
MACHINE :
DRILLED BY :
PROFILED BY : SH
TYPE SET BY : AM
SETUP FILE : MSJA4.SET

INCLINATION :
DIAM :
DATE : 23/01/2012
DATE : 23/01/2012
DATE : 02/02/12 16:35
TEXT : ..\11-863\Logs\Dothead.doc

ELEVATION :
X-COORD :
Y-COORD :

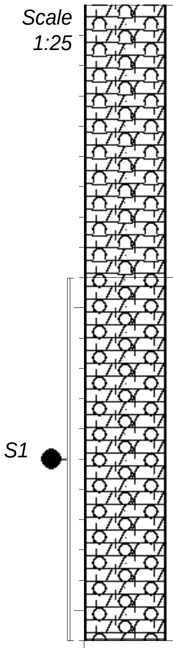
HOLE No: **IP34**

WP RSA
Amesfontein Solar (CSP)

HOLE No: **IP36**
Sheet 1 of 1

JOB NUMBER: 11-863

Scale
1:25



0.00

Slightly moist orange brown loose intact silty sandy GRAVEL. Gravel generally fine to medium and occasionally coarse to cobble abundant hard rock DOLOMITE and CHERT fragments. Transported.

0.90

Slightly moist slightly yellowish brown dense to very dense reworked silty sandy GRAVEL. Gravel generally fine to medium and occasionally coarse to cobble abundant tightly packed hard rock DOLOMITE fragments. Residual Dolomite.

2.10

NOTES

1) Refusal on very soft rock DOLOMITE.

2) No groundwater seepage.

3) No sidewall collapse.

4) Samples taken :
S1 0.90--2.10m (1 x Small)

5) Final depth 2.10m.

CONTRACTOR :
MACHINE :
DRILLED BY :
PROFILED BY : SH
TYPE SET BY : AM
SETUP FILE : MSJA4.SET

INCLINATION :
DIAM :
DATE : 23/01/2012
DATE : 23/01/2012
DATE : 02/02/12 16:35
TEXT : ..\11-863\Logs\Dothead.doc

ELEVATION :
X-COORD :
Y-COORD :

HOLE No: **IP36**

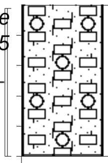
WP RSA
Amesfontein Solar (CSP)

HOLE No: **IP37**
Sheet 1 of 1

JOB NUMBER: 11-863

Scale
1:25

S1 ●



0.00

White indurated hard rock CALCRETE fragments in a matrix of slightly moist orange brown loose intact gravelly silty SAND of aeolian origin.

0.50

NOTES

1) Refusal on hard rock HARDPAN CALCRETE.

2) No groundwater seepage.

3) No sidewall collapse.

4) Samples taken :
S1 0.01--0.50m (1 x Small)

5) Final depth 0.50m.

CONTRACTOR :
MACHINE :
DRILLED BY :
PROFILED BY : SH
TYPE SET BY : AM
SETUP FILE : MSJA4.SET

INCLINATION :
DIAM :
DATE : 23/01/2012
DATE : 23/01/2012
DATE : 02/02/12 16:35
TEXT : ..\11-863\Logs\Dothead.doc

ELEVATION :
X-COORD :
Y-COORD :

HOLE No: **IP37**

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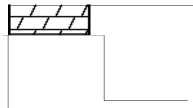
Amesfontein Solar (CSP)

HOLE No: **IP38**
Sheet 1 of 1

JOB NUMBER: 11-863

Scale
1:25



0.00

Medium to light grey slightly weathered calciferous hard rock DOLOMITE with a thin aeolian soil cover.

0.10

NOTES

1) Refusal on hard rock DOLOMITE BEDROCK.

2) No groundwater seepage.

3) No sidewall collapse.

4) No samples taken.

5) Final depth 0.10m (bedrock at surface).

CONTRACTOR :
MACHINE :
DRILLED BY :
PROFILED BY : SH

INCLINATION :
DIAM :
DATE : 23/01/2012
DATE : 23/01/2012

ELEVATION :
X-COORD :
Y-COORD :

HOLE No: **IP38**

TYPE SET BY : AM
SETUP FILE : MSJA4.SET

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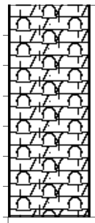
WP RSA
Amesfontein Solar (CSP)

HOLE No: **IP40**
Sheet 1 of 1

JOB NUMBER: 11-863

Scale
1:25



0.00

Slightly moist orange brown loose intact silty sandy GRAVEL. Gravel generally fine to medium and occasionally coarse to cobble subrounded (fine to medium) to angular (coarse and cobble) abundant tightly packed hard rock CHERT and DOLOMITE fragments. Transported.

0.70

NOTES

1) Refusal on hardrock hardpan CALCRETE.

2) No groundwater seepage.

3) No sidewall collapse.

4) No samples taken.

5) Final depth 0.70m.

CONTRACTOR :
MACHINE :
DRILLED BY :
PROFILED BY : SH

INCLINATION :
DIAM :
DATE : 23/01/2012
DATE : 23/01/2012

ELEVATION :
X-COORD :
Y-COORD :

HOLE No: **IP40**

TYPE SET BY : AM
SETUP FILE : MSJA4.SET

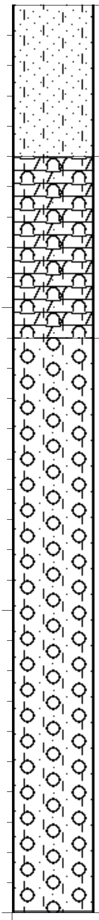
DATE : 02/02/12 16:35
TEXT : ..\11-863\Logs\Dothead.doc

WP RSA
Amesfontein Solar (CSP)

HOLE No: **IP41**
Sheet 1 of 1

JOB NUMBER: 11-863

Scale
1:25



0.00	Slightly moist orange brown loose intact silty SAND. Transported.
0.50	Slightly moist orange brown loose intact silty sandy GRAVEL. Gravel generally fine to coarse and occasionally cobble sub-angular abundant tightly packed hard rock CHERT and DOLOMITE fragments. Transported.
1.10	Slightly moist yellowish brown becoming off-white speckled and mottled dark grey (dolomite) dense calciferous moderately cemented friable silty sandy GRAVEL. Non-indurated Calcrete.
3.00	

NOTES

1) No refusal in dense to very dense material.

2) No groundwater seepage.

3) No sidewall collapse.

4) No samples taken.

5) Final depth 3.00m.

CONTRACTOR :
MACHINE :
DRILLED BY :
PROFILED BY : SH

INCLINATION :
DIAM :
DATE : 23/01/2012
DATE : 23/01/2012

ELEVATION :
X-COORD :
Y-COORD :

HOLE No: **IP41**

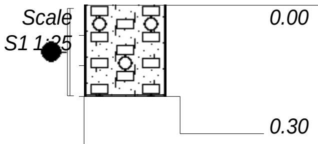
TYPE SET BY : AM
SETUP FILE : MSJA4.SET

DATE : 02/02/12 16:35
TEXT : ..\11-863\Logs\Dothead.doc

WP RSA
Amesfontein Solar (CSP)

HOLE No: **IP42**
Sheet 1 of 1

JOB NUMBER: 11-863



Dry white indurated fragments of hard rock CALCRETE in a matrix of slightly moist medium brown loose intact gravelly silty SAND of Aeolian origin.

NOTES

1) Refusal on hardrock HARDPAN CALCRETE.

2) No groundwater seepage.

3) No sidewall collapse.

4) Samples taken :
S1 0.01--0.30m (1 x Small)

5) Final depth 0.30m.

CONTRACTOR :
MACHINE :
DRILLED BY :
PROFILED BY : SH
TYPE SET BY : AM
SETUP FILE : MSJA4.SET

INCLINATION :
DIAM :
DATE : 23/01/2012
DATE : 23/01/2012
DATE : 02/02/12 16:35
TEXT : ..\11-863\Logs\Dothead.doc

ELEVATION :
X-COORD :
Y-COORD :

HOLE No: **IP42**

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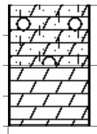
WP RSA
Amesfontein Solar (CSP)

HOLE No: **IP43**
Sheet 1 of 1

JOB NUMBER: 11-863

Scale
1:25



0.00	Dry medium brown loose intact gravelly silty SAND with abundant cobble sized calciferous DOLOMITE fragments. Transported.
0.20	Light grey slightly weathered thinly to medium bedded closely to moderately jointed hard rock calciferous DOLOMITE.
0.40	

NOTES

1) Refusal on hard rock calciferous DOLOMITE BEDROCK.

2) No groundwater seepage.

3) No sidewall collapse.

4) No samples taken.

5) Abundant of dolomite bedrock cropping out at surface.

6) Final depth 0.40m.

CONTRACTOR :
MACHINE :
DRILLED BY :
PROFILED BY : SH
TYPE SET BY : AM
SETUP FILE : MSJA4.SET

INCLINATION :
DIAM :
DATE : 23/01/2012
DATE : 23/01/2012
DATE : 02/02/12 16:35
TEXT : ..\11-863\Logs\Dothead.doc

ELEVATION :
X-COORD :
Y-COORD :

HOLE No: **IP43**

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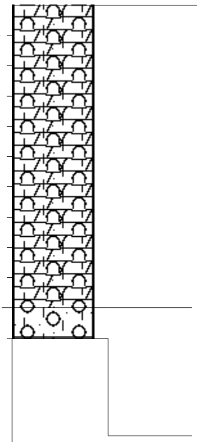
WP RSA
Amesfontein Solar (CSP)

HOLE No: **IP44**
Sheet 1 of 1

JOB NUMBER: 11-863

Scale
1:25



0.00

Slightly moist orange brown loose intact silty sandy GRAVEL. Gravel generally fine to coarse and occasionally cobble sub-angular abundant tightly packed hard rock CHERT and DOLOMITE fragments. Transported.

1.00

Slightly moist yellowish brown becoming off-white speckled and mottled dark grey (dolomite) dense calciferous moderately cemented friable silty sandy GRAVEL. Non-indurated Calcrete.

1.10

NOTES

1) Refusal on medium hard to hard rock HARDPAN CALCRETE.

2) No groundwater seepage.

3) No sidewall collapse.

4) Final depth 1.10m.

CONTRACTOR :
MACHINE :
DRILLED BY :
PROFILED BY : SH

TYPE SET BY : AM
SETUP FILE : MSJA4.SET

INCLINATION :
DIAM :
DATE : 23/01/2012
DATE : 23/01/2012

DATE : 02/02/12 16:35
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ELEVATION :
X-COORD :
Y-COORD :

HOLE No: **IP44**

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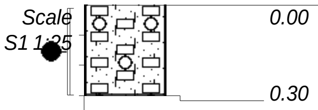
Amesfontein Solar (CSP)

HOLE No: **IP45**
Sheet 1 of 1

JOB NUMBER: 11-863



White indurated hard rock CALCRETE fragments in a matrix of slightly moist orange brown loose intact gravelly silty SAND of aeolian origin.

NOTES

1) Refusal on hard rock hardpan CALCRETE.

2) No groundwater seepage.

3) No sidewall collapse.

4) Samples taken :
S1 0.01--0.30m (1 x small)

5) Final depth 0.30m.

CONTRACTOR :
MACHINE :
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PROFILED BY : SH

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MOORE SPENCE JONES
+27 31 267 7202 www.msjdbn.com
GEOTECHNICAL, CIVIL & ENVIRONMENTAL ENGINEERS

WP RSA
Amesfontein Solar (CSP)

HOLE No: **IP46**
Sheet 1 of 1

JOB NUMBER: 11-863

Scale
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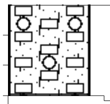

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White indurated hard rock CALCRETE fragments in a matrix of slightly moist orange brown loose intact gravelly silty SAND of aeolian origin.

0.30

NOTES

1) Refusal on hardpan CALCRETE (shows relic dolomite structure).

2) No groundwater seepage.

3) No sidewall collapse.

4) No samples taken.

5) Final depth 0.30m.

CONTRACTOR :
MACHINE :
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PROFILED BY : SH

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DIAM :
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DATE : 23/01/2012

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HOLE No: **IP46**

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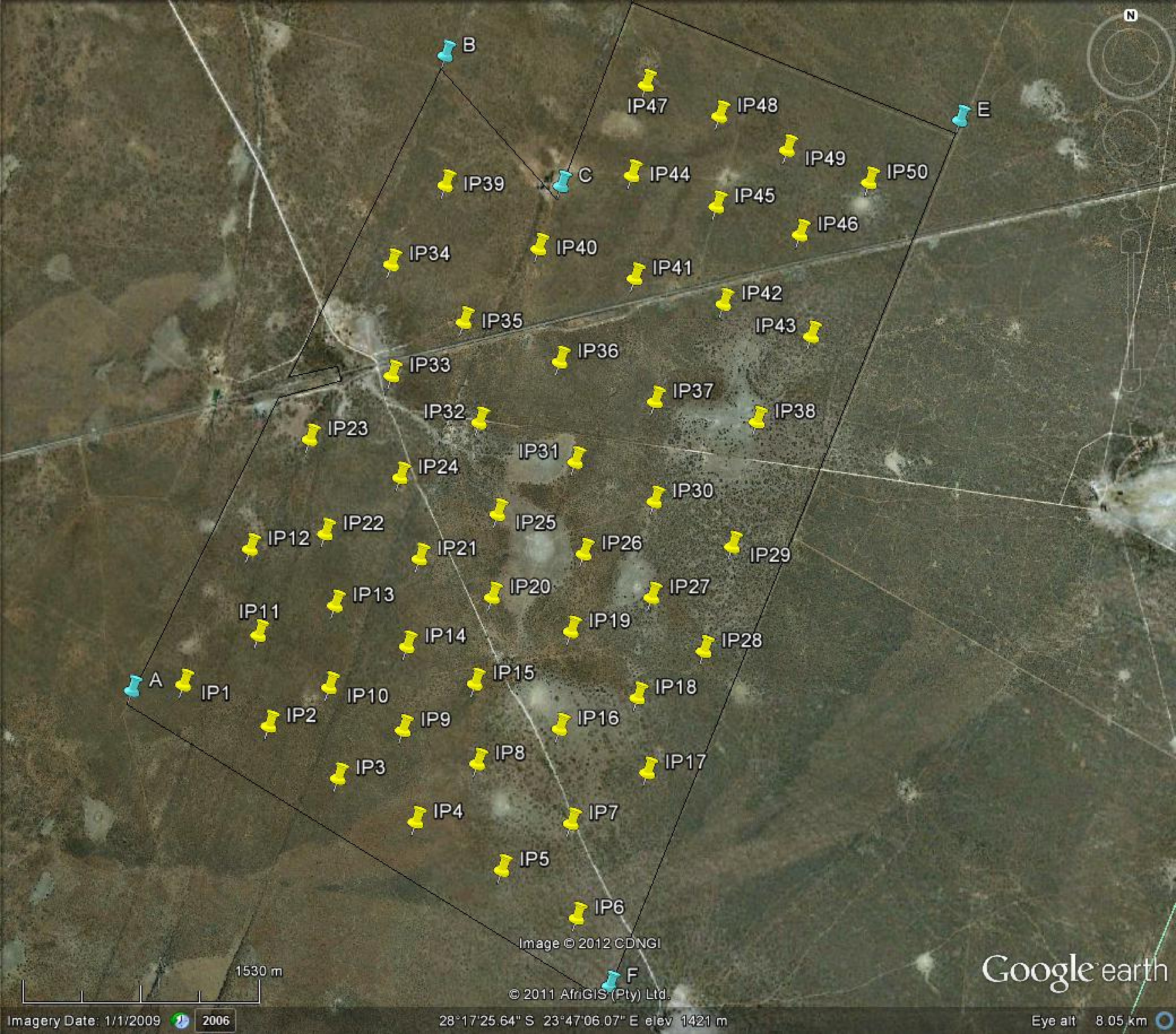
APPENDIX C
Site Plan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IP7
IP5
IP6
Image © 2012 CDNGI
1530 m
F
Google earth
© 2011 AfriGIS (Pty) Ltd.
Imagery Date: 1/1/2009
2006
28°17'25.64" S 23°47'06.07" E elev 1421 m
Eye alt 8.05 km

Appendix H–Geo Hydrological Environmental Impact Assessment

Geohydrological Impact Assessment Report for the Proposed Arriesfontein Concentrated Solar Power Plant

Report Prepared for

WorleyParsons RSA (Pty) Ltd

Report Number 441553/Impact

Report Prepared by

srk consulting

July 2012

Geohydrological Impact Assessment Report for the Proposed Arriesfontein Concentrated Solar Power Plant

WorleyParsons RSA (Pty) Ltd

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July 2012

Compiled by:	**Peer Reviewed by:**
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Email: dvisser@srk.co.za

Authors:

CJ Esterhuyse, Dr I Dennis (Independent Consultant) and D Visser

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Disclaimer

The opinions expressed in this Report have been based on the information supplied to SRK Consulting (South Africa) (Pty) Ltd (SRK) by WorleyParsons RSA (Pty) Ltd and the local land owners as well as NGA data from the Department of Water Affairs. SRK has exercised due care in reviewing the supplied information. Whilst SRK has compared the available data with expected values, the accuracy of the results and conclusions from the review are entirely reliant on the accuracy and completeness of the available data. SRK does not accept responsibility for any errors or omissions in the supplied information and does not accept any consequential liability arising from commercial decisions or actions resulting from them. Opinions presented in this report apply to the site conditions and features as they existed at the time of SRK's investigations, and those reasonably foreseeable. These opinions do not necessarily apply to conditions and features that may arise after the date of this Report, about which SRK had no prior knowledge nor had the opportunity to evaluate.

Glossary of Terms

Aquifer: A water-bearing geological formation capable of supplying economic quantities of groundwater to wells, boreholes and springs.

Aquitard: A saturated geological unit with a relatively low permeability that retards, but does not prevent the movement of water; while it may not readily yield water to boreholes and springs, it may act as a storage unit.

Aquiclude: A geological unit with a very low permeability that severely restricts groundwater movement. GRU boundaries are commonly formed by aquicludes, e.g. dykes.

Contamination: The introduction of any substance into the environment by the action of man.

Fractured-rock Aquifer: Aquifers where groundwater occurs within fractures and fissures in hard-rock formations.

Groundwater: Refers to the water filling the pores and voids in geological formations below the water table.

Groundwater Flow: The movement of water through openings and pore spaces in rocks below the water table i.e. in the saturated zone. Groundwater naturally drains from higher lying areas to low lying areas such as rivers, lakes and the oceans. The rate of flow depends on the slope of the water table and the transmissivity of the geological formations.

Groundwater Recharge: Refers to the portion of rainfall that actually infiltrates the soil, percolates under gravity through the unsaturated zone (also called the Vadose Zone) down to the saturated zone below the water table (also called the Phreatic Zone).

Groundwater Resource: All groundwater available for beneficial use, including by man, aquatic ecosystems and the greater environment.

Groundwater Resource Units: (GRU's) Represent provisional zones defined for the purposes of assessing and managing the groundwater resources of a region, in terms of large-scale abstraction from relatively shallow (depth < 300m) production boreholes. They represent areas where the broad geohydrological characteristics (i.e. water occurrence and quality, hydraulic properties, flow regime, aquifer boundary conditions etc.) are anticipated to be similar. Sometimes also called Groundwater Resource Units (GRU's).

Intergranular Aquifer: Aquifers where groundwater is contained in original intergranular interstices of sedimentary and weathered formations.

Major Aquifer System: Highly permeable formations, usually with a known or probable presence of significant fracturing and/or intergranular porosity; may be highly productive and able to support large abstractions for public supply and other purposes; water quality is generally very good.

Minor Aquifer System: Fractured or potentially fractured rocks that do not have a high primary permeability, or other formations of variable permeability; aquifer extent may be limited and water quality variable. Although these aquifers seldom produce large quantities of water, they are important both for local supplies and in supplying base flow for rivers.

Non-Aquifer: A groundwater body that is essentially impermeable, does not readily transmit water and/or has a water quality that renders it unfit for use.

