

HENKRIES SOIL REPORT

COMPLETE SOIL INVESTIGATION SURVEY TO ASCERTAIN THE SUITABILITY FOR THE CULTIVATION OF VIRGIN SOIL FOR THE PRODUCTION OF GRAPES AND DATES AT HENKRIES FARM, SPRINGBOK AREA, NORTHERN CAPE PROVINCE.

CONTRACT: NC/DALC/0529, PROJECT NR: 31440



3 DECEMBER 2014



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INTRODUCTION AND BACKGROUND

BVi Consulting Engineers was appointed to do a complete soil investigation at Henkries, Northern Cape Province. The purpose of the investigation is to ascertain the suitability of virgin soil for the production of grapes and dates under irrigation.

The planned development is approximately 142ha in size.

The proposed area was surveyed, and profile pits were set out on a 100m x 100m grid. The profile pits were prepared by a local contractor and filled-up after completion of the soil pit investigation.

BVi requested the services of Digital Soils Africa, under direction of Dr Pieter le Roux to assist with the soil investigation. Dr le Roux is very well known in the field of soil science and is an expert in this area.

The field work was completed in September, where after the chemical analysis and reporting was done.

Please find attached the complete soil report for Henkries. The contour map is also available in CAD format.

I trust that the report provides the necessary information as required. Please contact me should you require any further information.

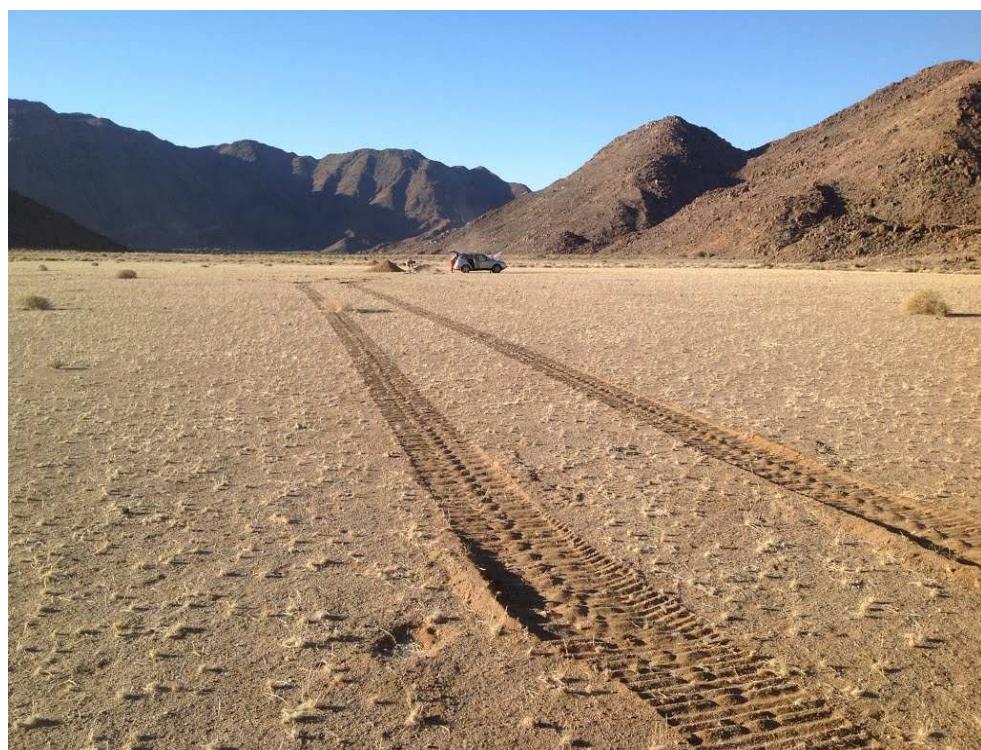


M. PRETORIUS Pr. Eng.

Soil Report on

Henkries Farm

Soil survey and irrigation suitability study for the production of dates and grapes at Henkries in the Springbok District, Northern Cape Provence



1. EXECUTIVE SUMMARY

The site has a high potential for production of grapes and dates under irrigation. The Departmental norms are met as the soils don't have thick gley layers within 400 mm and have a low clay content allowing high infiltration and drainage, are deep (3000 mm+) and therefore when waterlogged, drainage is easily installed and chemical properties can be easily rectified

The Dundee soil form cover the whole area. The orthic A horizon is poorly expressed. The only morphological property is stratification which varies in expression and thickness. The texture is sand with 37 % gravel fragments on average. The gravel is of a variety of sizes.

The soil meets the requirements for irrigation. Water infiltrates fast exceeding 200 mm per hour. Water will drain through the soil at more than 200 mm per hour. The same texture in the soil extends to depths exceeding 3 meters indicating that water logging by over irrigation unlikely. The water holding capacity is very low.

The chemical properties limit the selection of crops which prefer or are insensitive to a high pH. The climate limits selection to crops preferring or dependent on extremely high summer temperatures and low humidity.

The site is therefore suitable for the production of dates and grapes. Soil preparation has to include deep (1.2m) ripping in lines (grapes) or cross ripping (dates) to limit the impact of stratification on root growth. Irrigation methods are limited to micro or sprinkler irrigation. Cover of the soil surface with stones present in most soils, to limit evaporation, can improve water efficiency.