Non-Aquifer Systems: formations with negligible permeability that are generally regarded as not containing groundwater in exploitable quantities; water quality may also be such that it renders the aquifer unusable; groundwater flow through such rocks does take place and needs to be considered when assessing the risk associated with persistent pollutants.

Permeability: The ease with which a fluid can pass through a porous medium and is defined as the volume of fluid discharged from a unit area of an aquifer under unit hydraulic gradient in unit time (expressed as $m^3/m^2 \cdot d$ or m/d). It is an intrinsic property of the porous medium and is independent of the properties of the saturating fluid; not to be confused with *hydraulic conductivity*, which relates specifically to the movement of water.

Pollution: The introduction into the environment of any substance by the action of man that is, or results in, significant harmful effects to man or the environment.

Recharge: The addition of water to the zone of saturation, either by the downward percolation of precipitation or surface water and/or the lateral migration of groundwater from adjacent aquifers.

Saline Water: Water that is generally considered unsuitable for human consumption or for irrigation because of its high content of dissolved solids.

Saturated Zone: The subsurface zone below the water table where interstices are filled with water under pressure greater than that of the atmosphere

Specific Yield: Ratio of the volume of water that a given mass of saturated rock or soil will yield by gravity from that mass.

Storativity (S): The volume of water released from storage per unit of aquifer storage area per unit change in head.

Unconfined Aquifer: An aquifer with no confining layer between the water table and the ground surface where the water table is free to fluctuate.

Unsaturated Zone: That part of the geological stratum above the water table where interstices and voids contain a combination of air and water; synonymous with *zone of aeration* or *vadose zone*.

Water Table: The upper surface of the saturated zone of an unconfined aquifer at which pore pressure is at atmospheric pressure, the depth to which may fluctuate seasonally.

List of Abbreviations

CSPP	Concentrated Solar Power Plant
DWA	Department of Water Affairs (previously DWAF)
DWAF	Department of Water Affairs and Forestry
EC	Electrical Conductivity
GA	General Authorisation
GRU	Groundwater Resource Unit
ℓ/s	litres per second
m	metres
m amsl	metres above mean sea level
m bgl	metres below ground level
mg/ℓ	milligrams per litre
mm	millimetres
mS/m	milli-Siemens per metre
m^3/a	cubic metres per annum
m^3/d	cubic metres per day
m^3/hr	cubic metres per hour
m^3/m	cubic metres per month
NGA	National Groundwater Archive (Previously NGDB)
SRK	SRK Consulting (SA) Pty Ltd

1 Introduction

In October 2011 SRK Consulting was appointed by WorleyParsons RSA (Pty) Ltd on behalf of SolarReserve SA (Pty) LTD, to conduct a detailed groundwater resource assessment and provide specialist input to the Waste Management Licence Application, Environmental Impact Assessment and the Water Use Licence required for a proposed Concentrated Solar Power Plant (CSPP) on the farm Arriesfontein (the site) near Lime Acres in the Northern Cape Province.

SolarReserve SA (Pty) LTD, a renewable energy developer is proposing the development of a CSPP with an electricity generation of 100 MW on the Farm 267, Arriesfontein, Barkley Wes RD, within the Kgatelopele Local Municipality and the Siyanda District Municipality in the Northern Cape. The proposed site is situated approximately 32 km south-east of Danielskuil (**Figure 1**). The proposed CSPP will be constructed on an area that covers between 600 and 800 ha of the site, including all ancillary facilities.

Towns (Daniëlskuil and Lime Acres) and mines (Idwala Lime, PPC Lime and Finch) in the area are largely dependent on groundwater with a lesser portion of the demand being supplied by the Vaal-Gamagara pipeline. Farms are totally dependent on groundwater for domestic use, stock watering and some small-scale irrigation.

1.1 Scope of Work

The following scope of work and deliverables provided by WorleyParsons apply:

1. To provide a detailed description of the site topography, geological and geohydrological characteristics of the study area;
2. Depiction and characterization of the groundwater regime in a regional geological and geohydrological context indicating the overall characteristics of the geological settings and aquifer parameters, and identification of immediate groundwater users;
3. Data obtained from the hydrocensus survey as well as the data obtained from the National Groundwater Archive (NGA) to be incorporated into the GIS database for interpretation;
4. A desktop study to be undertaken for the analysis of data obtained from the National Groundwater Archive (NGA);
5. Site visit for purposes of the hydrocensus and consultation with relevant landowners to obtain additional (to the NGA) borehole data, if available;
6. Determination of pre-project groundwater quality by means of baseline groundwater quality monitoring and sampling;
7. Assess the potential impacts (direct, indirect and cumulative) of the proposed development and the significance thereof on groundwater resources and downstream water users in the general area.
8. Description of groundwater management measures related to all project phases;
9. Compile a groundwater monitoring protocol and a report containing groundwater data and analysis;
10. A groundwater model illustrating the above mentioned analysis will be required;

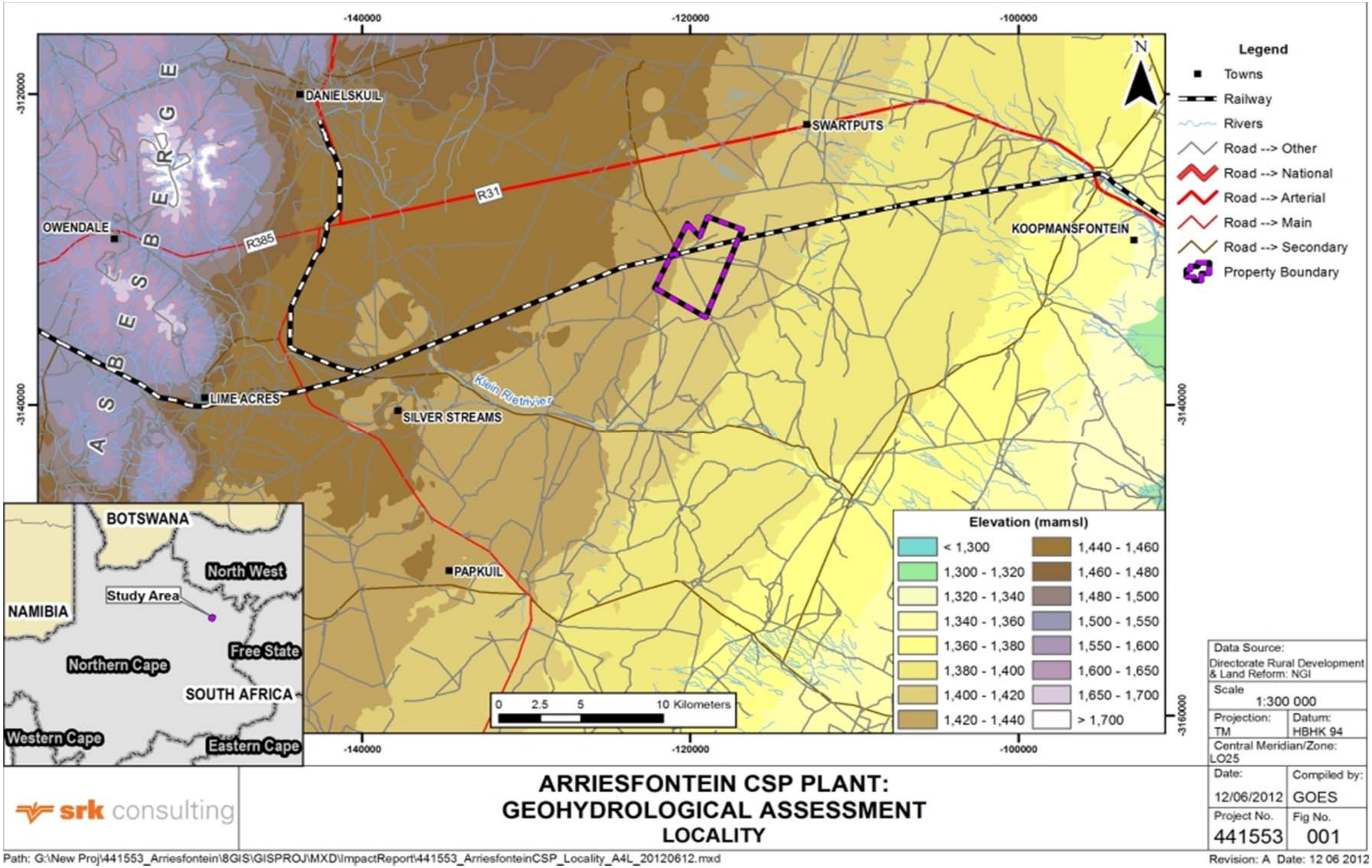

Figure 1: Locality of the Arriesfontein CSP Plant Site

11. Attend a specialist integration workshop to be held with the specialist project team during the EIA phase of the project prior to the finalisation of the respective specialist reports. The aim of this workshop will be to:
    1) Discuss and evaluate the findings of each of the various specialist studies;
    2) Integrate findings to identify workable solutions;
    3) Recommend appropriate mitigation measures, where required, and
    4) Formulate final recommendations.
12. Following the phase-specific specialist workshop, specialists will be required to finalise the various specialist reports for inclusion in the EIA Report.
13. Recommendations on any further studies / additional scope of work that may be required during or after the EIA process.

1.2 Deliverables

The Project deliverables are:

1. Groundwater Resource Assessment and Scoping Report (for the EIA/Waste Management Licence); and
2. Groundwater Impact Assessment Report (for the EIA/Waste Management Licence).

1.3 Methodology

The methodology employed for the investigation was as follows:

- All existing groundwater related information was collated and reviewed for the site and its surrounds. This included information from existing reports, the Department of Water Affairs' NGA, Water Authorisation and Registration Management System (WARMS database) and published maps;
- A detailed hydrocensus was carried out to locate existing boreholes, shallow wells and springs on the property, as well as a representative number of private boreholes, wells and springs that occur on the surrounding properties. During this field survey water levels, current abstraction, type of equipment, water usage, and basic chemistry based on field testing and any other information that was available from the owners/operators were measured and recorded;
- Groundwater resource units (GRUs) were delineated for the site and the surrounding catchment and the recharge, exploitation potential, and water balance of the groundwater resources in each GRU were derived. For this purpose the GIS grids generated for the DWA National Groundwater Resource Assessment, Phase 2 was used. The quality of the groundwater resources in each GRU was also assed. All data were captured into an ArcGIS 10 database and the aquifers defined and groundwater flow directions, aquifer boundaries, e.g. structural and lithological were defined;
- The current and anticipated groundwater uses were compared to the exploitation potential of the aquifers in the GRUs;
- Potential groundwater bearing structures and formations were mapped on satellite imagery and aerial photographs using the ArcGIS desktop software. The geological data of the area

were obtained and georeferenced for use in the GIS. The boreholes and other relevant groundwater information were superimposed on GIS generated maps for analysis;

- The data were analysed and a Scoping Report compiled.
- Limited geophysical surveys were carried out to assist in defining any dykes, faults and sinkhole structures that can transport contaminants and in siting of test and production boreholes.
- Four test boreholes were drilled to assess the aquifer parameters and groundwater quality at the CSP plant and waste water evaporation pond footprint area. One of these boreholes was drilled 10″ diameter and equipped with 8″ casing to test the yield capacity of the dolomitic aquifer for water supply. Based on the projected groundwater levels (5 – 10 m bgl) and the geology of the site area (dolomitic with dolerite dykes and karst formation), these boreholes were drilled ~50 m deep.
- The four test boreholes and two existing boreholes was test pumped to determine their yield capacity, aquifer parameters and water quality. Test pumping complied with the DWA's minimum requirements. Test pumping consisted of a step drawdown test (SDT) consisting of 4 x 60 minute consecutive tests each at a higher pumping rate. After completion the water level was allowed to recover whereafter a 24 to 72 hr constant discharge test (CDT) was carried out. *Note: Duration of CDTs depended on the blow yield / or reported yield of each borehole*. At completion the water level recovery was once again monitored for up to 48 hrs or until full recovery was achieved. During these tests the water level, discharge rate, electrical conductivity, pH and temperature of the water abstracted were measured at fixed intervals. Other nearby boreholes/springs, if any, was also monitored during testing. *Note: As the dolomitic aquifers can be high yielding, provision was made for test pumps that can yield up to 20 and 30 ℓ/s.*
- After testing of each of the existing boreholes, of which only the two highest yielding ones which were in good enough physical condition, were tested, the physical condition of the borehole (walls and casing) were to be inspected with a down-hole video camera. This camera survey was proposed to assess if the borehole can be safely use for production purposes, or not. The video log would have been recorded and transfer to CD/DVD, for inclusion in the report or provided to client of required. *Note: In view of the poor pump testing results of the existing boreholes, which rendered them unsuitable for production usage, it was decided that it would be a waste of money to carry out the proposed video-camera surveys.*
- The test pumping data were analysed by a SACNASP registered principal hydrogeologist in order to determine aquifer parameters such as transmissivity and storativity, as well as the sustainable yield and pumping schedule of each borehole.
- At the end of each CDT a groundwater sample was collected for macro-chemical and trace element analysis at a SANAS accredited laboratory.
- A conceptual and basic numerical hydrogeological model was drawn up to simulate the long term impacts of abstraction and potential contaminant transport.
- The potential impacts on the environment and other water users were assessed and mitigation measures formulated. A baseline and operational groundwater monitoring programme was defined and a hydrogeological report compiled for comparing the results to the anticipated demand, and for inclusion in the scoping report and EIA.

1.4 Work Programme

A hydrocensus of the boreholes on the site and the surrounding properties was conducted on 18 November 2011. The owners of three adjacent farms (Mr. Johan Visser of Hartebeesput, Mr. Keith Williams of Arbeidsloon and Mr. Kobus van Niekerk of Kristalpan) could not be located and the fourth, Mr. Gerrit Nieuwoudt, owner of the farms Constantia, Vlakpan and Hopefield, was busy with farming activities and could not meet with field personnel for the hydrocensus. Boreholes on Arriesfontein were visited in the presence of the owner, Mr. Gerrie Cloete, and geohydrological data such as borehole depths, yields, groundwater strikes and depth of pump intakes were obtained from him. Other relevant geohydrological data like groundwater levels, quality, equipment, etc. were measured and recorded. Simultaneously, the local geology was noted and red flag areas sensitive to geohydrological impact identified.

The scoping report was submitted on 30 November 2012. After a long delay due the unavailability of a site layout plan, site investigation continued in May 2012. A site layout and sensitivity plan was received on 24 May 2012. As these plans did not indicate a proposed position for the evaporation ponds, SRK subsequently selected a suitable site based on favourably geohydrological conditions. The geophysical surveys were carried out in April 2012, to locate sites for drilling of exploration/test boreholes. Drilling commenced on 7 May 2012 and was completed by 11 May 2012. Test pumping of the existing boreholes started on 26 April 2012 and testing of the new boreholes was completed by 20 May 2012.

2 Project Description

2.1 Introduction

SolarReserve SA (Pty) Ltd (hereinafter referred to as SRSA) plans to construct CSP plants on the site. The following project description was provided by WorleyParsons, *quote*:

The CSPPs are designed as Solar Power Towers, which capture and focus the sun's thermal energy with thousands of heliostats (tracking mirrors) with an effective area of approximately 1.1 million m^2*. The tower is erected in an inner circle inside the heliostat field. The heliostats focus concentrated sunlight towards the tower where it is absorbed by a receiver which sits on top of the tower. The concentrated sunlight within the receiver, heats the molten salt (heat transfer medium consisting of sodium and potassium nitrate) up to 580ºC, which then flows into a thermal storage tank for storage (maintaining 99% thermal efficiency).*

The molten salt is eventually pumped to a steam generator to generate steam to drive a standard turbine in order to generate electricity. This process, also known as the "Rankine cycle" and is very similar to the operations of a standard coal-fired power plant, except for the fact that it is fuelled by clean, renewable and free solar energy.

In short the electricity generation process can be summarised as follows:

- *Heliostats reflect the solar radiation towards the central receiver tower;*
- *The salt complex is pumped from the cold salts thermal storage tank to the central receiver. The salt complex is transported through the central receiver tower by means of extremely thin tubes;*
- *The molten salt complex is heated up to approximately 580ºC and is circulated in the central receiver tower;*
- *The molten salt concentration is then transported to the hot salt thermal storage tank;*

- *Energy is transferred by means of a heat exchanger or steam generator to generate steam for the turbine;*
- *The highly pressurised steam is then passed through a steam turbine to generate electricity;*
- *The salt complex cools down to an approximate 288ºC in the steam generator; and*
- *After this process is completed, the molten salt concentrate is transported to the cold salt thermal storage tank – in order for the electricity generation cycle to commence once more.*

The STEP Plant comprises four main subsystems which will be summarised below:

1. *Solar Field – the solar field consists out of all services and infrastructure related to the management and operation of the heliostats;*
2. *Molten Salt Circuit which includes the thermal storage tanks for storing the hot and cold liquid salt, a concentration tower, pipelines and heat exchangers);*
3. *The Power Block; and*
4. *Auxiliary facilities and infrastructure which includes the steam turbine, condenser-cooling system, electricity transmission lines, a grid connection, access routes, water supplies and facility start-up energy plant (gas or diesel generators).*

Three (3) different plant setups are under investigation for the Arriesfontein site of which 3 (Hybrid Cooled Zero Discharge System) is the preferred setup. The annual water demands of the different setups are as follow:

1. *Dry Cooled Zero Discharge System - 169,200* m^3
2. *Dry Cooled Non Zero Discharge System - 211,900* m^3
3. *Hybrid Cooled Zero Discharge System - 246,200* m^3

The facility will cover an approximate area of 600 – 800 ha and will also include arrays of photovoltaic (PV) cells. The sun emits photons (light), which generate electricity when they strike a photovoltaic cell. This is known as the photovoltaic effect. PV cells are made from a semi-conducting material. Thus the PV power plant generates power by converting sunlight – the most abundant energy source on the planet, directly into electricity. PV cells generate direct current (DC) electricity whilst the ESCOM grid distributes alternating current (AC) electricity. Therefore, feeding of PV generated electricity into the grid requires the transformation of DC into AC by a special, grid-controlled solar inverter.

The planned layout of the plant is shown in **Figure 2**. The bulk of the surface area of the plant will be covered by the heliostats in a circular configuration. The concentration tower will be the focal point of the heliostats and will be located slightly off-centre to the north of the circular heliostat field, due to the fact that the project is in the southern hemisphere and reflects the solar rays optimally to the tower as such.

All the ancillary infrastructure and facilities are to be located adjacent to the tower within the inner circle of the heliostat field.