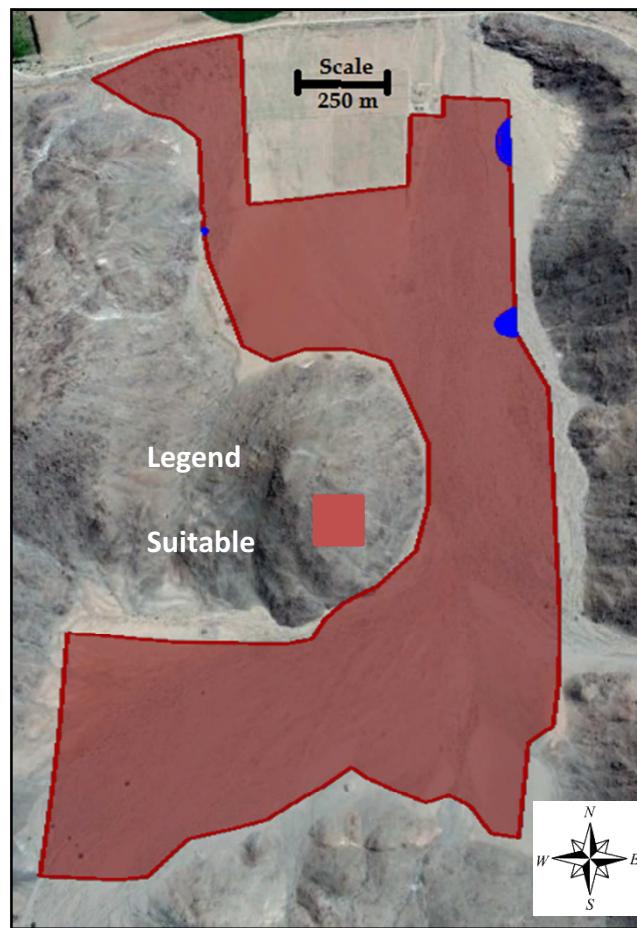


Figure 1 Suitability map

Table of Contents

1. EXECUTIVE SUMMARY.....	2
2. INTRODUCTION	4
2.1. Site Description	5
3. MATERIAL AND METHODS	7
4. RESULTS.....	7
4.1. Soil Classification.....	7
4.2. Morphological Properties	8
4.3. Chemical Properties.....	8
4.4. Physical Properties.....	15
5. Maps.....	18
5.1. Soil Map	18
5.2. Soil Depth Map.....	19
6. SUITABILITY FOR DATE PRODUCTION & IRRIGATION.....	21
6.1. Environmental indicators.....	21
6.2. Morphological indicators	21
6.3. Chemical indicators.....	21
6.4. Soil fertility	21
6.5. Agrometric potential.....	21
7. RECOMMENDATIONS	24
8. REFERENCES	25
9. Appendix 1.....	27
10. Appendix 2.....	31
11. Appendix 3.....	36
12. Appendix 4.....	44

1. INTRODUCTION

"A thorough knowledge of soil types in a potential irrigation project is absolutely essential for both economic and technical reasons." (ARC, 1997).

Assessment of soil, terrain and climate are the most important inputs of land evaluation for irrigation suitability. Soil surveys are important for effective irrigation planning and optimization of land use, decreasing the risk of land degradation and increasing the benefit of effective management. Soil suitability for irrigation is very dependent on soil type, effective depth and intended crop, with different scenarios requiring a different management practice for optimized results.

The main objective was to characterise and map the soils of Henkries and interpret them in terms of suitability for irrigation under these climate conditions. The properties limiting the suitability of the soils and precautionary measures normally recommended for sustained irrigation use will also be given.

1.1. Site Description

Henkries is situated 90 km north of Springbok in the Northern Cape Province (Figure 2).

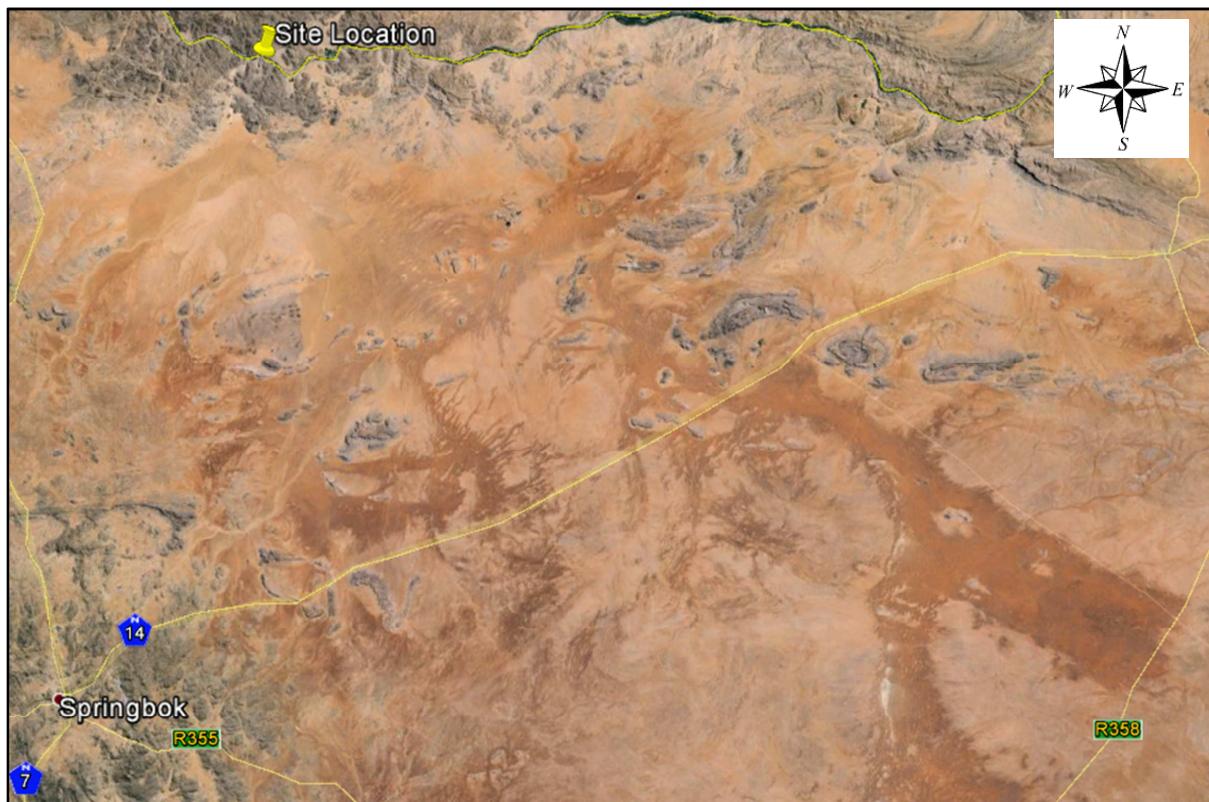


Figure 2 Location of Henkries farm in the Northern Cape Province

Henkries receive very little rain with the highest rainfall months being March and April, which is only 15 mm (Figure 3). The highest average maximum and minimum temperatures are in January, while July is the coldest month (Figure 4)

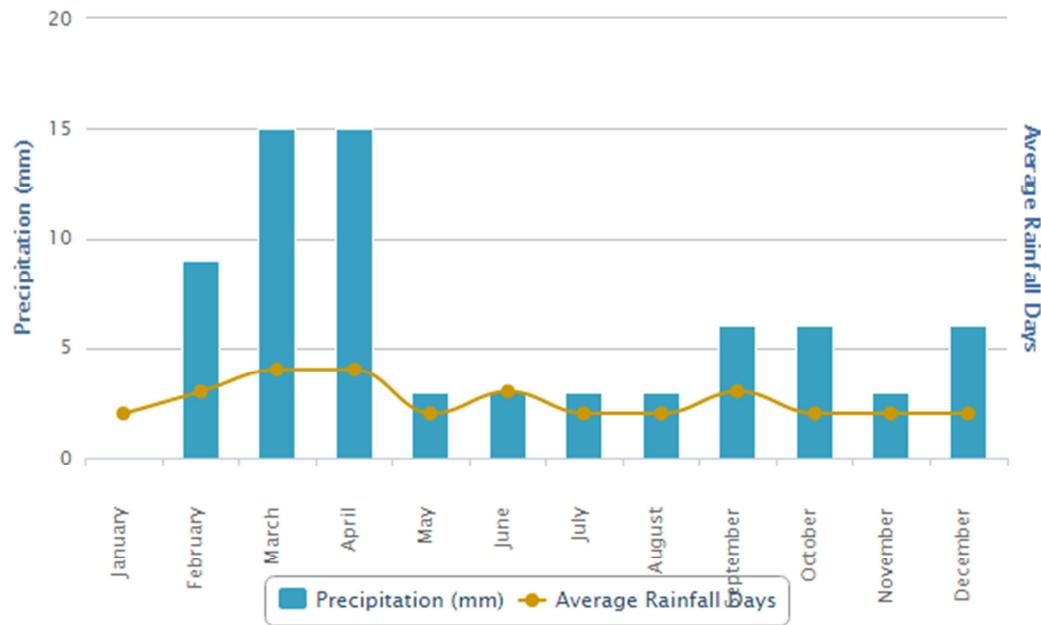


Figure 3 Average rainfall and rainfall days in Henkries.

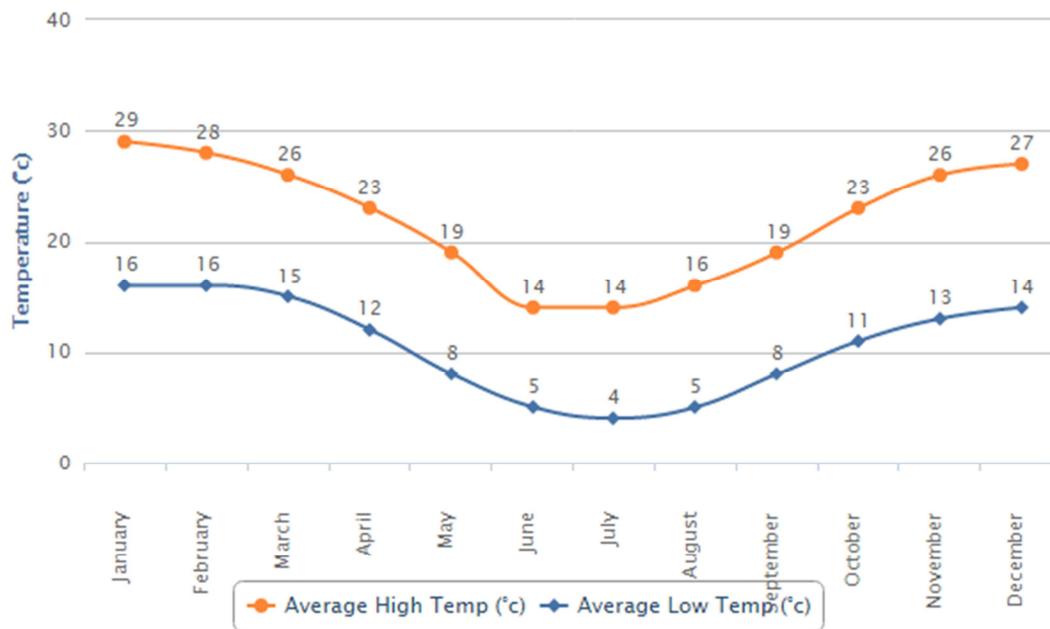


Figure 4 Average minimum and maximum temperatures in Henkries.

2. MATERIAL AND METHODS

The survey consisted 149 profiles classified according to Soil Classification Working Group (1991). Samples were taken from representative soil profiles at 0 to 300 mm, 300 to 600 mm and 600 to 900 mm depth. It was split and one sample was sieved and the gravel contents determined. Resistance of the bulk samples was determined. pH was measured using 1.0 N KCl extract at 1:2.5 ratio. The P content was measured using a spectrophotometer and a Bray I extract 1:7.5 ratio. Two methods were used in determining the cation concentrations. Firstly the soil was leached with Ammonium Acetate extract with a 1:10 ratio and trace elements were extracted using an 0.1 N HCl extract at a 1:2.5 ratio. Secondly cations were determined by the Mehlich III extract with a 1:10 ratio. The CEC was determined by saturation with Ammonium Acetate and extracted by 1.0 N KCL. Hydrometer was used to determine texture.

3. RESULTS

3.1. Soil Classification

Dundee soil form was the only soil form found in the surveyed area. The soils are of the Sabie family, non-red, no signs of wetness and calcareous.

Table 1 Soil form found in the study area

Soil Form	Master Horizon	Diagnostic Horizon
Dundee (Du)	A	Orthic
	C1	Stratified alluvium
	C2 etc.	Stratified alluvium

The soil only vary in degree of stratification and presence of larger stones. None of these will influence the suitability of the soils for irrigation. Examples of these soils are described in detail (Appendix 1). Weak stratification with smaller and larger stones (Figure 5a and b) and strong stratification with bigger stones (Figure 6).