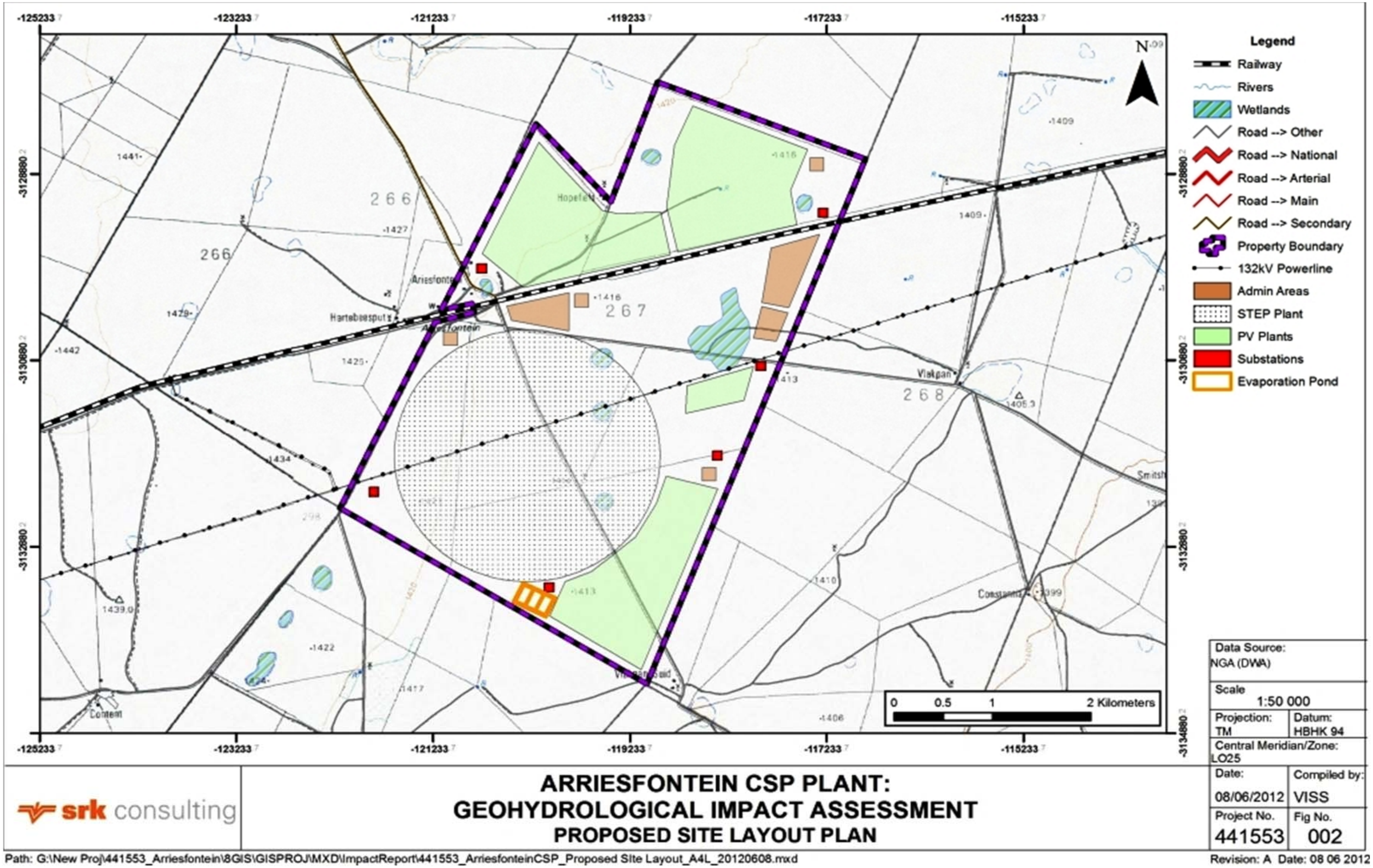

Figure 2: Layout Plan of the Proposed Arriesfontein CSP Plant

2.2 Water Use

2.2.1 Operational

During normal operational conditions the preferred CSPP will require approximately 272 400 m^3 per year with peak consumption of approximately 44.5 m^3/hr. The preferred plant operates on dry cooling as well as hybrid cooling depending on power plant operational point and cooling requirements. This provides an optimal solution between achieving required plant efficiencies and using as little water as possible.

The plant is also optimized to re-use water where possible and the total system discharge from the plant is fed to an evaporation pond, a yearly total of approximately 59 600 m^3.

2.2.2 Construction

During the construction phase water is needed to ensure and maintain soils/surfaces are kept hydrated (wet) during earthmoving operations to minimise dust generation. For a 100 MW CSPP it is estimated that approximately 117 500 m^3 of water will be required for the entire construction phase, which is estimated to extend over a period of 30 months, i.e. an average of 3 917 m^3/month or ~130 m^3/day.

2.3 Waste Water

The CSPP will generate several forms of liquid effluent as part of operations. The primary effluents sources generated include:

- Wastewater from the evaporation plant;
- Contaminated surface water i.e. stormwater and rainwater; and
- Sewage effluent.

For a 100 MW plant it is estimated that the total volume of discharge, inclusive of sewage water and evaporation system discharge will be between 116 320 and 145 400m^3 per annum.

The treatment options are based on the types of effluent to be treated. The following treatment options have been defined for each source of effluent:

- Contaminated water treatment system will be installed to separate both clean and dirty surface water where after the different types of grease/hydrocarbon products will be treated and clean surface runoff diverted away from site.
- A biological treatment system will be implemented to treat the sewage effluent from the offices.

3 Baseline Data

3.1 Physiography and Climate

The site is located ~32 km south-east of Daniëlskuil (**Figure 1**) and ~9 km south of the R31 route from Kimberley to Postmasburg. Drainage is in a southerly direction towards the Klein Riet River, which drains in a south-easterly direction to the Vaal River. The terrain in the study area is very flat with a general slope of ~1:2 000 or 0.05% to the south-east.

The elevation of the study area varies between ~1 410 m amsl in the south-eastern corner of the farm and 1 425 m amsl at the Arriesfontein homestead near the north-western boundary of the farm. Numerous pans occur in the area of which several could have formed by subsidence of sinkholes.

The climate of the area is typical of a semi-desert with very hot summers and cold winters. Temperature data for Kimberley, ~140 km east of the site (as supplied by the South African Weather Service), for the period 1961-2000 is summarized in **Table 1** below. The data indicate that January is the hottest month with an average maximum daily temperature of 32°C and June the coldest, with an average maximum daily temperature of 18.4°C. During July the average minimum daily temperature drops to only 2.5°C. The maximum temperature reached during this period was 40.9°C and the lowest -8.1°C.

Table 1: Temperature Data for Kimberley (South African Weather Service)

KIMBERLEY CLIMATIC AVERAGES 1960-2000													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
MAX TEMP	32.6	31.2	28.9	25	21.5	18.4	18.8	21.4	25.7	28	30.1	32.1	26.2
MIN TEMP	17.7	17.3	15.2	10.7	6.2	2.8	2.5	4.7	8.8	11.9	14.5	16.5	10.7
AVE TEMP	25.2	24.3	22	17.9	13.9	10.6	10.6	13.1	17.3	19.9	22.3	24.3	18.5
KIMBERLEY CLIMATIC ABSOLUTES 1960-2000													
HIGHEST TEMP	40.4	39.9	37.8	34.9	31.3	26.6	26.8	31.2	36.6	37.6	39.2	40.9	40.9
LOWEST TEMP	6.5	5.6	2	-2.8	-5.7	-7.9	-8.1	-7.8	-5.5	-0.5	2.5	3.8	-8.1

The average monthly precipitation and standard deviation (SD) values for the study area, as provided by the South African Rain Atlas, are summarized in **Table 2** below. The site falls within the summer rainfall area with a mean annual precipitation (MAP) of 458 mm.

Table 2: Precipitation Statistics for the Arriesfontein Area (Source: South African Rain Atlas)

Month	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Year*
Mean (mm):	*73.9*	*87.1*	*88.8*	*48.5*	*17.1*	*5.9*	*4.1*	*6.4*	*12.8*	*25.3*	*35.7*	*52.4*	***458.2***
SD (mm):	*40.3*	*44.6*	*43.5*	*30.8*	*16.3*	*8.8*	*7.2*	*9.8*	*14.9*	*21.1*	*24.9*	*32.0*	***94.2***

Station Coordinates: S28°17' E023°46' SD = Standard Deviation

The data indicate that 84% of the precipitation occurs during the months November to April. This phenomenon is characteristic of a summer rainfall area. March is the wettest month with an average precipitation of ~89 mm, whilst July is the driest with 4 mm.

The rainfall distribution for the study area is indicated in **Figure 3**. Rainfall generally decreases from site to the east, west and south and increases to the north. The highest precipitation in the Arriesfontein area and its direct surrounds occurs immediately north of the northern corner of the property, where the MAP exceeds 480 mm. The lowest precipitation occurs in the southern part of the farm with a MAP of ~445 mm.

3.2 Geology

The geology of the study area is depicted in **Figure 4** (page 12). The geological map indicates that significant parts of the study area are covered by Recent-age deposits of mainly red to pale coloured windblown sand of the Gordonia Formation, surface limestone and some rock rubble. These deposits occur along the flat laying areas and are generally thin, seldom exceeding 10 m in vertical thickness in this area. However, thick Recent-age deposits can occur along drainage channels and in some pans where leaching of the dolomite took place. Closer to the Asbestos Hills the rubble can reach a vertical thickness of >70 m as indicated by exploration drilling supervised by the author during the 1990s. During this exploration drilling a northwest-southeast striking palaeo-river channel was intersected on the farm Beadle ~22 km west of Arriesfontein. The exploration borehole intersected some surface limestone on top followed by banded ironstone gravel. Dolomitic bedrock was only intersected at 60 m bgl. Diamonds are presently mined from these alluvial deposits.

A salt pan located on the farm Soutpan ~17 km south of Ariesfontein has formed as a result of Dwyka sediments collapsing into a sinkhole. These sediments are ~80 m thick at this location (Based on a hydrocensus survey conducted by the author during the early 1990s).

Arriesfontein homestead is located between the parallel northeast-southwest striking dolerite dykes, which are thought to be linked to faults in the dolomitic rocks of the Lime Acres Member of the Ghaap Plateau Formation, Campbell Group. Rocks of this member consist mainly of dolomite with interbedded limestone, chert and chert breccia. Though not indicated on geological maps, drilling programmes have indicated that thin interlayers of black shale occur in the dolomite and limestone. These layers are seldom >1 m in vertical thickness and show a negative weathering[1] characteristic due to their relative softness. The interbedded chert formations occur as layers and lenses, whilst the limestone occurs mostly as lenses.

Dolerite dykes seldom outcrop, but can in most cases be identified on surface by prominent tree lines and calcrete ridges. These linear ridges can protrude >1 m above the surrounding flat areas. A prominent chert layer occurs east of the farm. This layer forms the base of the Lime Acres Member, with the Fairfield Member, consisting mainly of re-crystallized dolomite, underneath.

The general dip of the sediments in this area is ~2^O to the west, but the dip steepens westwards towards the Asbestos Hills. On the eastern flank of the Asbestos Hills dips of >6^O west can be encountered.

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[1] Weathers easier and more rapidly than the surrounding or adjacent rock-types thereby forming a depression or valley.

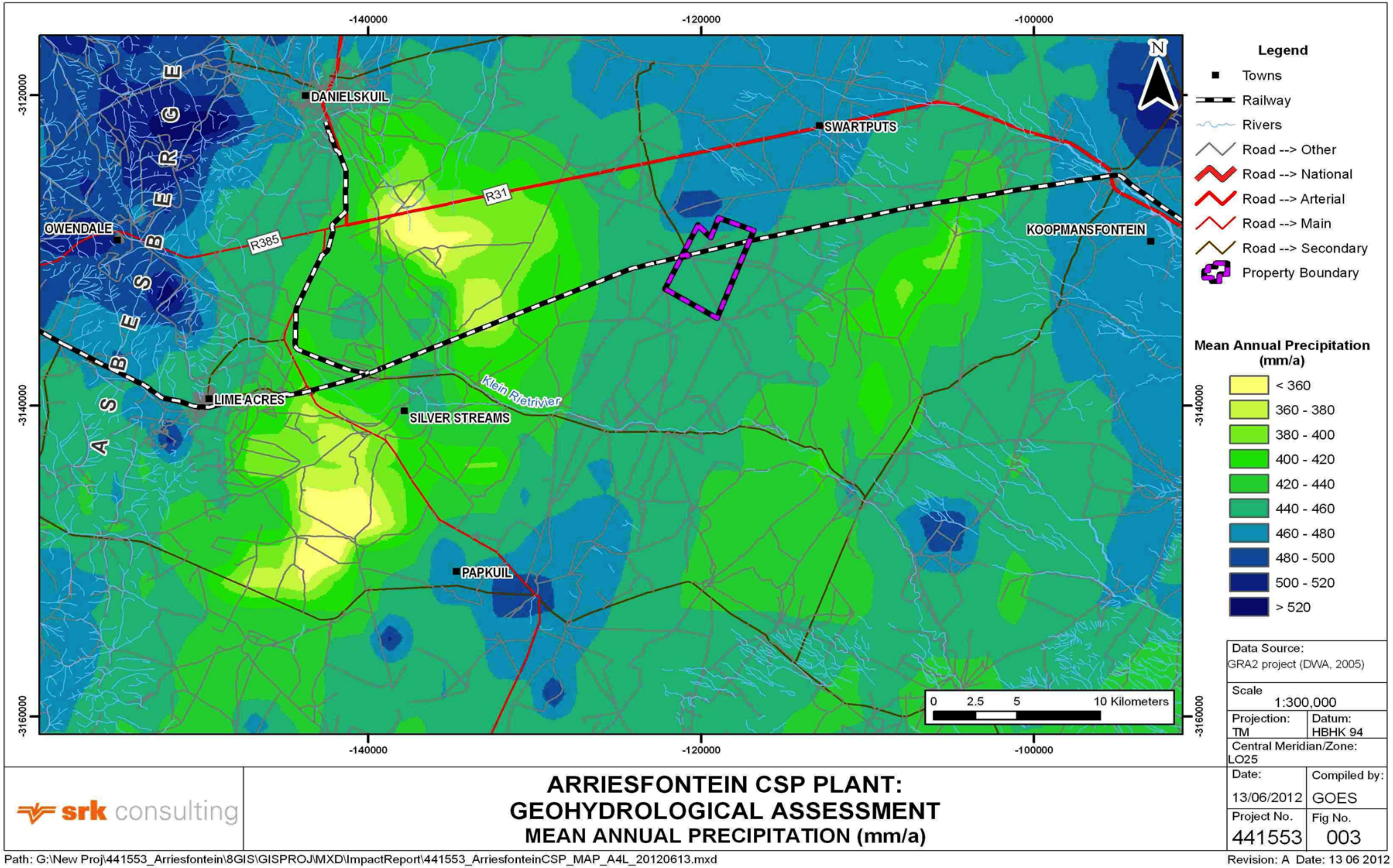

Figure 3: Rainfall Distribution in the Study Area

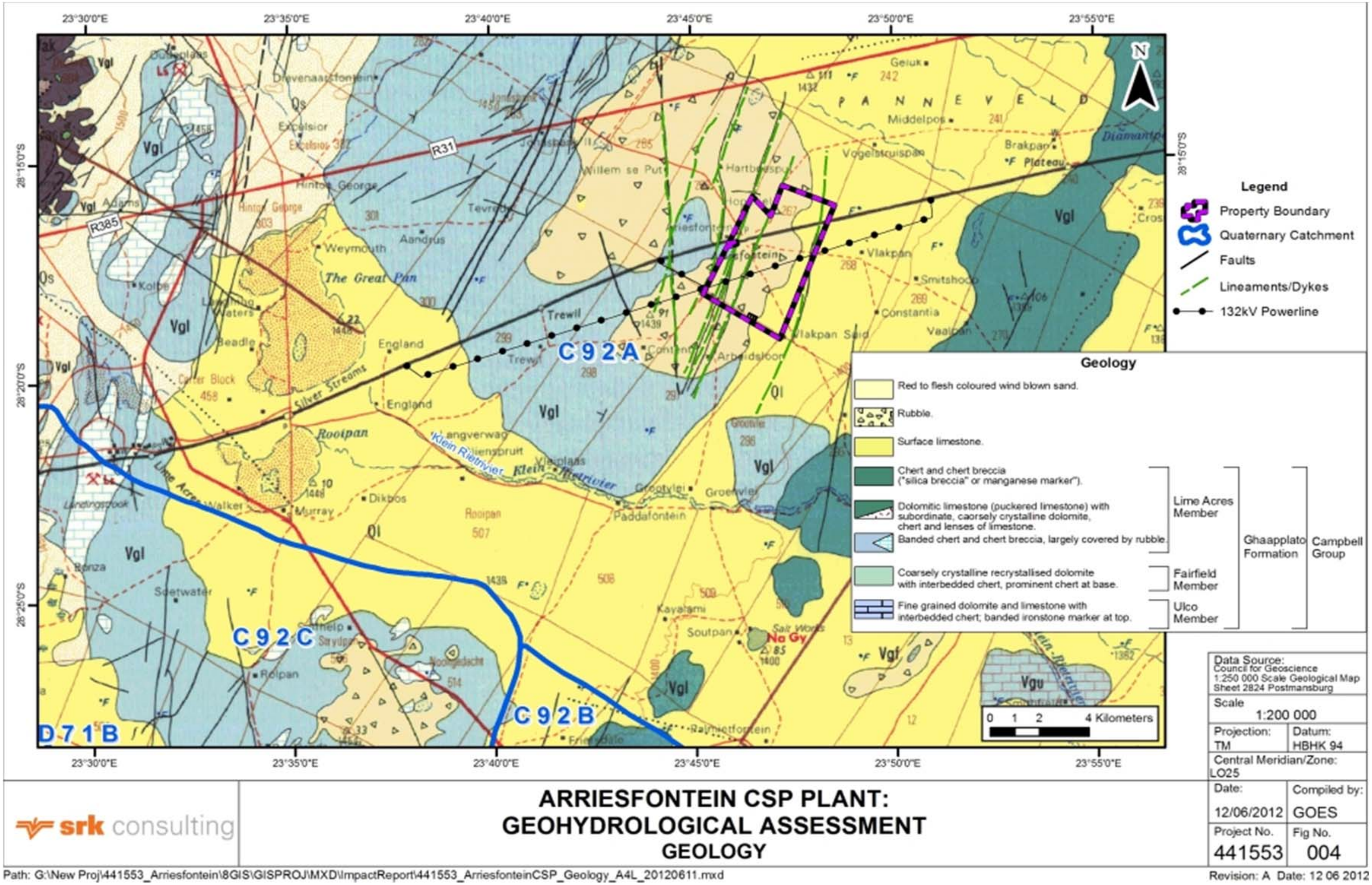

Figure 4: Geology of the Study Area (after the Council for Geoscience)

3.2.1 Lineament Mapping

During the hydrocensus attention was given to structures that can pose a risk to groundwater pollution from surface sources. The visible dykes could be identified on the ground. Satellite imaginary was used to identify other less visible lineaments and these were used to define the GRUs. Five semi-parallel NE-SW striking dolerites dykes occur in the area. These are intersected by two E-W striking dykes and a N-S striking dyke to form four groundwater compartments in the area. The easternmost three of these compartments form the three GRUs at Arriesfontein, whilst the western compartment falls outside the site boundary.

These structures were mapped and overlaid on the geological map as indicated in **Figure 4**. In planning the layout of the evaporation ponds, special care should be exercised to avoid these lineaments.

3.3 Geohydrology

3.3.1 Aquifer Type

Groundwater in this area occurs mainly in semi-confined fractured-rock aquifers, also known as secondary aquifers (**Figure 6** page 16). These aquifers are formed by jointing and fracturing of the otherwise solid bedrock by compressional and tensional forces that operate in the Earth's crust from time to time. The fractures are formed by faulting, folding, intrusion of dolerite dykes and other geological forces. Slightly acidic rainwater infiltrates along these joints and fractures and slowly dissolves the alkaline rocks to eventually form solution cavities. Solution cavities commonly also form on contact zone of dolomite with other rock types like chert and black shale.

Unconfined intergranular aquifers (also known as primary aquifers) occur in and near drainage channels and in some pans where the groundwater levels are shallow and within the unconfined unconsolidated sediments and weathered zone. These areas have been leached by water and are characterized by loose, unconsolidated material extending to well below 10 m bgl. The unconsolidated deposits and weathered zone on the site are, however, limited in both horizontal and vertical extend and consist mainly of clay and silt. These result in a poorly developed, low yielding primary aquifer that is vulnerable to droughts. Therefore, the primary aquifer in this area can be regarded as insignificant.

3.3.2 NGA Data

The geohydrological information retrieved from the NGA is summarized in **Appendix A**. The data indicate that borehole yields are highly variable and four of the 115 boreholes identified have yields >12 ℓ/s. The average borehole yield of the successful boreholes is 2.02 ℓ/s compared to the median yield of 0.43 ℓ/s, which emphasize the fact that the average borehole yield is skewed by a few extraordinary high yielding boreholes. Therefore the median yield is a much better indication of the yield that can be expected from a successful borehole in this area. The median yield correlates well with DWA's yield map which suggests an average yield of 0.1 - 0.5 ℓ/s for successful boreholes.

Average borehole depths for this area are >50 m bgl whilst the median depth is ~40 m bgl. This again indicates that the average borehole depth is skewed by a few deep boreholes (>200 mbgl) drilled on the farms Rooipan and Geluk. The localities of the NGA boreholes in the study area are indicated in **Figure 5**.

Field measured electrical conductivities (ECs) are generally well below 200 mS/m except for a few anomalous ECs recorded on the farms Jonasbank, Weiveld and Farm 266. The very high EC (for this area) of 404 mS/m recorded at Jonasbank is suspected to be a result of pollution from soak-away pits, kraals and or stock water points.