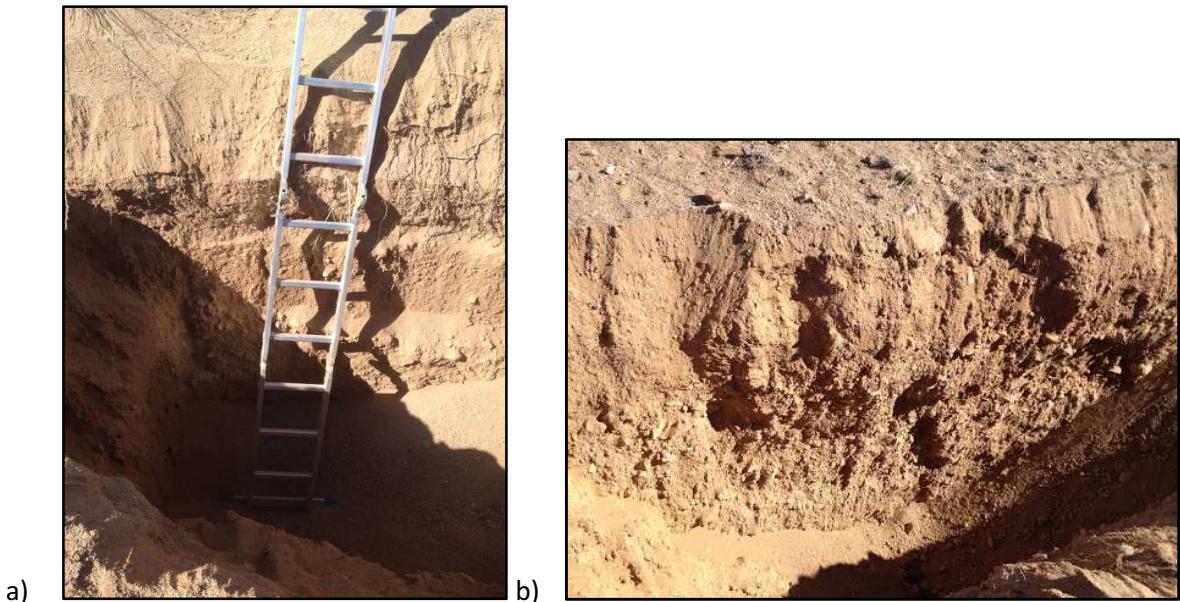


Figure 5 Small stones with a) strong stratification (P7) and b) weak stratification (P67).



Figure 6 Bigger stones and weak stratification.

3.2. Morphological Properties

Stratification varies extremely in thickness, expression and size of gravel and rocks. The soil texture does not vary much as it is all sand.

3.3. Chemical Properties

The pH (Table 2) ranges from acidic to alkaline (Table 3). The pH is high for sandy soils, indicating a low degree of leaching, expected in low rainfall areas. Therefore there is a low risk of acidification (Hazelton & Murphy, 2007). The high pH is an indication of high Na contents. The range of pH values in profiles are limited compared to the variation between samples of different profiles.

Table 2 Summarized chemical properties of representative profiles

Ref No	pH	P	K	Na	Ca	Mg	CEC
	(KCl)	mg/kg					cmol(c)/kg
H7.1	6.83	43	59	9	1096	87	1.29
H7.2	7.04	24	56	7	789	59	1.47
H7.3	6.86	7	103	11	1823	50	2.61
H27.1	7.78	72	262	466	1323	79	3.34
H27.2	6.40	17	24	103	974	34	1.52
H27.3	6.74	7	23	73	3686	36	4.68
H50.1	6.26	30	178	24	1861	125	1.93
H50.2	6.66	15	22	193	8425	47	2.16
H50.3	6.55	11	37	536	8884	54	2.67
H68.1	5.75	22	242	79	1762	119	1.45
H68.2	7.03	20	89	161	3863	81	2.19
H68.3	7.22	12	37	20	6898	65	2.42
H91.1	8.05	42	58	14	810	67	1.08
H91.2	8.01	17	76	12	2295	70	1.71
H91.3	7.24	16	121	22	3354	49	2.24
H97.1	8.18	21	63	10	721	48	0.87
H97.2	7.18	15	126	9	1986	41	1.63
H97.3	7.82	11	109	14	2061	47	1.71
H101.1	6.24	25	268	448	3297	100	4.52
H101.2	7.39	17	53	792	2859	50	3.26
H101.3	7.84	13	52	821	3199	54	3.81
H121.1	7.63	43	144	27	1798	114	2.74
H121.2	7.75	18	105	93	2300	83	3.06
H121.3	7.28	15	86	924	6131	71	3.28
H123.1	8.03	30	103	33	1314	76	1.95
H123.2	7.07	22	102	28	1824	55	2.02
H123.3	7.50	22	75	277	2561	61	3.94
H137.1	6.81	15	98	12	1863	34	1.95
H137.2	6.40	33	203	73	2143	100	2.82
H137.3	7.32	25	74	224	3146	82	4.59
H139.1	7.61	13	121	12	682	68	2.43
H139.2	7.71	13	118	34	2090	93	2.96
H139.3	7.90	9	85	328	3241	101	3.34

Table 3 General interpretation of pH ranges (Bruce & Raymond, 1982)

pH	Rating
>9	Very strongly alkaline
9 - 8.5	Strongly alkaline
8.4 - 7.9	Moderately alkaline
7.8 - 7.4	Mildly alkaline
7.3 - 6.6	Neutral
6.5 - 6.1	Slightly acid
6 - 5.6	Moderately acidic
5.5 - 5.1	Strongly acidic
5 - 4.5	Very strongly acidic

The Ca concentrations range from low to very high (Table 6). Deductions are difficult due to the stratification, but the subsoil is generally Ca enriched either by translocation during leaching or a large deposit that had a high Ca content. The high percentage of Ca on the exchange complex is probably the reason for the high pH, which is not restrictive to plant growth. The Mg contents are low in all the samples. The K contents range from very low to moderate, the highest K values are generally in the topsoil horizon. The Na contents range from very low to very high. The exchangeable sodium percentage (ESP) cannot be calculated as the soils have free salts. The Ca:Mg ratio of the extractable cations indicates no dispersion.