Depth to water table ranges from 2.7 to 26.6 m bgl with a median depth of 6.4 m bgl. The deeper water levels are most likely a result of abstraction.

3.3.3 Hydrocensus Results

The hydrocensus results are summarized in **Table 3** with the localities of these boreholes indicated in **Figure 5** and also in **Figure 8**.

Table 3: Summary of Hydrocensus Results of the Arriesfontein Area.

Bh No	Latitude	Longitude	Depth (mbgl)	Yield (ℓ/s)	WL* (mbgl)	EC** (mS/m)	pH	Equipment	Use	Pump Intake (mbgl)	Est. Abstrac-tion (m^3/a)	Comments
AFN1	-28.28006	23.76747	9	2.0	3.55			WP 100mm Cylinder	Domestic, Stock	7.5	3 400	
AFN2	-28.28016	23.76793	40	1.5	3.21	76	7.80	32mm Submersible	Domestic, Stock	15.0	3 942	
AFN3	-28.27929	23.76800	60	>10.0				None	None		0	Blocked
AFN4	-28.28235	23.76771		>10.0				None	None		0	Was pumped at 12 m bgl
AFN5	-28.28499	23.77537	30	10.0	1.87	173	7.65	Plunger Pump 60mm Cylinder	Stock	12.0	629	Artesian during wet spells
AFN6	-28.30119	23.76640	80	0.2	29.68	101	7.45	WP 60mm Cylinder	Stock	70.0	1 359	Pumping WL suspected
AFN7	-28.27605	23.78019	36	0.6		111	7.30	WP 60mm Cylinder	Stock	18.0	1 359	
AFN8	-28.27961	23.76912	0	0.5	0.00	80	7.70	None	None		15 768	Spring, flows intermittently
		Average	**36.43**	**4.35**	**7.66**	**108.2**	**7.58**			**TOTAL**	**26 457**	
		Median	**36.00**	**1.75**	**3.21**	**101.0**	**7.65**					
***WL = Water Level **EC=Electrical Conductivity Coordinate System = WGS84**												

Seven boreholes and one non-perennial spring were surveyed on the site. Of these three were equipped with windpumps, one with a submersible pump and one with a plunger pump for stock watering purposes. The two high yielding boreholes AFN3 and AFN4 have been vandalized and can no longer be used as production boreholes. All three high yielding boreholes (AFN3, AFN4 and AFN5) are close to dolerite dykes. The relatively deep water level measured in borehole AFN6 could be due to a recovering water level after pumping having been measured. According to the owner, borehole AFN5 becomes artesian after good rains.

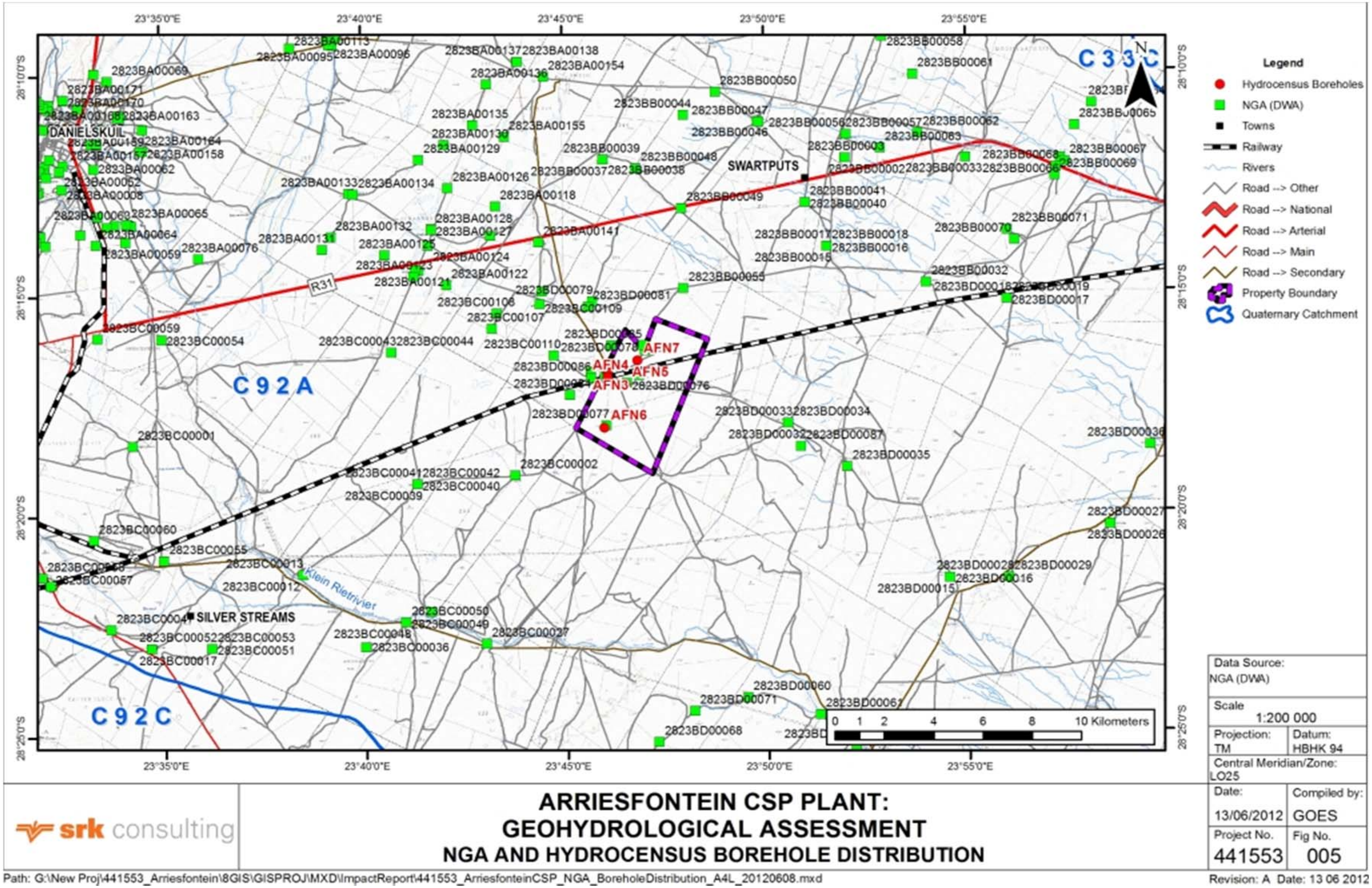

Figure 5: Map Showing Localities of the NGA and Hydrocensus Boreholes in the Study Area

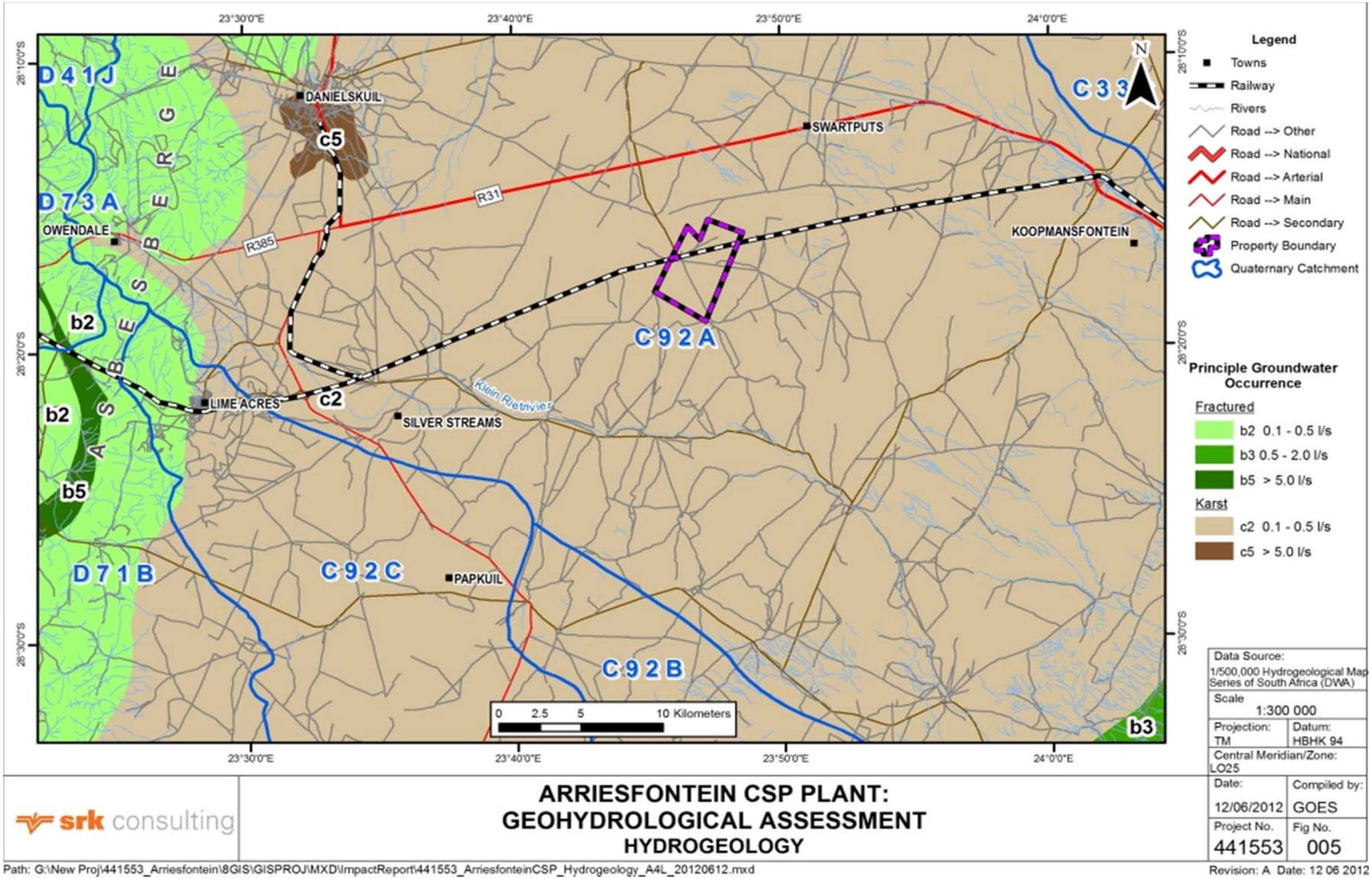

Figure 6: Aquifer Type and Yield Potential in the Study Area (After the DWA 1:500 000 Scale Hydrogeological Map Series Data)

Groundwater is mainly abstracted for stock watering purposes, except for the groundwater flowing out at the Arriesfontein non-perennial spring during wet spells. A small ~0.25 ha field planted with lucerne was observed on the adjacent farm Hartebeesput, but the owner could not be located and the borehole(s) supplying the irrigation water could therefore not be visited. The owners of three adjacent farms (Mr. Johan Visser of Hartebeesput, Mr. Keith Williams of Arbeidsloon and Mr. Kobus van Niekerk of Kristalpan) could not be located and the fourth, Mr. Gerrit Nieuwoudt owner of the farms Constantia, Vlakpan and Hopefield, was busy with farming activities and could not meet with SRK's personnel doing the hydrocensus. These owners, except for Mr Nieuwoudt, are only part time farmers who reside in towns as far as Douglas and Hopetown. Kristalpan (Vlakpan Suid on map) is south-east of Arriesfontein, Arbeidsloon south and Hartebeesput immediately west thereof. Mr Gerrit Nieuwoudt stays on Constantia south-east of the property. Vlakpan is located east of Arriesfontein and Hopefield north-east thereof. (The latter was part of Arriesfontein, but has been sold off to Mr Nieuwoudt).

3.3.4 Current Abstraction

The estimated current abstraction from the site is summarised in **Table 3**. For the three windpumps a 24 h/d operation at 12% of the maximum yield (which is determined by the cylinder size) was assumed. This assumption is based on the author's personal experience in the Karoo area. The Arriesfontein (spring) flow during the hydrocensus was estimated as 0.5 ℓ/s. Unfortunately, the flow could not be measured as the spring is partially submerged by the outflow, which accumulates in a pan where it largely evaporates. According to the owner this spring only flows during exceptional wet periods and has only flowed during 1974-1976, 1988 and since the beginning of 2011. No large scale irrigation takes place in the area and most of the farms are uninhabited. Based on the assumptions a total current abstraction of approximately 26 500 m^3/a is calculated for the site. During normal to dry years the spring does not flow and therefore the total groundwater abstraction for this area will only be ~10 700 m^3/a.

3.3.5 Groundwater Resource Potential

The site falls within the western part of the Quaternary Drainage Region D92A (see **Figure 4**) for which the amount of water available under General Authorisation is listed under Zone A of the Groundwater Taking Zones, where no water may be taken from this drainage regions except as set out under Schedule 1[2] and small industrial users[3] (DWAF, 2004 and DWA, 2012). Therefore, if the water demand is to be satisfied from the groundwater resources, a Water Use Licence Application will have to be submitted.

Three GRUs were defined for this area. These are based on surface drainage, measured groundwater elevations and lineaments such as faults and dykes. The boundaries of these GRUs are indicated in **Figure 4**. The GRA2 grid datasets (DWAF, 2005) were used to derive the MAP, effective recharge and groundwater resource potential for each GRU. As boreholes cannot intersect all the available recharge in an area, an exploitability factor (DWAF, 2005) was used to calculate the volume of groundwater that can actually be abstracted through boreholes. Current abstraction based on the hydrocensus data was subtracted from this value to determine the current

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[2] Not taking more than 10 cubic metres from groundwater on any given day.

[3] "Small industrial users" mean water users who qualify as work creating enterprises that do not use more than twenty cubic metres per day (i.e. 20 000 litres/day) and identified in the Standard Industrial Classification of All Economic Activities (5th edition), published by the Central Statistics Service, 1993, as amended and supplemented, under the following categories:-
a) 1: food processing;
b) 2: prospecting, mining and quarrying;
c) 3: manufacturing;
d) 5: construction

Groundwater Exploitation Potential, for so-called wet and dry periods. These calculated values are summarised in **Table 4** below.

Table 4: Groundwater Exploitation Potential of the Site

Quaternary Catchment/GRU Number	Area (m^2)	Volume of Water stored in Aquifer (m^3/a)	5m Drawdown Storage Volume (m^3/a)	Mean Annual Potential Recharge (m^3/a)		Average Groundwater Resource Potential (m^3/a)		Groundwater Exploitation Potential (m^3/a)	
				Wet Period	Dry Period	Wet Period	Dry Period	Wet Period	Dry Period
C92A	3 913 568 868	2 508 530 000	164 529 000	40 286 400	26 763 500	199 557 000	186 037 000	80 706 200	75 380 300
Arriesfontein	18 401 759	11 795 209	773 622	189 428	125 843	938 325	874 753	379 484	354 441
C92A-1	6 178 275	3 960 167	259 739	63 599	42 251	315 037	293 693	127 409	119 001
C92A-2	5 468 394	3 505 146	229 895	56 292	37 396	278 839	259 948	112 770	105 328
C92A-3	15 776 359	10 112 373	663 248	162 402	107 889	804 453	749 951	325 342	303 873
TOTAL	**27 423 027**	**17 577 686**	**1 152 882**	**282 293**	**187 536**	**1 398 329**	**1 303 592**	**565 522**	**528 202**

The GRA2 data indicate that the three Ariesfontein GRUs (C92A-1, C92A-2 and C92A-3) have a combined estimated average mean recharge of ~188 000 m^3/a for dry periods and ~282 000 m^3/a for wet periods. The average groundwater exploitation potential for these GRUs is ~528 000 m^3/a for dry periods and ~566 000 m^3/a for wet periods. The volume of water that is potentially stored in the aquifers of the three GRUs is ~17.6 million m^3, whilst the potential storage of the upper 5 m[4] is ~1.2 million m^3.

The mean annual recharge map for the site is shown in **Figure 7**. The map indicates that the recharge decreases from the north-west of the site towards the south-east. Average annual recharge values vary between 11 mm/a in the extreme north-western corner of the site and 9 mm/a in the south-eastern corner thereof.

3.3.6 Geophysics, Exploration Drilling and Test Pumping Results

In order to obtain on-site aquifer parameters and assess the yield potential, four new boreholes were sited, drilled and test pumped (see **Figure 8** for positions). Two of the existing boreholes, AFN1 and AFN7, were also pump tested. *Note: Borehole AFN5 could not be tested as it has collapsed at 6 mbgl*.

The four new boreholes were sited after electrical resistivity surveys had been carried out at target sites. The position of these survey lines are shown in **Figure 9** whilst the results are included in **Appendix B**. The selection of these target sites was based on the purpose of the borehole to be drilled and the geological structures. The selection criteria for drilling the new boreholes and testing of the existing boreholes are summarised in **Table 5** (p. 22). Two of the new boreholes, ANE1 and ANE3, were drilled for water supply to the proposed development, whilst the other two, ANE2 and ANE4, were drilled to assess the geohydrologic suitability of the site proposed for locating the evaporation ponds.