Table 4 Ca:Mg ratio to measure dispersivity

Ref No	Ca:Mg	Interpretation
H7.1	7.677369	Non dispersive
H7.2	8.187973	Non dispersive
H7.3	22.21828	Non dispersive
H27.1	10.20407	Non dispersive
H27.2	17.68346	Non dispersive
H27.3	63.14523	Non dispersive
H50.1	9.100582	Non dispersive
H50.2	109.2956	Non dispersive
H50.3	99.90832	Non dispersive
H68.1	9.042674	Non dispersive
H68.2	29.05466	Non dispersive
H68.3	64.80496	Non dispersive
H91.1	7.330604	Non dispersive
H91.2	20.07354	Non dispersive
H91.3	41.79386	Non dispersive
H97.1	9.237107	Non dispersive
H97.2	29.84171	Non dispersive
H97.3	26.97879	Non dispersive
H101.1	20.0884	Non dispersive
H101.2	34.69725	Non dispersive
H101.3	36.36305	Non dispersive
H121.1	9.580977	Non dispersive

Ref No	Ca:Mg	Interpretation
H121.2	16.98333	Non dispersive
H121.3	52.52302	Non dispersive
H123.1	10.53342	Non dispersive
H123.2	20.30163	Non dispersive
H123.3	25.67242	Non dispersive
H137.1	33.74092	Non dispersive
H137.2	13.05811	Non dispersive
H137.3	23.27615	Non dispersive
H139.1	6.117941	Non dispersive
H139.2	13.77593	Non dispersive
H139.3	19.55493	Non dispersive

The resistance in the soils are higher in the first two horizons and then decrease in the bottom of the profile with highest resistance measured as 24000 Ω (Table 5). The average resistance for top middle and bottom horizons are 9715 Ω, 7714 Ω and 5590 Ω respectively.

Table 5 Resistance of selected profiles

Profile	Resistance (Ω)	Resistance (Ω)	Resistance (Ω)
H1	10900	11100	24000
H3	7900	8600	5900
H5	7200	5700	2200
H7	24000	13100	7800
H9	9600	13300	5100
H11	10600	8500	7600
H13	5400	1420	480
H27	2700	750	620
H28	4950	1060	1440
H30	11000	8000	2640
H32	8700	6750	2840
H34	10800	5850	680
H36	14200	13000	4650
H38	12600	5550	3150
H40	17600	16200	9900
H42	6700	2080	385
H44	9400	3400	440
H46	3400	660	292
H48	4350	335	262
H50	5200	1520	500
H52	12000	13400	14400
H54	16000	11400	7300
H56	17800	12200	11400
H58	13600	6000	8800
H60	11400	6700	4400
H62	1760	650	375
H64	9700	11000	3850
H66	11000	12400	11800
H68	5100	3450	7350
H70	11400	8200	10600
H72	12400	14000	17200
H74	10600	10600	640
H76	2140	2280	1160
H78	12800	9500	6600
H80	13400	15200	7100
H82	15200	11200	7600
H84	13600	12400	10600
H86	13000	13800	7000

Profile	Resistance (Ω)	Resistance (Ω)	Resistance (Ω)
H88	15400	14200	7300
H89	7600	6900	9100
H91	15200	13000	8700
H93	14200	3350	8900
H95	8500	14000	10200
H97	9700	11600	8700
H99	6900	1760	4550
H101	2080	22	236
H103	14700	11200	6800
H105	10800	10200	8800
H107	2140	2460	1300
H109	8050	3200	1040
H111	9600	3250	1420
H113	10400	8900	5300
H115	10200	10200	7700
H117	10600	12400	10600
H119	9400	4450	1700
H121	6800	6200	280
H123	7900	8500	3700
H125	11800	11200	12600
H127	3600	9000	8300
H129	540	190	138
H131	8300	10200	6400
H133	12400	10600	6000
H135	2140	1360	345
H137	11800	5800	3600
H139	10600	6000	600
Average	9715	7714	5590

Table 6 Ratings of cation concentrations in soil (Metson, 1961)

Cation	Very low	Low	Moderate	High	Very high
Ca mg/kg	0- 400	400 - 1000	1000-2000	2000-4000	>4000
Mg mg/kg	0- 35	35- 120	120- 360	360-970	>970
Na mg/kg	0- 23	23- 70	70- 160	160- 460	>460
K mg/kg	0- 80	80- 120	120- 275	275- 780	>780

The cation exchange capacities (CEC) of the soils are very low (Table 7), expected from a sandy apedal soils. The highest CEC is 4.86 which are very low.

Table 7 Cation exchange capacity ratings

Rating	CEC (cmol(+) kg ⁻¹)
Very low	<6
Low	6-12
Moderate	12-25
High	25-40
Very high	>40

3.4. Physical Properties

The soils are very sandy with all the samples in the sand texture range (Table 8), the highest clay content is 12% and the lowest is 6%.

Table 8 Particle size distribution and Texture class

Ref No	Clay (%)	Silt (%)	Sand (%)	Texture class
H7.1	8	2	90	Sand
H7.2	8	2	90	Sand
H7.3	10	2	88	Sand
H27.1	10	2	88	Sand
H27.2	10	2	88	Sand
H27.3	10	2	88	Sand
H50.1	10	2	88	Sand
H50.2	10	2	88	Sand
H50.3	10	6	84	Sand
H68.1	10	2	88	Sand
H68.2	10	2	88	Sand
H68.3	10	5.88	84.12	Sand
H91.1	8	2	90	Sand
H91.2	6	2	91.6	Sand
H91.3	10	2.7	87.3	Sand
H97.1	8	2	90	Sand
H97.2	8	2	90	Sand
H97.3	10	0.64	89.36	Sand
H101.1	14	7.36	78.64	Sand
H101.2	12	3	85	Sand
H101.3	12	5.04	82.96	Sand
H121.1	10	2.26	87.74	Sand
H121.2	10	2.52	87.48	Sand
H121.3	14	5.34	80.66	Sand
H123.1	8	2	90	Sand
H123.2	8	2	90	Sand

Ref No	Clay (%)	Silt (%)	Sand (%)	Texture class
H123.3	12	4.38	83.62	Sand
H137.1	8	2	90	Sand
H137.2	12	3.22	84.78	Sand
H137.3	12	6.22	81.78	Sand
H139.1	6	3.6	90.4	Sand
H139.2	8	2.06	89.94	Sand
H139.3	10	5.54	84.46	Sand

There is a general increase in gravel content with depth (Table 9). The average gravel content in the topsoil is 30.4%, middle 37% and 44.4% at the bottom.