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[4] Guideline use to

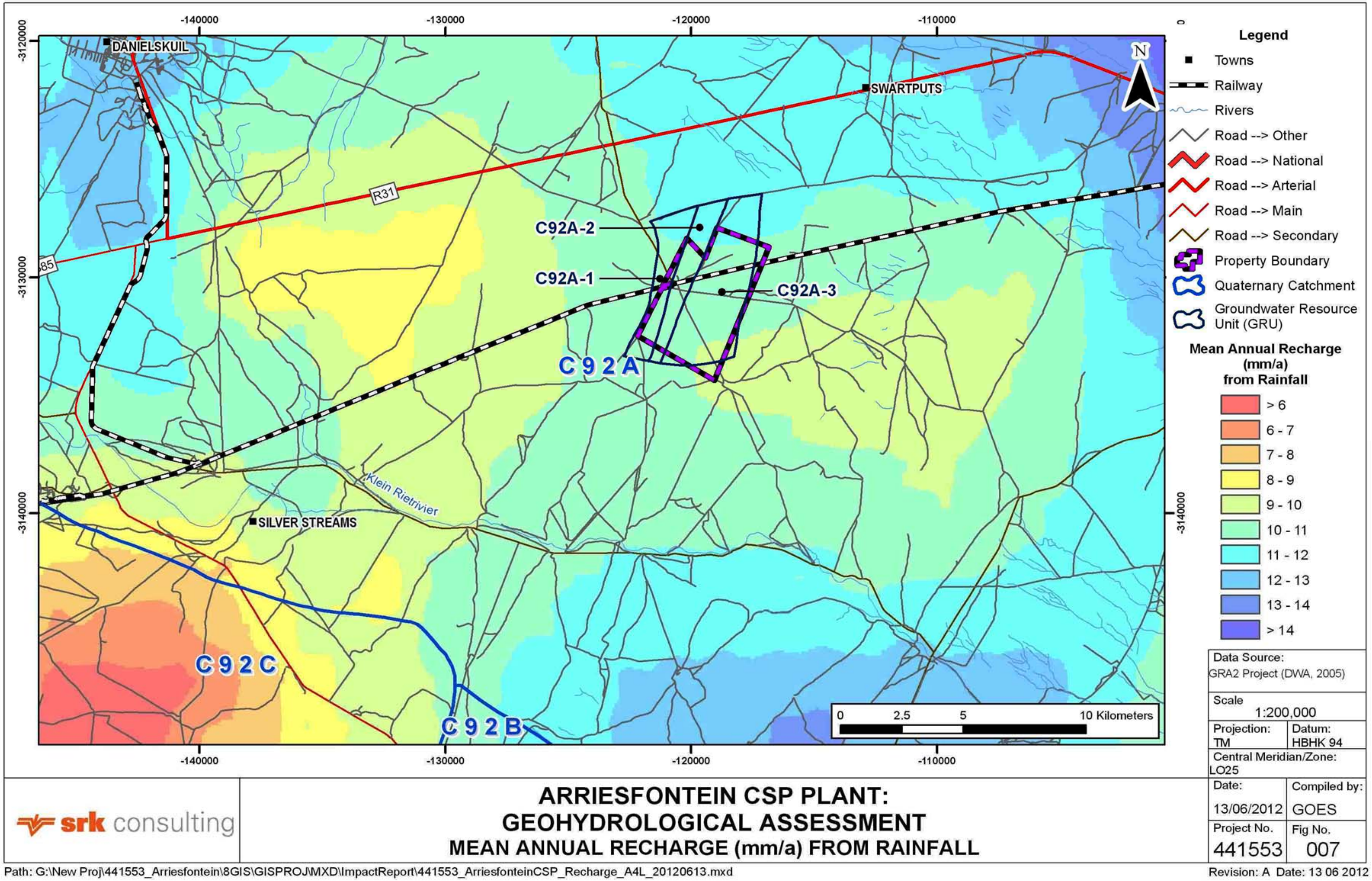

Figure 7: Mean Annual Recharge in the Arriesfontein Area

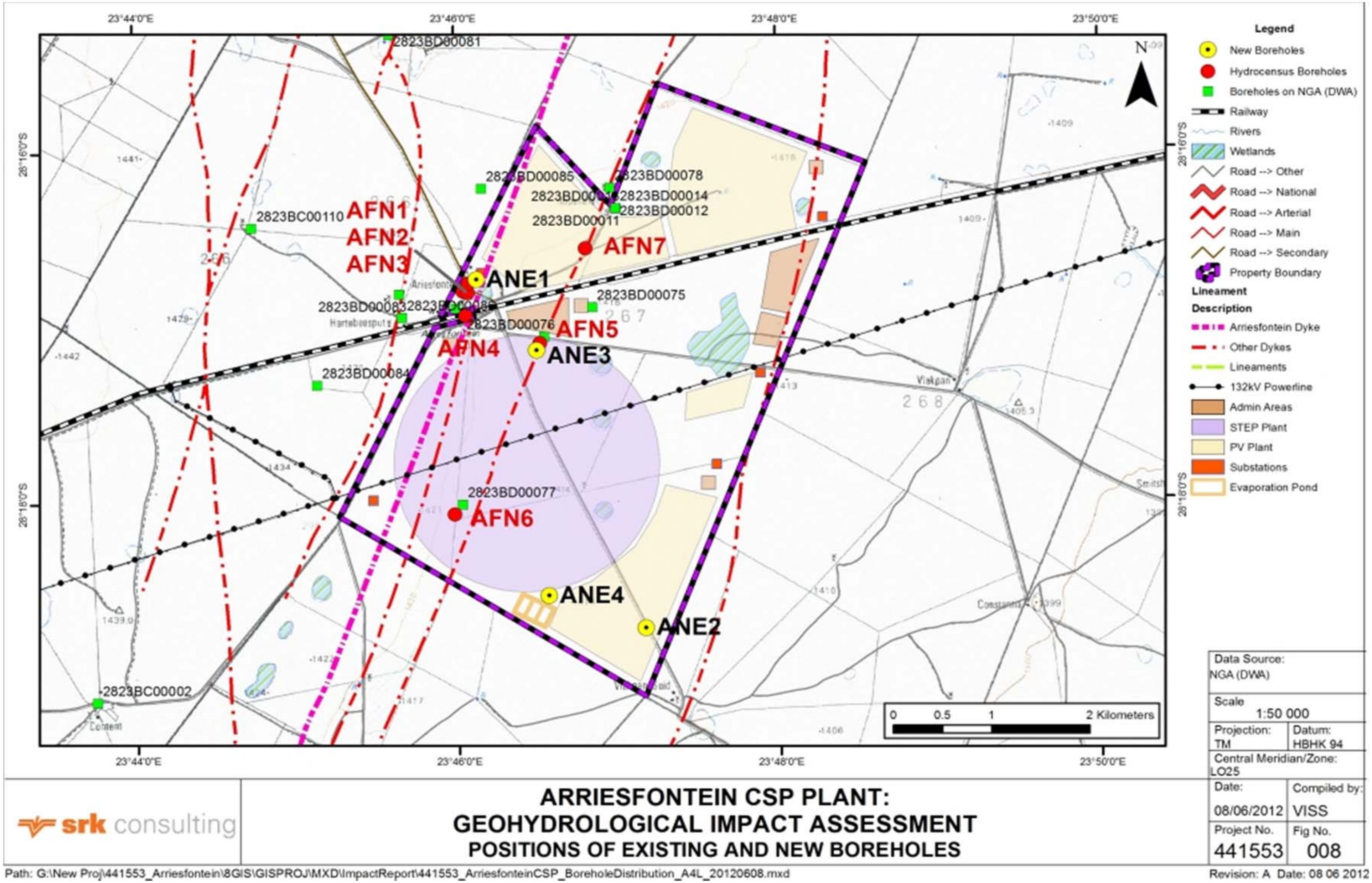

Figure 8: Map Showing Localities of the Existing and New Boreholes at Arriesfontein

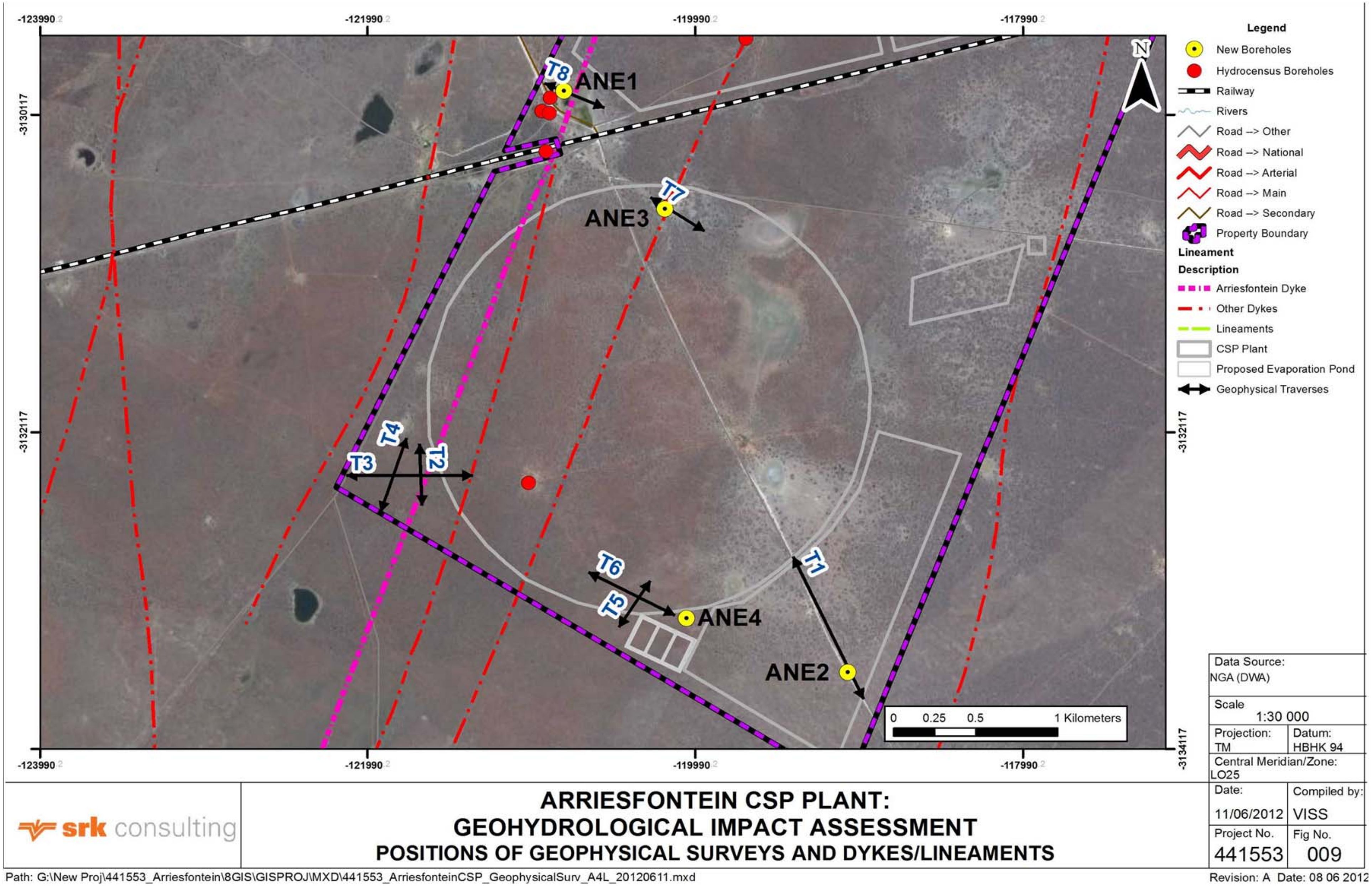

Figure 9: Map Showing the Positions of the Geophysical Surveys and Dykes/Lineaments

Table 5: Summary of Selection Criteria for Drilling and Testing of Boreholes

Borehole No.	Selection Criteria
New Boreholes ANE1 & ANE3	• To investigate the yield potential of the dolomitic aquifers associated with the leached/fractured dolerite dyke contact zones for water supply purposes to the proposed project. • To obtain aquifer parameters, water level and water quality information for the dolomitic aquifers associated with the leached/fractured dyke contact zones.
New Boreholes ANE2 & ANE4	• To obtain aquifer parameters, water level and water quality information of the dolomitic aquifers away from dolerite dykes and in the area identified as most suitable for locating the proposed waste water evaporation ponds in. • To establish monitoring boreholes downstream of the proposed evaporation ponds.
Existing Boreholes AFN1, 5 & 7	• To obtain information on the yield capacity of the existing boreholes as well as aquifer parameters, water level and water quality information.

The results of the drilling programme are summarised in **Table 6** whilst the borehole logs are included in **Appendix C**.

Table 6: Summary of Drilling Results for the New Boreholes

BH No.	Degrees Latitude	Degrees Longitude	Elevation (m amsl)	Final Depth (m bgl)	Main Water Strike (m bgl)	First Water Strike (m bgl)	Blow Yield (ℓ/s)	Water Level (m bgl)	EC (mS/m)	Date Drilled	Aquifer Type
ANE1	-28.27893	23.76885		54	25	8	40	0.68	78	08-May-12	Fractured Dolomite
ANE2	-28.31213	23.78613		42	22	22	0.3	2.76	117	09-May-12	Dolomite (matrix)
ANE3	-28.28570	23.77505		60	39	10	15	2.10	81	09-May-12	Fractured Dolomite
ANE4	-28.30899	23.77612		42	24	11	0.2	3.39	171	10-May-12	Dolomite (matrix)

The drilling results indicate that the depth of weathering extents to approximately 25 m bgl. Groundwater was intersected in all of the boreholes towards the lower part of this weathered zone. The groundwater in all the boreholes is locally confined as indicated by the first water strike that is ~7 to 19 m deeper than the rest water level. This means that the upper zone above the first water strike is mostly unsaturated. In the area proposed for locating the evaporation pond this unsaturated zone extent to approximately 11 m bgl, whilst the rest water level in the test borehole (ANE4) is ~3.4 m bgl.

The four new boreholes and two of the existing boreholes were subjected to controlled pumping tests in order to obtain their yield capacities, aquifer parameters and samples for water quality analysis. The pumping test results are summarised in **Table 7** whilst the raw data and water level graphs are included in **Appendix D**

Two of the boreholes, ANE1 and ANE3, are high yielding and can be used for water supply. Both these boreholes are drilled in fractured/leached dolomite near dolerite dykes. The other two new boreholes, ANE2 and ANE4, are low yielding and can be used for monitoring purposes. Both these two boreholes were drill away from the dolerite dykes in relatively unfractured dolerite. Small amounts of water were, however, intersected in the weathered zone.

Table 7: Summary of Pumping Test Results

Description	ANE1	ANE2	ANE3	ANE4	AFN1	AFN7
Starting Date	4-May-2012	4-May-2012	4-May-2012	4-May-2012	4-May-2012	4-May-2012
Pre-pumping water level in m bgl	0.68	2.76	2.10	3.39	3.46	3.71
Borehole depth at testing in m	54.4	41.5	48.4	42.6	30.3	65.5
Pump intake depth in m bgl	45.3	32.4	39.2	32.3	26.0	65.0
Available drawdown m	44.6	29.7	37.1	28.9	22.6	61.0
SDT (60 min/step) pumping rates in ℓ/s and drawdown in (m)	5.0 (0.67) 10.1 (1.22) 15.2 (2.11) 20.1 (2.73)	0.22 (3.88) 0.31 (7.60) 0.41 (20.93) 0.70 (29.70)	5.06 (2.62) 10.03 (7.69) 15.14 (17.34) 20.01 (29.39)	0.20 (7.01) 0.30 (15.29) 0.41 (28.91)	1.03 (0.87) 4.00 (22.60)	0.27 (54.27)
Recovery SDT time in min and residual drawdown (m)	150 (0.0)	120 (0.00)	110 (0.00)	160 (0.15)	15 (0.00)	240 (8.50)
CDT duration	72	24	72	24	72	Not done
CDT rate in ℓ/s and drawdown in (m)	18.0 (2.61)	0.22 (7.13)	12.0 (13.56)	0.21 (13.08)	1.5 (3.50)	-
Recovery CDT time in min and drawdown (m)	1 080 (0.04)	360 (0.00)	240 (0.00)	1 440 (0.09)	300 (0.00)	-
Water Temp. Start – End of CDT in °C	21.5 – 22.3	20.4 – 19.1	19.4 – 18.4	16.7 – 16.1-	21.6 – 21.6	-
pH Start – End of CDT	6.5 – 6.0	10.4 – 9.8	7.4 – 7.6	9.4 – 9.9	8.2 – 8.5	-
EC Start – End of CDT in mS/m	62 – 60	90 – 90	64 – 66	141 – 141	78 – 90	-
Observation borehole No. and distance from Test BH (m)	AFN1 & AFN2 (151 & 183)	None	None	None	None	-
Drawdown in m in Observation BH at end of CDT	0.00 & 0.00	-	-	-	-	-
Notes:	AFN7 was too low yielding to warrant a CDT. AFN5 could not be tested as it is blocked at ~6 mbgl.					

Table 8: Summary of Aquifer Parameters for the Tested Boreholes

BH No.	**BH Depth**	**T- Early Pumping**	**T- Late Pumping**	**T- Median Recovery**	**T- CJ**	**T- Theis**	**T- median**	**Estimated Storage Coefficient**	**Aquifer Type**	**Proposed Usage**	**Comments**
	(m)	**m^2/day**	**m^2/day**	**m^2/day**	**m^2/day**	**m^2/day**	**m^2/day**				
ANE1	**54**	**939**	**258**	**2 102**	**1 395**	**1 281**	**1 281**	**4.44E-03**	**Fractured/Leached Dolomite**	Production	Arriesfontein dolerite dyke of 50 m wide with 150 m wide highly T fractured/leached zones on each side.
ANE3	**60**	**193**	**203**	**811**	**176**	**110**	**193**	**3.93E-04**	**Fractured/Leached Dolomite**	Production	Dolerite dyke of 25 m wide with 50 m wide highly T fractured/leached zones on each side.
AFN1	**30**	**113**	**10**	**682**	**22**	**30**	**30**	**2.97E-03**	**Fractured/Leached Dolomite**	Monitoring	Dolerite dyke of 50 m wide with 150 m wide highly T fractured/leached zones on each side. BH near edge of zone
ANE2	**42**	**1**	**1**	**7**	**1**	**1**	**1**	**1.24E-03**	**Unfractured Weathered Dolomite**	Monitoring	Upper 25 m of weather dolomite away from dykes. To of unweathered dolomite = <1 m^2/d
ANE4	**42**	**1**	**1**	**8**	**1**	**1**	**1**	**1.87E-03**	**Unfractured Weathered Dolomite**	Monitoring	Upper 25 m of weather dolomite away from dykes. To of unweathered dolomite = <1 m^2/d
Median Fractured		**193**	**203**	**811**	**176**	**110**	**193**	**2.97E-03**			
Median Unfractured		**1**	**1**	**7**	**1**	**1**	**1**	**1.55E-03**			
Notes:	**No boreholes drilled into dolerite dykes to determine T-value for dolerite dykes.** **T for upper 25 m of weathered dyke assumed to be ~30 m^2/d for Arriesfontein Dyke** **T for upper 25 m of weathered dyke assumed to be ~30 m^2/d for the other narrower (~25 m wide) dykes** **T for unweathered dyke assumed to be <1 m^2/d, i.e. below 25 mbgl**										

The pumping test data were analysed by using an Excel-based software package developed by Van Tonder *et al* (2002). In the software package various methods such as the Flow Characteristic method (FC-method), porous aquifer solutions (Theis, Cooper-Jacob and Hantush methods) and fractional pumping test analysis (Barkers Generalised Radial Flow Model) were used to estimate a risk-based sustainable yield for the borehole as well as aquifer parameters such as transmissivity (T) and the storage coefficient (S). In the analyses the following aquifer input parameters were used:

- Effective recharge of 9 mm per annum.
- Data were extrapolated for 15 years.
- The permissible available drawdown below the water table for each borehole was taken as 5 m (DWAF, 2005).

The aquifer parameters derived by these analyses are summarised in **Table 8**, whilst the operational and management recommendations for the two boreholes proposed for water supply are summarized in **Table 9**. The diagnostic plots and yield analyses are included in **Appendix E**.

Table 9: Recommended Pumping Rates and Management Criteria for the Proposed Water Supply Boreholes

BH No.	BH Depth	BH Diameter	Pre-Pumping Water Level	Pump Intake	24 hr/day Pumping Schedule		12 hr/day Pumping Schedule		Max. Allowable Pumping Drawdown Level
	(m)	(mm)	(m bgl)	(m bgl)	(ℓ/s)	(m^3/d)	(ℓ/s)	(m^3/d)	(m bgl)
ANE1	54	200	0.68	35	14.0	1 210	18.0	778	6
ANE3	60	165	2.10	35	4.5	389	6.0	259	8
Total					18.5	1 598	24.0	1 037	
Total/annum						583 416		378 432	

From the pumping test analysis it can be concluded that the two production boreholes can together yield approximately 18.5 ℓ/s for 24 hr/day pumping schedule (1 600 m^3/d), or an estimated 583 000 m^3/a. In comparison to this the preferred CSPP will require approximately 272 400 m^3/a with peak consumption of approximately 12.4 ℓ/s (44.5 m^3/hr).

The T-value for the aquifer beneath the area earmarked for location of the proposed waste water evaporation ponds is ~1 m^2/d, which is low and therefore makes the area suitable for establishing such and evaporation pond. In comparison the T-values derived for the aquifers of the fractured/leached zones near (25 to 50 m from the dyke contacts) the dolerite dykes are much higher and in the order of 190 to 1 300 m^2/d. These highly transmissive zones are unsuitable for placement of the evaporation ponds or other possible sources of contaminants and must be taking cognisance off as such during planning of the CSP plant layout.

The S-value for the aquifers range between ~0.0016 (0.16%) for the weathered zone of areas away from the dolerite dykes to ~0.003 (0.3%) for the fractured/leached zones near the dykes.

3.3.7 Depth to Water Table and Inferred Groundwater Flow Directions

The hydrocensus data indicate that the depth to water level at the site varies between ground surface (Arriesfontein spring) and ~30 m bgl. On the site the depth to water level is predominantly between 2.0 and 3.5 m bgl, except in boreholes where there is pumping. These data and data from the NGA were used to plot the groundwater elevations on the topographical map, from which the groundwater flow directions were inferred (**Figure 10**). The groundwater elevations generally mimics the surface elevation contours and generally flows from higher lying to lower lying areas. The inferred flows are from the higher lying areas west of the property towards east and the lower lying Riet River south thereof. The general direction of groundwater flow can be diverted by NE-SW striking dolerite dykes to form springs in low laying areas.

3.3.8 Groundwater Quality

The groundwater salinity, expressed as EC in mS/m, of the site and surrounds is shown in **Figure 11** (page 27). The map suggests that the groundwater quality throughout the area falls in the range 70 – 300 mS/m. Field measured ECs at equipped boreholes and the spring at Arriesfontein vary between 76 and 173 mS/m, which correlates well with this suggested value. Based on field measured ECs only the groundwater from borehole AFN5 is unsuitable for long term human consumption[5]. The variable groundwater quality is likely caused by pollution from over flowing dams and kraals.