Table 9 Gravel content of soils

Top soil	Rock %	Middle soil	Rock %	Bottom soil	Rock %
H1.1	16.37676	H1.2	29.35722	H1.3	36.61306
H3.1	28.9502	H3.2	27.15122	H3.3	44.91587
H5.1	25.33105	H5.2	55.82507	H5.3	56.12085
H7.1	42.7432	H7.2	44.19703	H7.3	54.06369
H9.1	19.21707	H9.2	20.15522	H9.3	43.42257
H11.1	34.37949	H11.2	35.25568	H11.3	51.31406
H13.1	38.52352	H13.2	49.93501	H13.3	31.77419
H27.1	26.14699	H27.2	36.1018	H27.3	40.9492
H28.1	28.233	H28.2	27.5516	H28.3	32.99243
H30.1	34.71775	H30.2	47.13537	H30.3	67.28808
H32.1	23.82803	H32.2	48.85611	H32.3	60.19334
H34.1	21.66243	H34.2	42.99808	H34.3	55.81599
H36.1	24.73753	H36.2	49.64109	H36.3	57.23765
H38.1	15.2056	H38.2	27.12844	H38.3	31.59559
H40.1	40.77954	H40.2	37.09383	H40.3	51.26543
H42.1	36.86123	H42.2	33.46332	H42.3	38.01657
H44.1	23.10457	H44.2	34.21903	H44.3	38.46079
H46.1	29.43429	H46.2	17.61404	H46.3	29.87193
H48.1	22.20081	H48.2	36.09701	H48.3	22.94652
H50.1	16.76538	H50.2	53.21177	H50.3	35.90448
H52.1	27.35687	H52.2	45.9612	H52.3	48.70659
H54.1	29.60058	H54.2	54.7477	H54.3	46.12207
H56.1	28.60176	H56.2	62.89672	H56.3	42.02255
H58.1	21.73248	H58.2	40.72777	H58.3	46.11742
H60.1	16.78701	H60.2	24.29905	H60.3	53.67105

Top soil	Rock %	Middle soil	Rock %	Bottom soil	Rock %
H62.1	34.8922	H62.2	30.32982	H62.3	33.18322
H64.1	21.44225	H64.2	25.42738	H64.3	40.73286
H66.1	26.73371	H66.2	38.37976	H66.3	61.41218
H68.1	29.51082	H68.2	27.39584	H68.3	19.50232
H70.1	47.37588	H70.2	41.82399	H70.3	57.233
H72.1	34.14251	H72.2	41.34785	H72.3	60.4269
H74.1	29.10957	H74.2	41.13818	H74.3	17.17983
H76.1	20.8715	H76.2	40.85894	H76.3	33.53676
H78.1	34.62061	H78.2	37.60187	H78.3	38.55077
H80.1	28.74878	H80.2	37.32471	H80.3	36.30473
H82.1	26.59358	H82.2	40.65727	H82.3	34.50816
H84.1	32.1586	H84.2	29.99961	H84.3	41.81124
H86.1	30.91754	H86.2	31.23167	H86.3	57.41488
H88.1	73.38415	H88.2	48.46764	H88.3	39.58672
H89	25.73359	H89.2	42.28671	H89.3	41.69515
H91.1	26.85486	H91.2	33.10135	H91.3	52.18818
H93.1	25.4005	H93.2	51.40945	H93.3	51.91114
H95.1	51.80126	H95.2	57.27164	H95.3	49.50654
H97.1	51.9754	H97.2	25.61427	H97.3	44.30361
H99.1	23.96932	H99.2	29.21026	H99.3	49.13972
H101.1	43.61922	H101.2	32.67868	H101.3	39.54131
H103.1	30.13262	H103.2	35.6798	H103.3	59.39654
H105.1	46.00421	H105.2	39.23187	H105.3	63.51292
H107.1	34.46991	H107.2	36.073	H107.3	72.65816
H109.1	35.23596	H109.2	45.89487	H109.3	49.19748
H111.1	22.81275	H111.2	45.69406	H111.3	67.54291
H113.1	23.71389	H113.2	25.55621	H113.3	37.66044
H115.1	12.99295	H115.2	19.03066	H115.3	33.40556
H117.1	20.5192	H117.2	28.85209	H117.3	49.98627
H119.1	17.62436	H119.2	19.53286	H119.3	20.75146
H121.1	20.79351	H121.2	38.09442	H121.3	30.00135
H123.1	39.48156	H123.2	29.61802	H123.3	52.53458
H125.1	34.84464	H125.2	43.66702	H125.3	42.13128
H127.1	37.91802	H127.2	47.59782	H127.3	44.77519
H129.1	38.63833	H129.2	26.79982	H129.3	34.30368
H131.1	54.49031	H131.2	29.95935	H131.3	50.37192
H133.1	51.25265	H133.2	34.01176	H133.3	53.31764
H135.1	27.2773	H135.2	40.55353	H135.3	60.25729

Top soil	Rock %	Middle soil	Rock %	Bottom soil	Rock %
H137.1	17.31481	H137.2	28.81176	H137.3	25.11834
H139.1	18.27691	H139.2	30.00254	H139.3	22.57047
Average	30.41426		37.07444		44.40869

4. Maps

4.1. Soil Map

All 149 profiles were classified as Dundee soil form (Figure 7).



Figure 7 Soil map and position of observations

4.2. Soil Depth Map

All but 3 profiles were deeper than 2000 m, all three shallow profiles were located on the outskirts of the surveyed area (Figure 8).



Figure 8 Soil depth map

5. SUITABILITY

5.1. Environmental indicators

The soil requirements for the production of dates are not well researched. The production of dates on a nearby site extends into a brack wetland. The date tree is not sensitive for salinity and sodicity, including extremely high pH.

5.2. Morphological indicators

The low clay content, apedal structured soils have high infiltration and fast internal drainage are ideal for water saturation sensitive plants and irrigation. There are no signs of restrictive layers indicating a fast external drainage. There is no risk of waterlogging but artificial drainage can be easily implemented. The profiles have high stone contents which can be removed during cultivation or be used for a cover. The apedal structure and texture of the soils are more prone to compaction but avoidable by appropriate traffic control and tillage practices.