Groundwater samples were taken at the existing boreholes AFN2, AFN5 and AFN7, as well as the new boreholes ANE1 to 4, and delivered to M&L Laboratories in Johannesburg for chemical analysis. The results are summarised and compared to the South African National Standards for Drinking Water (SANS 241-2011) in **Table 10** and the analysis certificates are attached in **Appendix F**. Overall the water from the new boreholes, especially the two boreholes earmarked for water supply (ANE1 and ANE3) is of good quality and chemically fit for human consumption. The arsenic concentration of AFN2 and AFN7 were suspiciously high for the samples collected during the hydrocensus. In comparison the arsenic concentrations of samples taken during the pumping tests were below detection limit for all the samples, including AFN7. The initially high concentrations are suspect and probably a measuring error or the unit was incorrectly stated on the analysis certificate.

3.3.9 Aquifer Vulnerability

Figure 12 over page shows aquifer vulnerability as determined by evaluating seven parameters (DWAF, 2005), namely:

- Depth to groundwater;
- Recharge;
- Aquifer media;
- Soil media;
- Topography;
- Impact on vadose zone; and
- Hydraulic conductivity.

Aquifer vulnerability is defined as the likelihood for contamination to reach a specified position in the groundwater system after being introduced at some point above the uppermost aquifer. The aquifers at Arriesfontein are classified as having very high vulnerability to contamination. Though not indicated on the map, the lowest vulnerability occur in the southern part of the farm where the groundwater levels are deeper, whilst the highest vulnerability occurs at the homestead where the groundwater level is very shallow and leached zones associated with the well-defined dyke allow rapid vertical infiltration of contaminated surface water

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[5] ≤150 mS/m is acceptable for long term human consumption (SABS, 2006)

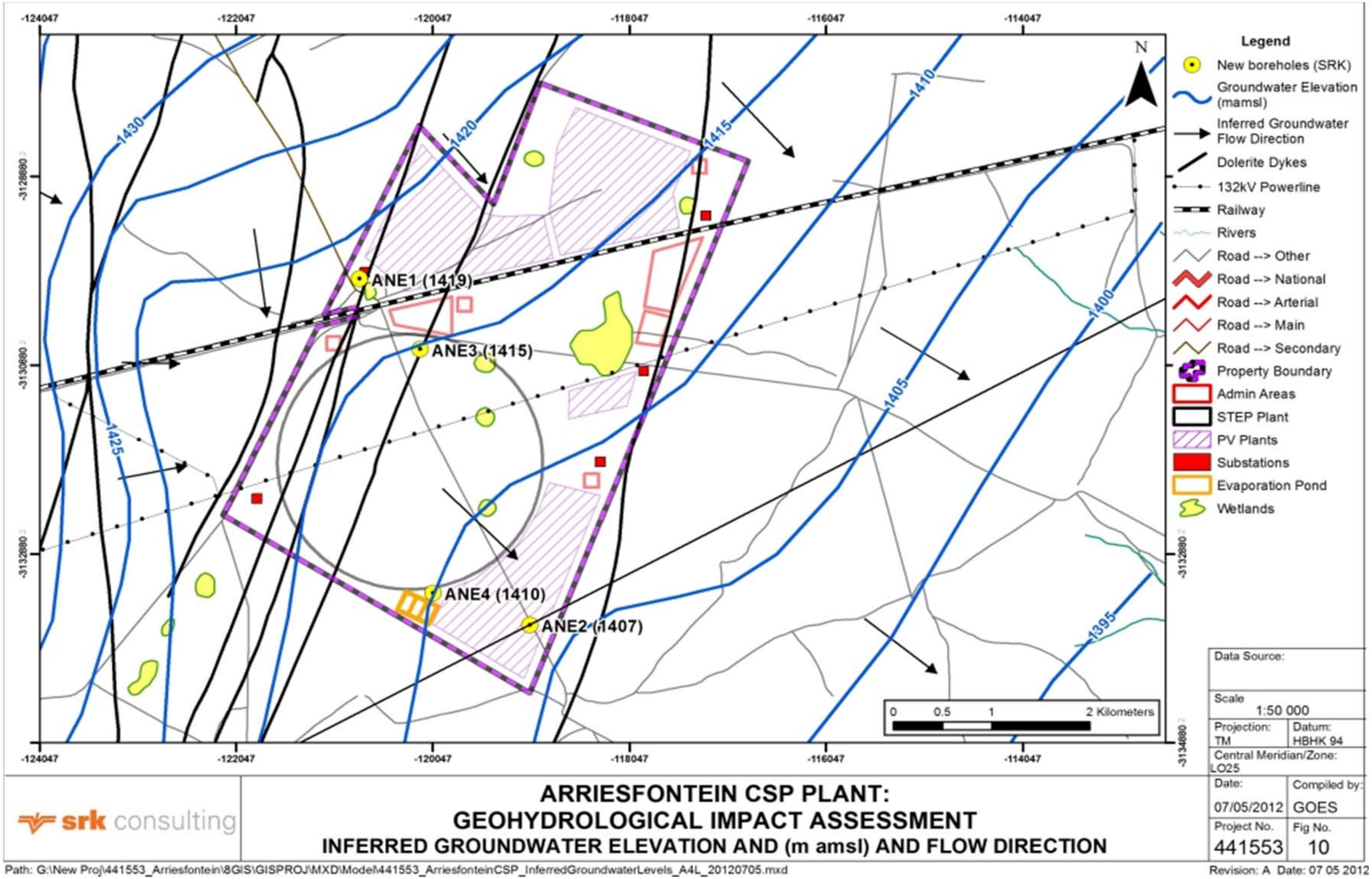

Figure 10: Map Showing Inferred Groundwater Elevation Contours and Flow Directions

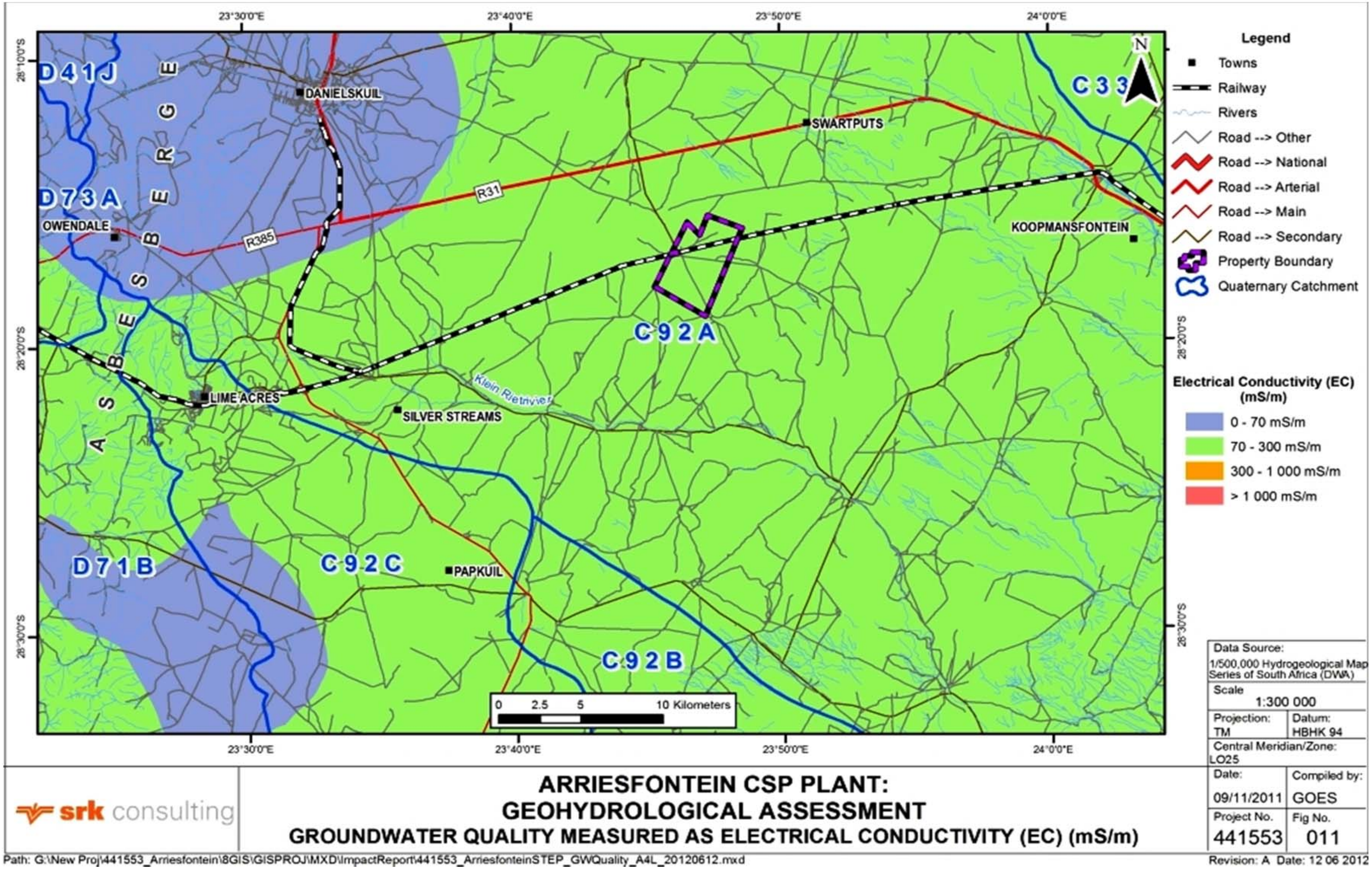

Figure 11: Map Showing Groundwater Salinity as EC in mS/m

Table 10: Chemistry of Selected Groundwater Samples Compared to SANS 241-2011 Drinking Water Guidelines

Determinants	ANE1	ANE2	ANE3	ANE4	AFN1	AFN2	AFN7	AFN7	SANS 241:2011 Standard Limits[a]	Risk
Date sampled	2012/05/04	2012/05/04	2012/05/04	2012/05/04	2012/05/04	2012/11/18	2012/11/18	2012/05/04		
Unit of measurement in mg/ℓ unless indicated otherwise										
Conductivity (mS/m)	85.4	101	91.1	158	99.1	81.5	117	99.0	≤170	Aesthetic
pH (Lab @ 25°C)[c]	7.6	7.6	7.8	7.7	7.9	7.4	7.2	7.8	≥5.0 – ≤9.7	Operational
Turbidity N.T.U[b]	0.2	1.7	0.2	0.3	0.3	0.4	0.2	**103**	≤1	Operational
									≤5	Aesthetic
Chloride as Cl	32	59	49	201	61	38	79	94	≤300	Aesthetic
Fluoride as F	0.3	0.4	0.3	0.4	0.3	0.5	0.8	0.4	≤1.5	Chronic health
Nitrate as N	2.0	1.5	1.7	0.8	2.0	2.7	0.8	4.5	≤11	Acute health - 1
Sodium as Na	14.3	28	18.9	59	27	24	38	35	≤200	Aesthetic
Sulfate as SO_4^{-2}	22	39	30	91	40	28	65	44	≤400	Acute health - 1
									≤250	Aesthetic
Zinc as Zn	0.005	<0.005	<0.005	<0.005	0.005			0.09	≤5	Aesthetic
Unit of measurement µg/ℓ										
Aluminum as Al	80	70	70	80	50			60	≤300	Operational
Antimony as Sb	<10	<10	<10	<10	<10			<10	≤20	Chronic health
Arsenic as As	<1	<1	<1	<1	<1	**42**	**50**	<1	≤10	Chronic health
Cadmium as Cd	1	1	1	<1	1			1	≤3	Chronic health
Total Chromium as Cr	5	3	5	4	4			3	≤50	Chronic health
Cobalt as Co	<1	<1	1	<1	<1			<1	≤500	Chronic health
Copper as Cu	30	30	30	40	30			40	≤2 000	Chronic health
Iron as Fe	20	<15	20	<15	20	34	21	30	≤2 000	Chronic health
									≤300	Aesthetic
Lead as Pb	<1	<1	-	-	-			<1	≤10	Chronic health
Manganese as Mn	1	5	1	<1	<1	1	5	50	≤500	Chronic health
									≤100	Aesthetic
Mercury as Hg	2	<1	<1	<1	<1	<1	<1	<1	≤6	Chronic health

Determinants	ANE1	ANE2	ANE3	ANE4	AFN1	AFN2	AFN7	AFN7	SANS 241:2011 Standard Limits [a]	Risk
Nickel as Ni	<3	<3	<3	<3	<3			<3	≤70	Chronic health
Selenium as Se	2	2	3	5	1	<1	<1	2	≤10	Chronic health
Vanadium as V	150	170	160	**210**	170			190	≤200	Chronic health

[a] The health-related numerical limits are based on the consumption of 2 ℓ of water per day by a person of a mass of 60 kg over a period of 70 years.

[b] Values in excess of those given in column 10 (Standard Limits) may negatively impact disinfection.

[c] Low pH values can result in structural problems in the distribution system.

[d] This is equivalent to nitrate at 50 mg NO_3/ℓ

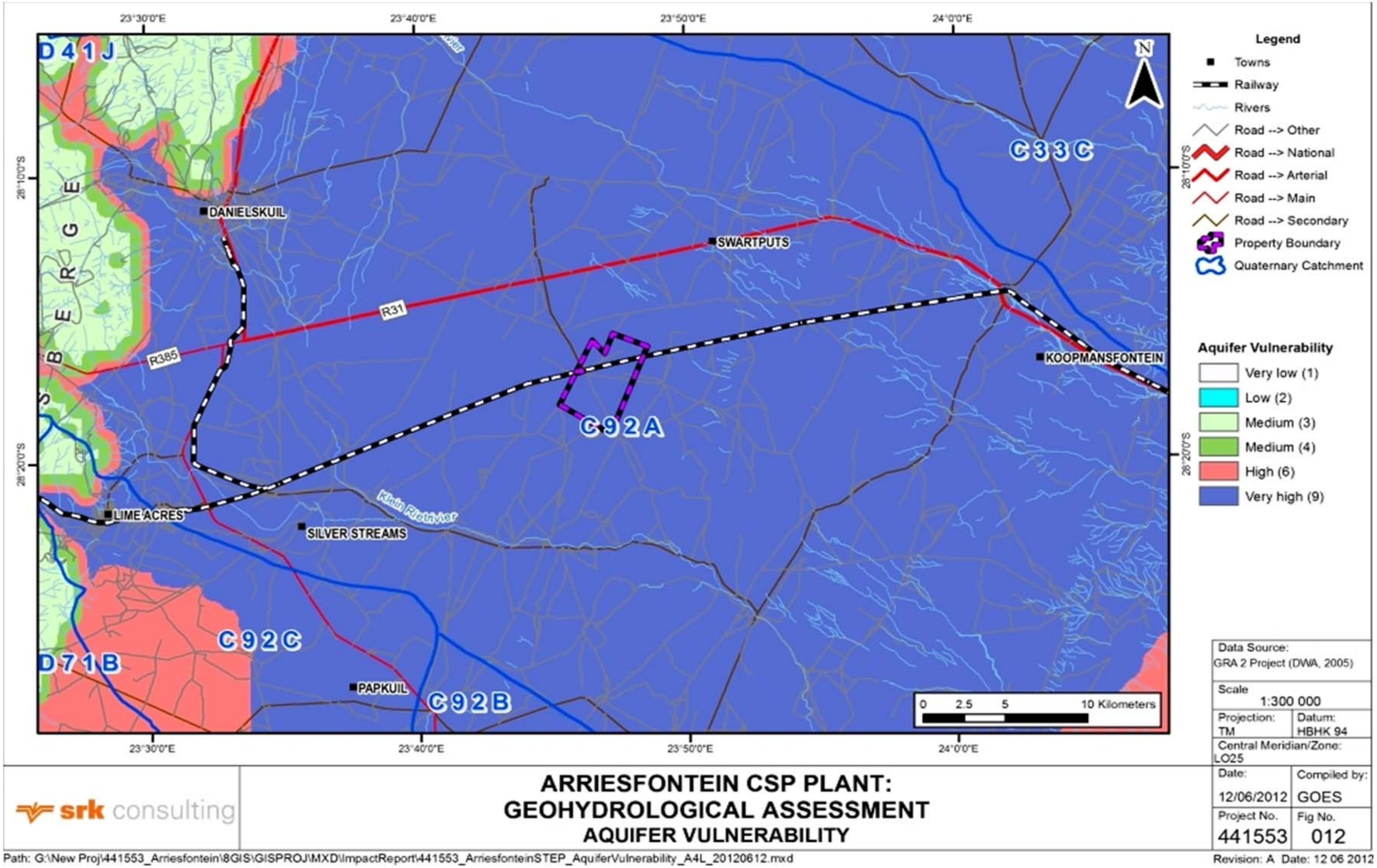

Figure 12: Aquifer Vulnerability Map of the Study Area

In view of this aquifer vulnerability, care should be taken to establish the facilities with the highest contamination risk, e.g. the evaporation ponds, as far as possible away from the high risk areas, i.e. dykes and areas with shallow groundwater levels. The best position for these facilities will be in the southern and south-eastern parts of the site where the aquifer vulnerability is lowest due to relatively deep water levels.

3.3.10 Conceptual Model

The geological information, hydrocensus information and drilling results were used to compile a three dimentional (3-D) conceptual geohydrological model of the site. This 3-D model is shown in **Figure 13** below. The drilling results indicate the depth of the weathered zone to be approximately 25 m and the depth to water table approximately 3 m. Groundwater movement is in a south-easterly direction and the intrusive dolerite dykes with their lower T compartmentalised the aquifers to a certain extent. Drilling and test pumping results also indicates that the highest yields and transmissivities are associated with the fractured/leached contract zones of the dolerite dykes. These contact zones are expected to vary in horizontal thickness of between 25 and 100 m, the latter being representative the wider Arriesfontein Dyke. The upper weathered dolerite zone also forms an aquifer, albeit of a lower yield and T. Potential paths for contaminants to reach the groundwater are:

- The fractured/leached dyke contact zones;
- The weathered dolomite; and
- Existing boreholes where safeguards such as sanitary seals and concrete collars have not been installed. *Note: These have been installed at the new boreholes.*

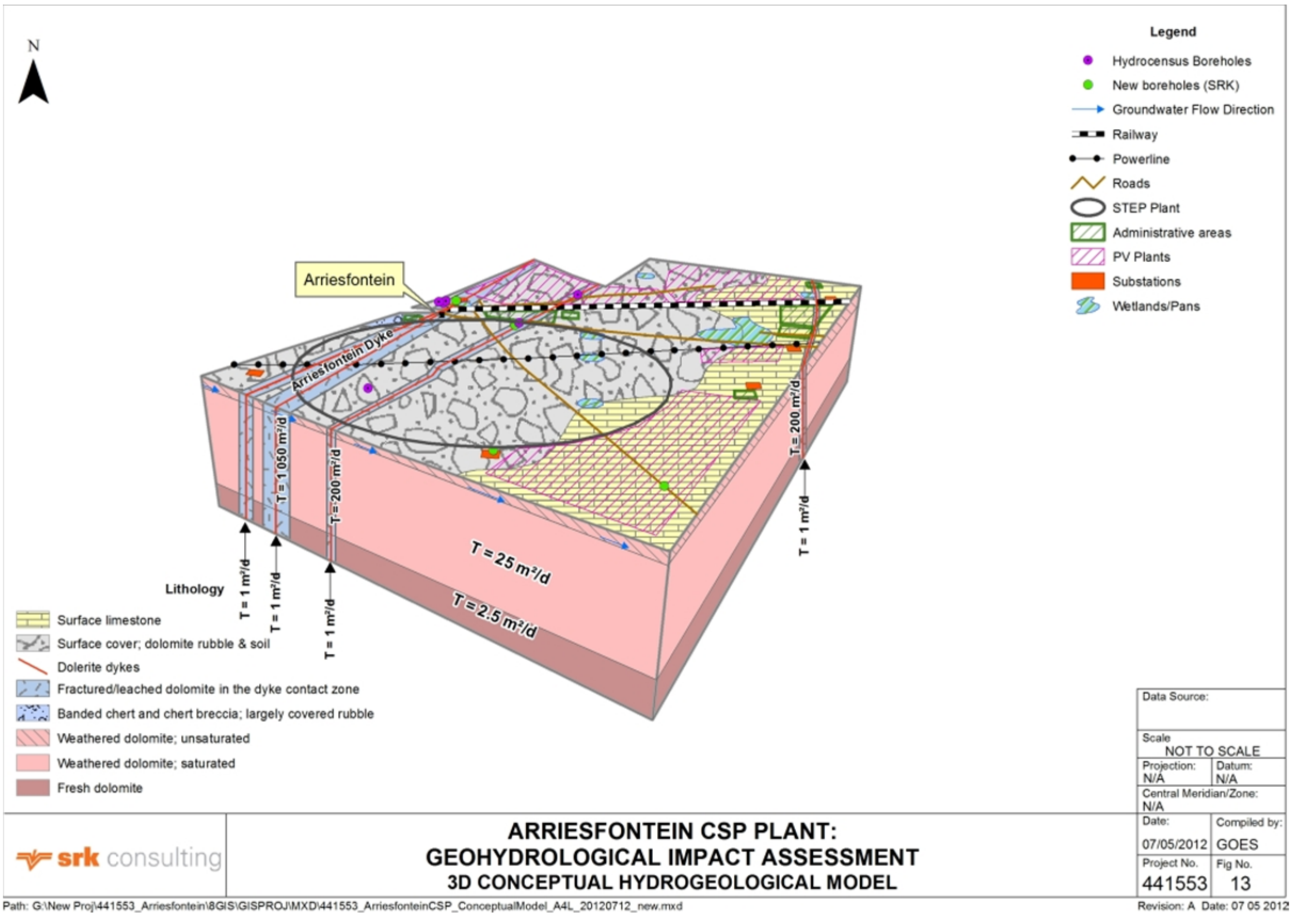

Figure 13: 3-D Conceptual Geohydrological Model of the Site

4 Numerical Flow Model

4.1 Background

The simulation of groundwater flow and transport by numerical models is used for the study of complex groundwater problems. Numerical models basically represent an assembly of many single-cell models. Tremendous advances in computer technology have made them the standard procedure for the solution of groundwater flow and mass transport models.