5.3. Chemical indicators

The pH are above 7.5 and some profiles are high in Na. It is not foreseen to affect cropping of grapes and dates but due to the good drainage of the soils Na could be leached out of the profile. The calcareous nature and high Ca contents will act as a buffer against acidification caused by agricultural practices. High resistance indicating little salt accumulation and should not impede crop production.

5.4. Soil fertility

Soils are typical of virgin sandy arid soils with low CEC, K and Mg, with high Ca contents. The low nutrient status of the soils can be remediated by fertilization.

5.5. Agrometric potential

5.5.1. Date palm

Date palms require a long dry and hot growing season for high yields of quality fruits. Temperatures below -4°C can damage newly planted offshoots. Growth of mature trees ceases below 12°C but no permanent injury will occur even with freezing temperatures as low as -7°C. Rain and humidity can influence date pollen production and fruit quality negatively. Strong winds can damage tall trees with shallow root systems. Highly stratified soils with an abrupt change from fine to moderately fine topsoil to coarse subsoil are major barriers to root penetration. Uniform soils throughout the root

zone are the best for number, distribution and depth of the roots. Physical properties that may restrict palm growth are compaction, stratification and a high water table.

Dates will grow in a wide variety of soils. Dates will grow best on sand, sandy loam, clay and other heavy soils. Soil should have a good drainage capacity and well aerated to allow for optimum root growth. In the bearing stage date palms become top heavy and therefore need a well deep developed root system to support the plant. Soil depth influences drainage and leaching and the minimum soil depth for dates are 1.5-2.0 m. Up to 80% of the roots are present in the first 2 m and can spread 2 m on both sides of the tree.

Soil quality is mainly related to drainage capacity when soils are salty or the irrigation water is characterized with a high salt content. Most date plantations of the old world are planted on sandy soils. The growth of palms is influenced by either salinity or acid soil conditions that will result in lower yields. Saline and alkaline soils are characterized by high soluble salts, and exchangeable sodium. Dates are more tolerant to alkali or salt than most other crops. However, excessive salt will stunt growth and influence the yield and quality of dates negatively. Saline soils have an electric conductivity of more than 4 mmhos cm⁻¹ at 25°C, a sodium absorption rate of less than 15 and a pH less than 8.5. Alkaline soils are usually difficult to correct however, it is recommended to eliminate the excess sodium by addition of gypsum, sulphate of iron or sulphur.

Fertilization of date palms:

Young trees up to 18 months: 0.3 kg N tree⁻¹ annum⁻¹

Small trees: 0.5 -1.0 kg N tree⁻¹ annum⁻¹

Medium size trees: 1.5 – 2 kg N tree⁻¹ annum⁻¹

Large trees: 2.5-3.5 kg N tree⁻¹ annum⁻¹

Micro nutrient deficiency S, Cu, Fe, Mg, Mn

In some countries such as Iraq it is standard practice to apply 20 kg organic fertilizer per tree per annum for fruit bearing trees.

Date palms is probably the best crop for this soil but as was stated earlier that crop selection cannot be based solely on soil data but long term climatic data, pest and disease occurrence if any in the area and even economic data is needed to make final recommendations.

5.5.2. Grapes

Permanent crops such as grapes are planted for a period of about 15-20 years. An optimal soil environment should be ensured for roots to be able to grow and develop to ensure for healthy vine growth. It is also important to maintain this optimum environment for the life time of the vineyard. After a proper physical evaluation and chemical analyses of the soil amendments must be made to the soil if necessary during soil preparation. The performance of the vine above the ground is directly correlated with the development of its root system. Grapes perform the best on deep, well aerated and drained soils. Soil fertility can be managed with fertilization but poor quality sandy soils can be problematic.

The root system of grapes can penetrate the soil up to 6 m and even deeper. However, 60% of the roots of grapevines are found in the top 60 cm of the soil. Soil depth is the most important factor determining root depth and distribution. Root density in the top 20 cm of sandy soils are low and the reason for this may be the rapid drying and extreme temperatures of the soil, shortening the lifespan of roots. Rootstocks also differ in their root depth and densities. This is one of the important reasons why rootstock-cultivar combination is of importance.

Good drainage is important for a healthy well developed root system. According to the physical soil evaluation no signs of periodic or permanent wetness were detected so no additional drainage is required. Any compact layers will restrict root growth but this was however not detected during the soil evaluation. Stratification can impede the vertical drainage and root growth if there is difference in the bulk densities of the layers. The stratification that can however be manipulated mechanically.

Grapes require a soil pH_(KCl) of more than 5.5. Although the pH is not low and do not require lime the soil pH of the studied area varies and tend to be more alkaline and should be monitored and managed accordingly. Soil with a high pH are difficult to manage. Brackish soil conditions can be managed through gypsum application and drainage. Irrigation needs to be adapted in order to avoid brackish salt in the topsoil and to use tolerant rootstocks.

It is important to rectify the soil P before planting due to the fact that it does not move freely in the soil. Applying P before planting allows for working it into the soil deep enough. For grapes the

following standards can be used as an indication of whether there is a need for the nutritional status of the soil to be improved. In sandy soil the P should be between 15-25 ppm and K between 30-50 ppm. Potassium should be 8%, Ca 70%, Mg 22% and Na 8% of the CEC of the soil.

The choice of irrigation system will be very important in this sandy soil. In sandy soil the horizontal water distribution is very poor and need to be taken in consideration selecting an irrigation system. Irrigation and fertilisation management will be a challenge in this soil. It will be crucial not to under irrigate or fertilize the crop.

In general, there are no obvious reasons why grapes cannot be planted on this soil according to the soil data on condition that the necessary soil amendments are made before planting during soil preparation. It is also however, important to emphasize that a soil report on its own cannot be used to do any recommendation concerning the suitability of a crop for a specific area. Long term climatic data is of the utmost importance. Soil data in combination with long term climatic data should be used to make the final recommendations concerning the suitability of grape for the specific area. This data is also important in order to select the correct rootstock-cultivar combination.

6. RECOMMENDATIONS

The soil meets the requirements for irrigation. Water infiltrates fast exceeding 200 mm per hour. Water will drain through the soil at more than 200 mm per hour. The same texture in the soil extends to depths exceeding 3 meters indicating that water logging by over irrigation unlikely. The water holding capacity is very low.