The numerical model solves both complex and simple problems. Once the numerical model is completed, various scenarios can be realised without undue effort. The dominance of the numerical models has led to the use of 'groundwater model' as a synonym for numerical groundwater models. The basic steps involved in modelling can be summarised as:

- Collecting and interpreting field data: Field data are essential to understand the natural system and to specify the investigated groundwater problem. The numerical model actually develops into a site-specific groundwater model when real field parameters are assigned. The quality of the simulations depends largely on the quality of the input data.
- Calibration & validation: Model calibration and validation are required to overcome the lack of input data, but they also accommodate the simplification of the natural system in the model. In model calibration, simulated values like potentiometric surface or concentrations are compared with field measurements. The model input data are altered within ranges, until the simulated and observed values are fitted within a chosen tolerance. Input data and comparison of simulated and measured values can be altered either manually or automatically.
- Model validation is required to demonstrate that the model can be reliably used to make predictions. A common practice in validation is the comparison of the model with a data set not used in model calibration. Calibration and validation are accomplished if all known and available groundwater scenarios are reproduced by the model without varying the material properties or aquifer characteristics supplied to the model.
- Modelling scenarios: Alternative scenarios for a given area may be assessed efficiently. When applying numerical models in a predictive sense, limits exist in model application. Predictions of a relative nature are often more useful than those of an absolute nature.

4.2 Assumptions and Limitations

The following conditions typically need to be described in a model:

- Geological and geohydrological features;
- Boundary conditions of the study area (based on the geology and geohydrology);
- Initial water levels of the study area;
- The processes governing groundwater flow; and
- Assumptions for the selection of the most appropriate numerical code.

Field data are essential in solving the conditions listed above and developing the numerical model into a site-specific groundwater model. Specific assumptions related to the available field data include:

- The top of the aquifer is represented by the generated groundwater heads;
- The available geological/ hydrogeological information was used to describe the different aquifers. The available information on the geology and field tests are considered as correct;

- Many aquifer parameters related to the contamination have not been determined in the field and therefore have to be estimated based on published data for similar conditions and formations.

In order to develop a model of an aquifer system, certain assumptions have to be made. The following assumptions were made:

- The system is initially in equilibrium and therefore in steady state, even though natural conditions have been disturbed by abstraction of water for farming practises.
- The boundary conditions assigned to the model are considered correct.
- The impacts of other activities (adjacent agriculture and mining) have not been taken into account.

It is important to note that a numerical groundwater model is a representation of the real system. It is therefore at most an approximation, and the level of accuracy depends on the quality of the data that is available. This implies that there are always errors associated with groundwater models due to uncertainty in the data and the capability of numerical methods to describe complex natural physical processes.

4.3 Generation of the Finite Difference Network

In order to investigate the behaviour of aquifer systems in time and space, it is necessary to employ a mathematical model. *MODFLOW*, a modular three-dimensional finite difference groundwater flow model, which was developed by U.S. Geological Survey is the software used during this investigation. It is an internationally accepted modelling package, which calculates the solution of the groundwater flow equation using the finite difference approach.

The mesh constructed for the site consists of 360 x 312 cells in the x and y directions respectively. **Figure 14** is a schematic representation of the mesh. Each of the cells is 25 x 25 m. The coordinates[6] for the modelled area are -123 800 m, -3 135 000 m (lower left corner) to -116 000 m, -3 126 000 m (upper right corner). The model consists of two layers namely:

- Layer 1: Upper weathered zone, 25 m thick
- Layer 2: Unweather dolomite, 100 m thick

The model network extends over a larger area than the area under investigation to ensure that the model boundaries will not affect simulated results.

Once the network has been set up, all initial and boundary conditions, sources, sinks, and aquifer parameters are entered. A steady state calibration is then conducted to ensure the flow model has the same behaviour as the actual system under investigation.

4.4 Boundary Conditions

One of the first and most demanding tasks in groundwater modelling is that of identifying the model area and its boundaries. Consequently, a model boundary is the interface between the model area and the surrounding environment. Conditions on the boundaries, however, have to be specified. Boundaries occur at the edges of the model area and at locations in the model area where external influences are represented, such as rivers, wells, and leaky impoundments.

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[6] Coordinates are in WGS84, LO band 25

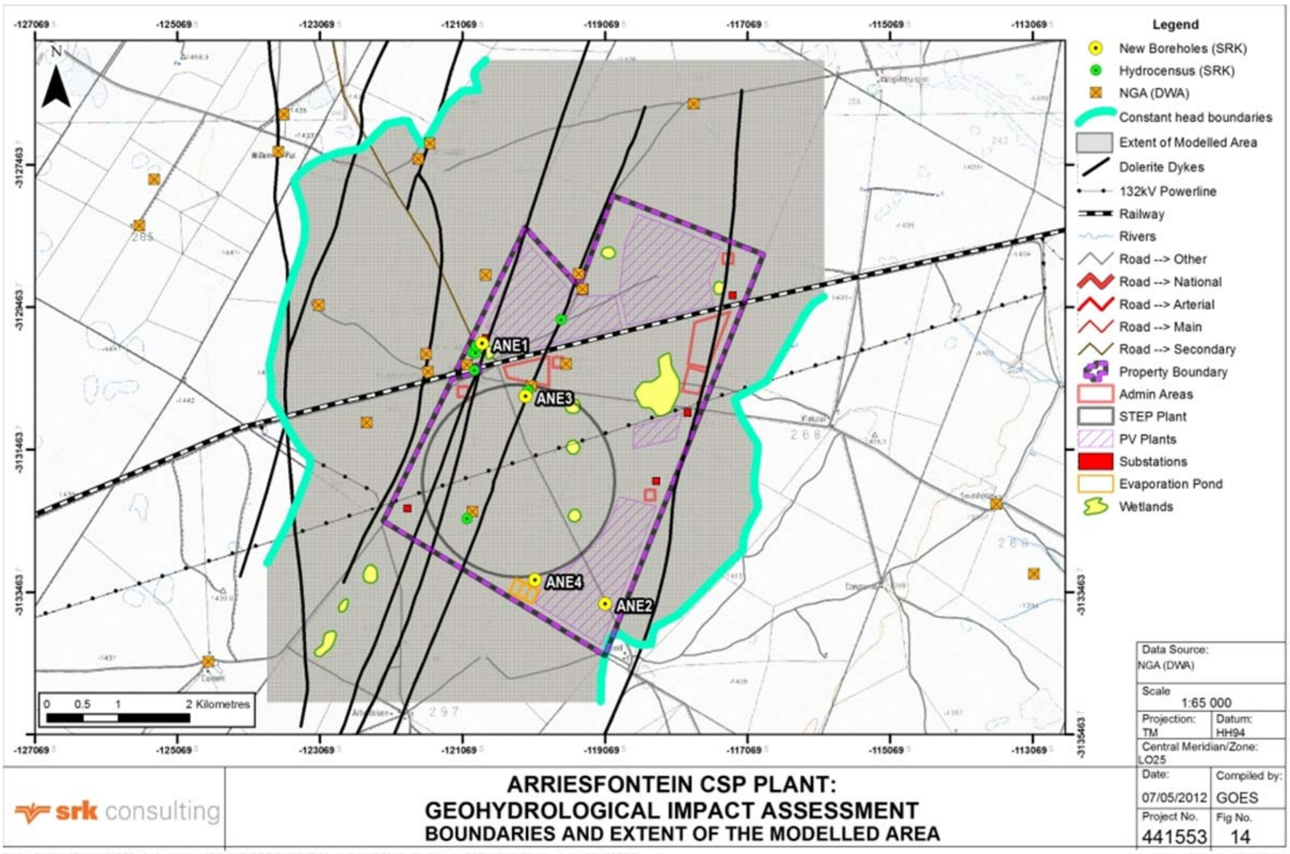

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Figure 14: Map Showing Boundaries and Extent of the Modelled Area

Criteria for selecting hydraulic boundary conditions are primarily topography, hydrology and geology. The topography, geology, or both, may yield boundaries such as impermeable strata or potentiometric surface controlled by surface water, or recharge/discharge areas such as inflow boundaries along mountain ranges. The flow system allows the specification of boundaries in situations where natural boundaries are a great distance away.

Boundary conditions must be specified for the entire boundary and may vary with time. At a given boundary section just one type of boundary condition can be assigned. As a simple example, it is not possible to specify groundwater flux and groundwater head at an identical boundary section. Boundaries in groundwater models can be specified as:

- Dirichlet (also known as constant head or constant concentration) boundary conditions.
- Neuman (or specified flux) boundary conditions.
- Cauchy (or a combination of Dirichlet and Neuman) boundary conditions.

There are no physical features such as major rivers, topographic divides or catchment in the area that can be used as boundaries. Therefore, topographic contour line 1 436 m amsl and 1 414 m amsl were used as the north-western and south-eastern constant head boundaries respectively (**Figure 14**). These boundaries have been chosen as they are far enough from the study area as not to influence to results of the predictive scenarios.

4.5 Initial Conditions

Initial conditions are vital for modelling flow problems. Initial conditions must be specified for the entire area. Generally, the initial water level/head distribution acts as the starting distribution for the numerical calculation. The depth to water level data was obtained from monitoring boreholes within and close to the study area, and privately owned boreholes situated in the vicinity of the study area.

An interpolation technique, using the available data, was used to simulate water levels over the entire model area. The interpolation technique used is referred to as Bayesian interpolation where water levels are correlated with the surface topography. All available levels were plotted against topography as shown in **Figure 15**. The results indicate a correlation of 78.9%, which is a very good correlation. Therefore, Bayesian interpolation is valid and was used to calculate water levels for the entire model area. The groundwater level contours are shown in **Figure 10**.

As groundwater levels follow topography it can be assumed that groundwater flow takes place under semi-confined conditions.

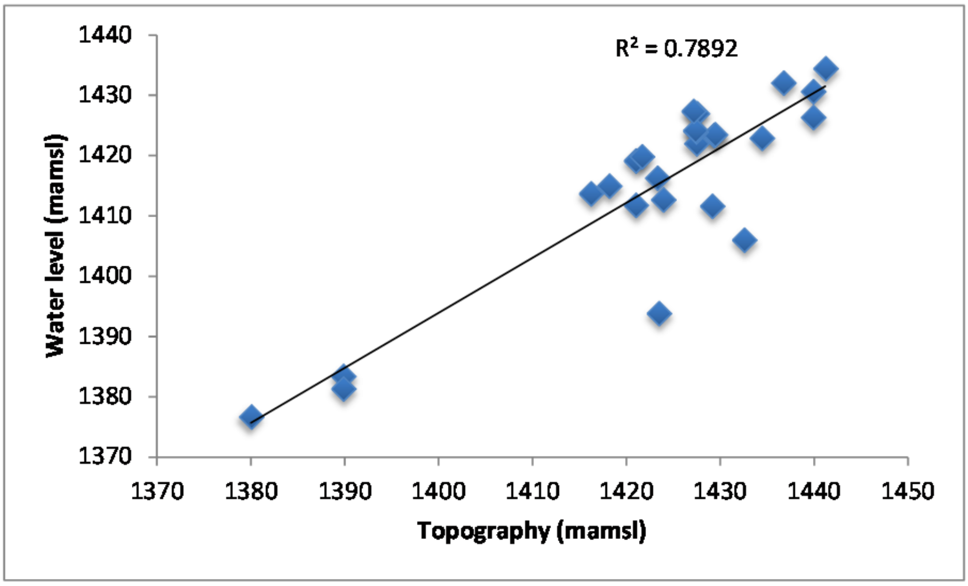

Figure 15: Correlation between Groundwater Levels and Topography

4.6 Sources and Sinks

Sources and sinks can be defined as recharge and abstraction sources in the aquifer. Recharge is the addition of water to the saturated zone, either by the downward percolation of precipitation or surface water and/or the lateral migration of groundwater from adjacent aquifers. Abstraction can be abstraction boreholes, springs, evapotranspiration and outflow to surface water. The recharge for the study area (see subsection 3.3.5) varies between 9 – 11 mm/a.

4.7 Aquifer Parameters

Water in a fractured rock aquifer flows along fractures, faults, joints and bedding planes within the rock matrix. The results of aquifer tests performed as part of this study (see subsection 3.3.6) are summarised in **Table 11**.

Table 11: Summary of Aquifer Parameters

Borehole No.	T (m^2/d)	Estimated storativity	Aquifer Type
ANE1	1 281	4.44E-03	Fractured/leached dolomite
ANE3	193	3.93E-04	Fractured/leached dolomite
ASN1	30	2.97E-03	Fractured/leached dolomite
ANE2	1	1.24E-03	Non-fractured weathered dolomite
ANE4	1	1.87E-03	Non-fractured weathered dolomite
Median fractured	193	2.97E-03	
Median non-fractured	1	1.55E-03	

Transmissivity is a measure of the ease with which groundwater flows in the subsurface. Transmissivity is related to hydraulic conductivity (K):

$$\mathrm{T = Kd}$$

Where d is the saturated thickness of the aquifer. The variable transmissivities are typical of a fractured rock environment. Storativity (S) is a volume of water per volume of aquifer released as a result of a change in head.

4.8 Numerical 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 for example the contamination sites are taken into account.

The simulation model (*MODFLOW*) 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]

Kx,Ky,Kz = 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]

For steady state conditions the groundwater flow Equation (1) reduces to the following equation:

$$\frac{\partial}{\partial x}(K_x \frac{\partial h}{\partial x}) + \frac{\partial}{\partial y}(K_y \frac{\partial h}{\partial y}) + \frac{\partial}{\partial z}(K_z \frac{\partial h}{\partial z}) \pm W = 0 \qquad (2)$$

The steady state head distribution is dependent upon the recharge, T, sources, sinks and boundary conditions specified. For a given recharge component and set of boundary conditions, the head distribution across the aquifer under steady-state conditions can be obtained for a specific T value. The simulated water level distribution can then be compared to the measured water level distribution and the T or recharge values can be altered until an acceptable correspondence between measured and simulated water levels is obtained. An advantage of a steady state model is that the parameter for storativity is not required to solve the groundwater flow equation, therefore, there are less unknown parameters to determine.

The calibration process was done by changing the model parameters for T and recharge. Nine boreholes (including the newly drilled and hydrocensus boreholes) were used to calibrate the steady state groundwater flow model (**Figure 16**).

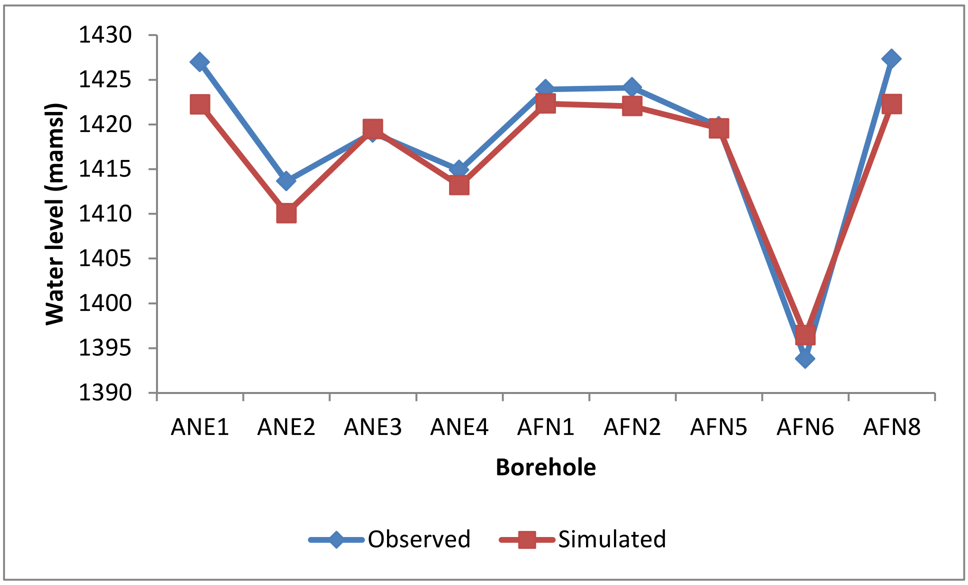

Figure 16: Calibration Results for Hydrocensus Boreholes

The calibration objective was reached when an acceptable correlation was obtained between the observed and simulated water levels. A correlation of 96.3% was achieved (**Figure 17**). It is important to note that only a steady state calibration was performed and this is not ideal. The confidence in the model would be increased if the model was calibrated with time series data. *Note: There are no water level monitoring data available for the site*.

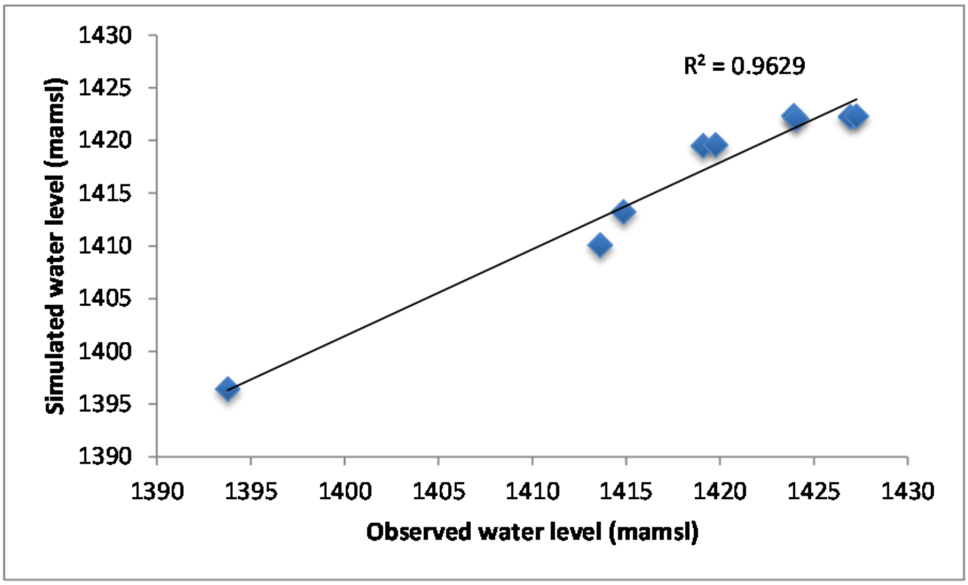

Figure 17: Correlation between Simulated and Observed Water Levels in the Hydrocensus Boreholes

If the NGA boreholes monitored in 1994 are included in the calibration results (**Figure 18**), a correlation of 84.4% is achieved (**Figure 19**).

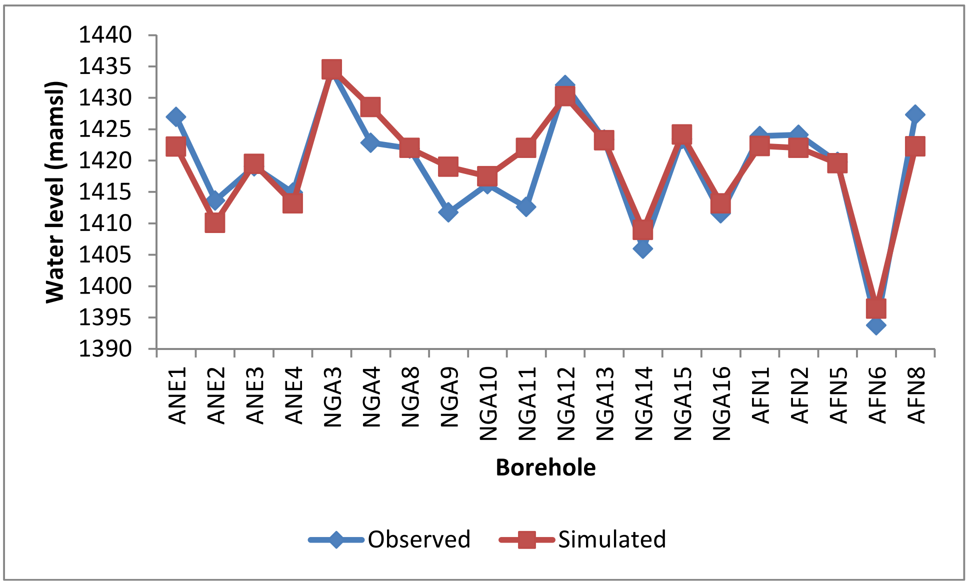

Figure 18: Calibration Results for the NGA Boreholes

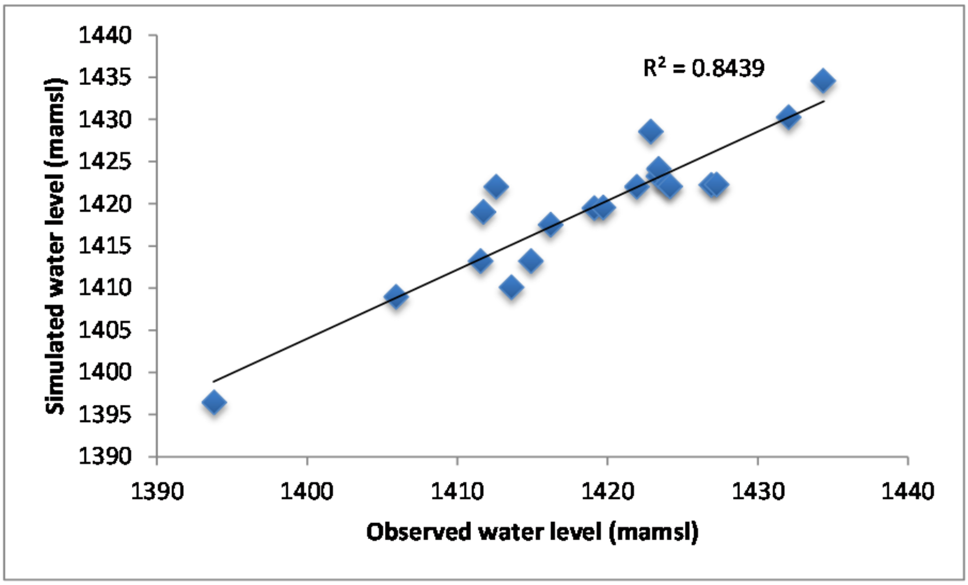

Figure 19: Correlation between Simulated and Observed Water Levels in the NGA Boreholes

The model calibrated with a recharge value of 10 mm/a, which is equivalent to 3% of the mean annual rainfall. The resultant T and vertical hydraulic conductivity (K_v) values used in the model are shown in **Table 12**. *Note: These values differ from the test pumping values shown in Table 11, as these are average values on a more regional scale whereas the test pump values are site specific and represent a much smaller area.*

Table 12: Calibrated Transmissivities

Geology	**T (m^2/d)**	**K_v (m/d)**
Dolerite dykes	1	0.001
Weathered zone parallel to dykes	200	0.2
Weathered zone parallel to the Arriesfontein Dyke	1 050	1
Weathered dolomite	25	0.1
Unweathered dolomite	2.5	0.003

4.9 Mass Transport Model

Mass transport modelling in this situation refers to the simulation of water contamination or pollution due to deteriorating water quality in response to man's disturbance of the natural environment (for example construction of evaporation dams, pollution control dams, etc.). Transport through a medium is mainly controlled by the following two processes:

- 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.
- Hydrodynamic dispersion comprises two processes:

- Mechanical dispersion is the process whereby the initially close group of labelled particles are spread in a longitudinal as well as in a transverse direction because of 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 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.

The MT3D software was used to provide numerical solutions for the concentration values in the aquifer in time and space. Input required in the software is:

- input concentrations of contaminants;
- transmissivity values;
- porosity values;
- longitudinal dispersivities;
- transversal dispersivities;
- hydraulic heads/water levels in the aquifer over time.

Input concentrations in the model were specified at cells over the areas where contamination is expected e.g. across the areas of the evaporation dams and waste sites. The input concentrations were specified as a percentage of the source concentration.

Transmissivities for the aquifer were specified according to the values obtained during the scenario of the steady state water level calibration. The hydraulic head values as calculated during the steady simulations were specified in the model.

One of the biggest uncertainties encountered during transport modelling of pollutants is the kinematic porosity of the aquifer. Porosities were set as 14% as determined by Aqtesolv.com (2012).

A longitudinal dispersivity value of 50 m was selected for the simulations (based on Table D.3 – Field-Scale Dispersivities in Spitz and Moreno, 1996). Bear and Verruijt (1992) estimated the average transversal dispersivity to be 10 to 20 times smaller than the longitudinal dispersivity. An average value of 5 m was selected for this parameter during the simulations.

No mass transport calibration was possible due to the unavailability of onsite monitoring data.

5 Modelling of Predictive Scenarios

5.1 Scenario 1: Simulation of Groundwater Abstraction for Water Supply

In this scenario the plant is dependent on groundwater for water supply utilising the two new production boreholes. The one borehole, ANE1, is located near and just northwest of the Arriesfontein Dyke whilst the second borehole, ANE3, is located along and northwest of the adjacent dyke (for localities see **Figure 8**). According to WorleyParsons (2012) the quantity of water required for normal operations is 272 400 m^3/a, therefore, in this simulation, ANE1 was pumped at 560 m^3/d and ANE2 at 186 m^3/d. The resultant water level drawdown after 5, 15 and 30 years of pumping are shown in **Figure 20**, **Figure 21** and **Figure 22**, respectively. After 5 years the 0.5 m zone of drawdown would have extended ~5.5 km in a northeast - south-westerly direction parallel to the dykes and ~3.2 km in a northwest - southeast direction across the dykes. The drawdown zone may extend to beneath two of the pans (seasonal wetlands), albeit these should not be affected as they are not linked to the groundwater system. These pans, or wetlands, are seasonally inundated by rainwater runoff. The Arriesfontein Spring and wetland, which is approximately 100 m east of borehole ANE1, and is known to only flow after years of above normal rainfall, would experience a water level drop of approximately 2.5 m. Four of the boreholes (NGA) on the neighbouring farm to the west of the site may also experience a water level drop of between 1.5 and 2 m, which is unlikely to negatively affect the productivity of these boreholes.

Steady state conditions are reached after approximately 10 years with the 0.5 m zone of drawdown extending ~5.8 km in a northeast - southwest direction and ~3.9 km in a northwest - southeast direction. The four boreholes (NGA) on the neighbouring farm to the west of the site may experience a water level drop of between 1.5 and 2 m, whilst a fifth borehole may experience a drop of between 0.5 and 1 m. The drop in water level is unlikely to negatively affect the productivity of these boreholes, reason being that in this area the water strikes are mostly much deeper (>10 m bgl) whereafter the rest water level rises to between 0.5 and 3.5 m bgl.

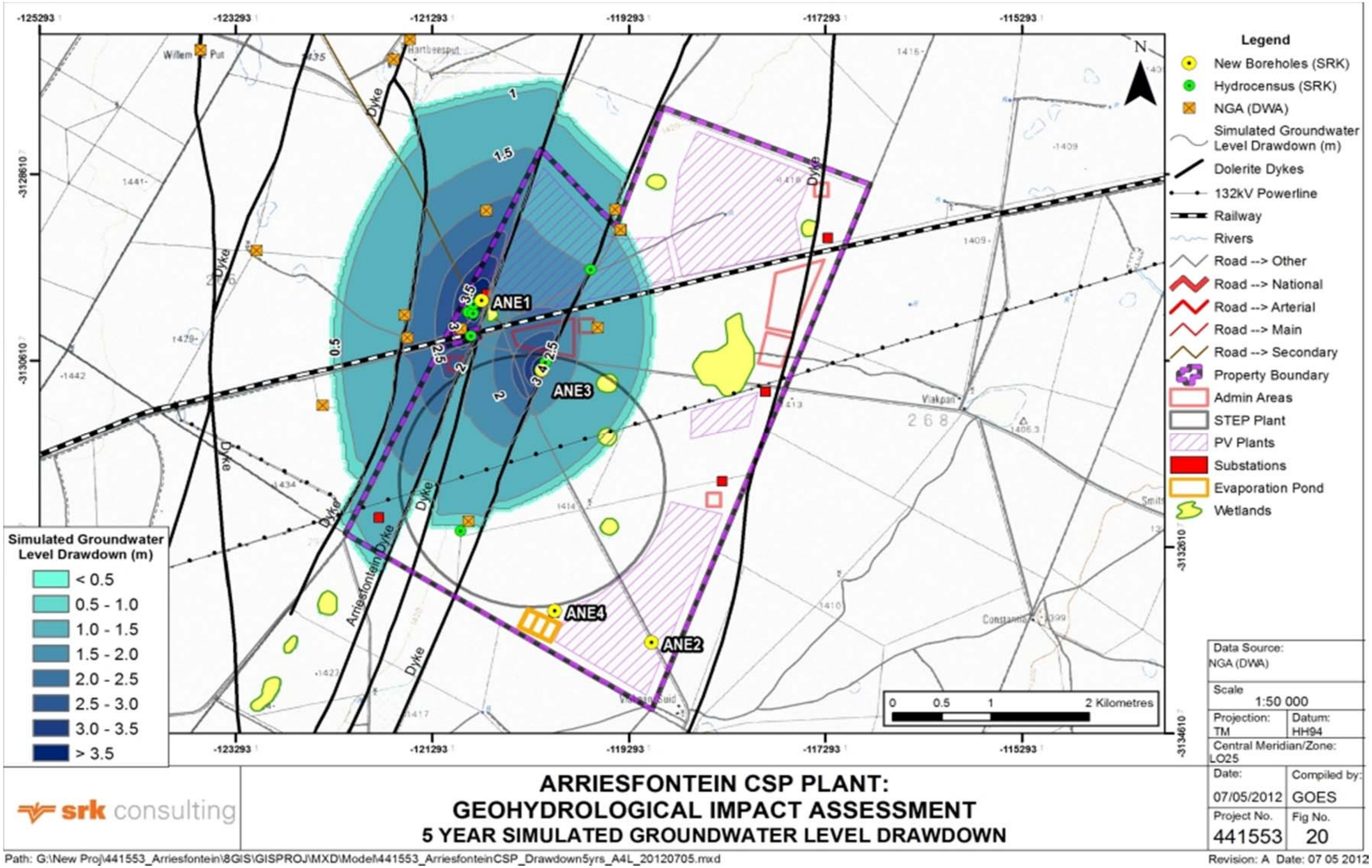

Figure 20: Simulated Abstraction Drawdown after 5 Years

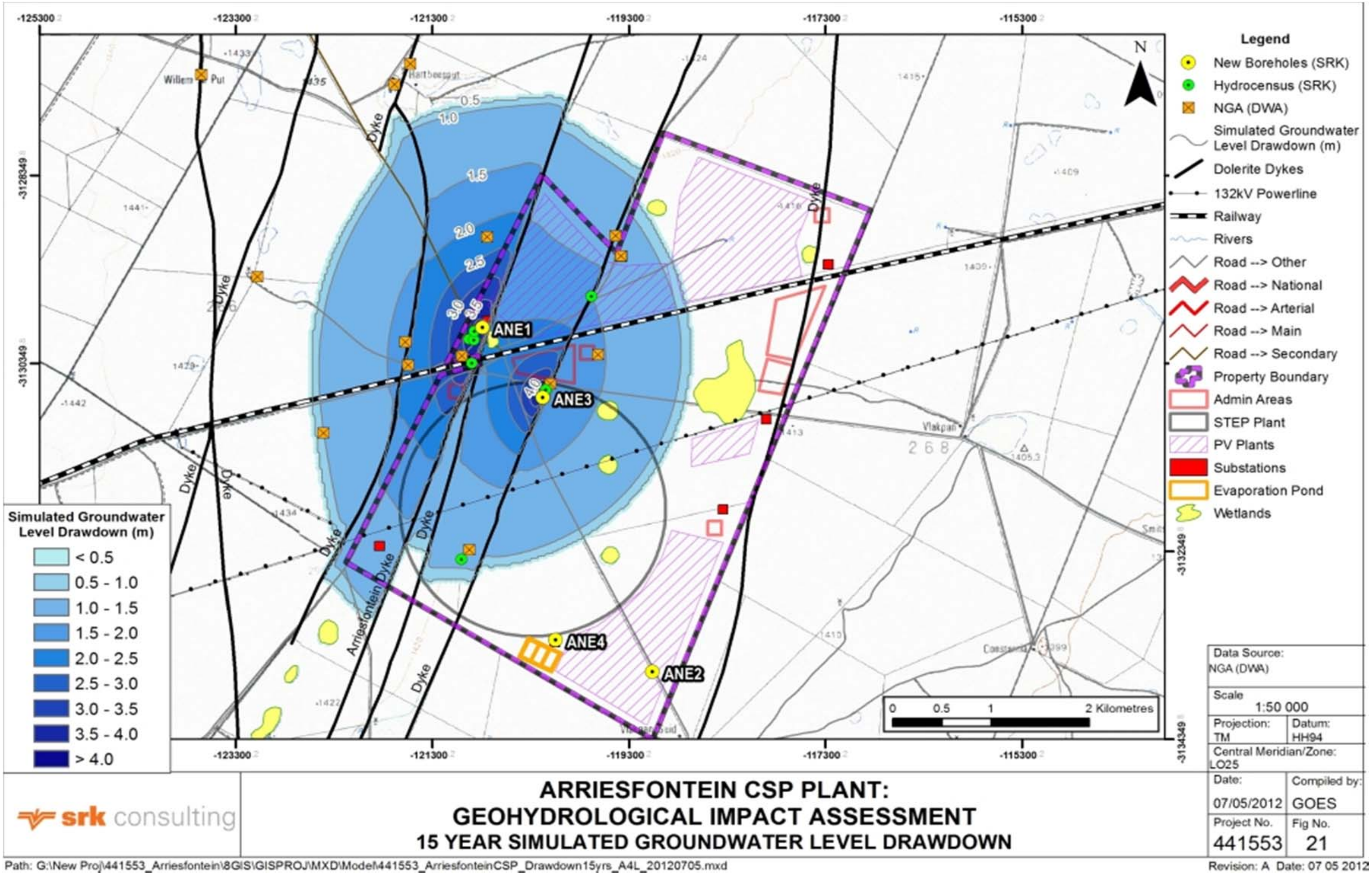

Figure 21: Simulated Abstraction Drawdown after 15 Years

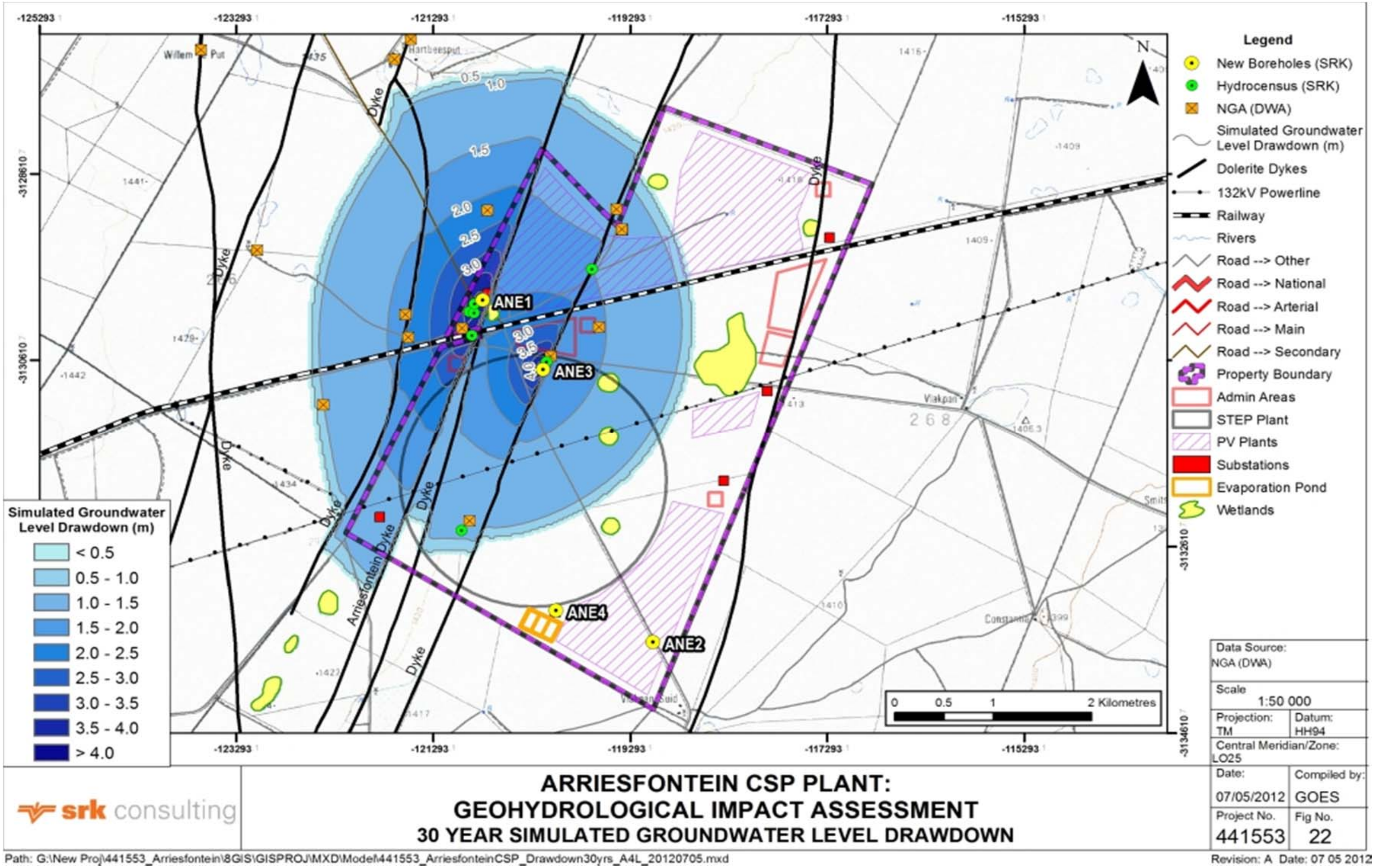

Figure 22: Simulated Abstraction Drawdown after 30 Years