The chemical properties limit the selection of crops which prefer or are insensitive to a high pH and elevated salinity. The accumulation of salts in the topsoil and first subsoil is typical of arid climates. The salts can be flushed out of the system and if any doubts exists. The climate limits selection to crops preferring or dependent on extremely high summer temperatures and low humidity.

The site is therefore suitable for the production of dates and grapes. Soil preparation has to include deep (1.2m) cross ripping to limit the impact of stratification on root growth. Irrigation methods are limited to micro or sprinkler irrigation. Cover of the soil surface with stones present in most soils, to limit evaporation, can improve water efficiency.

Therefore the soils are high potential irrigation soils and suitable for irrigation.

The climate is suitable for grapes and dates.

The terrain is slightly sloping to the river.

The site is suitable for production of grapes and dates.

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Appendix 1

Modal Profile description forms

Profile No	P7				Soil Family			Nonti	
Latitude	-28 54 03.68275				Slope			0	
Longitude	18 08 41.67404				Planform curvature			LL	
Surface stoniness	Very few				Profile curvature			LL	
Chemical weathering	None				TMU			5	
Parent material	Alluvial				Occurrence of Flooding			Yes	
Geology					Vegetation			Shrub	
Master Horizon	Depth (mm)	Diagnostic Horizon	Transition	Structure			Stone content (Size)	Mottling	Comment
				Type	Size	Grade			
A	-	-	-	-	-	-	-	Strong stratification and larger fragments in the subsoil	
C1	300	Sa	Abrupt	Apedal	Layered	-	15% (M)	None	
C2	650	Sa	Abrupt	Apedal	Layered	-	50% (M)	None	
C3	1300	Sa	Abrupt	Apedal	Layered	-	5% (M)	None	
C4	3000	Sa	Abrupt	Apedal	Layered	-	20% (S)	None	

Stone content size M- medium gravel (0.6-2 cm), S- stones (6-20 cm), B- boulders (20-60 cm)

Profile No	P27					Soil Family			Nonti
Latitude	-28 54 26.51038					Slope			0
Longitude	18 08 56.25136					Planform curvature			LL
Surface stoniness	Very few					Profile curvature			LL
Chemical weathering	None					TMU			5
Parent material	Alluvial					Occurrence of Flooding			Yes
Geology						Vegetation			Shrub
Master Horizon	Depth (mm)	Diagnostic Horizon	Transition	Type	Size	Grade	Stone content (Size)	Mottling	Comment
A	-	-	-	-	-	-	-	-	Strong stratification and smaller fragments
C1	300	Sa	Abrupt	Apedral	Layered	-	5% (M)	None	
C2	850	Sa	Abrupt	Apedral	Layered	-	15% (M)	None	
C3	1850	Sa	Abrupt	Apedral	Layered	-	5% (M)	None	
C4	3000	Sa	Abrupt	Apedral	Layered	-	30% (M)	None	

Stone content size M- medium gravel (0.6-2 cm), S- stones (6-20 cm), B- boulders (20-60 cm)

Profile No	P50					Soil Family			Nonti
Latitude	-28 54 26.51038					Slope			0
Longitude	18 08 56.25136					Planform curvature			LL
Surface stoniness	Very few					Profile curvature			LL
Chemical weathering	None					TMU			5
Parent material	Alluvial					Occurrence of Flooding			Yes
Geology						Vegetation			Shrub
Master Horizon	Depth (mm)	Diagnostic Horizon	Transition	Type	Size	Grade	Stone content	Mottling	Comment
A	-	-	-	-	-	-	-	-	Strong stratification and large fragments
C1	500	Sa	Abrupt	Apedal	Layered	-	10% (M)	None	
C2	600	Sa	Abrupt	Apedal	Layered	-	40% (B)	None	
C3	3000	Sa	Abrupt	Apedal	Layered	-	40% (M)	None	

Stone content size M- medium gravel (0.6-2 cm), S- stones (6-20 cm), B- boulders (20-60 cm)

Profile No	P49					Soil Family			Nonti
Latitude	-28 54 26.48705					Slope			0
Longitude	18 08 52.56043					Planform curvature			LL
Surface stoniness	Very few					Profile curvature			LL
Chemical weathering	None					TMU			5
Parent material	Alluvial					Occurrence of Flooding			Yes
Geology						Vegetation			Shrub
Master Horizon	Depth (mm)	Diagnostic Horizon	Transition	Type	Size	Grade	Stone content	Mottling	Comment
A	-	-	-	-	-	-	-	-	Large fragments and weak stratification
C1	500	Sa	Abrupt	Apedral	Layered	-	10% (M)	None	
C2	3000	Sa	Abrupt	Apedral	Layered	-	50 (C)	None	

Stone content size M- medium gravel (0.6-2 cm), C- coarse gravel (2-6 cm), S- stones (6-20 cm), B- boulders (20-60 cm)

Appendix 2

Profiles in the study area

Nr	Code	Lat. D M S	Long. D M S
H1	C2	-28 54 00.38810	18 08 34.31933
H2	D2	-28 54 00.41157	18 08 38.01000
H3	E2	-28 54 00.43501	18 08 41.70066
H4	B3	-28 54 03.61234	18 08 30.60195
H5	C3	-28 54 03.63584	18 08 34.29265
H6	D3	-28 54 03.65931	18 08 37.98334
H7	E3	-28 54 03.68275	18 08 41.67404
H8	C4	-28 54 06.88357	18 08 34.26596
H9	D4	-28 54 06.90704	18 08 37.95669
H10	E4	-28 54 06.93048	18 08 41.64742
H11	M4	-28 54 07.09379	18 09 07.48257
H12	N4	-28 54 07.11701	18 09 11.17331
H13	E5	-28 54 10.17821	18 08 41.62080
H14	L5	-28 54 10.31828	18 09 03.76540
H15	M5	-28 54 10.34153	18 09 07.45617
H16	N5	-28 54 10.36475	18 09 11.14694
H17	E6	-28 54 13.42595	18 08 41.59417
H18	F6	-28 54 13.44936	18 08 45.28497
H19	L6	-28 54 13.56602	18 09 03.73896
H20	M6	-28 54 13.58927	18 09 07.42976
H21	N6	-28 54 13.61248	18 09 11.12057
H22	E7	-28 54 16.67368	18 08 41.56754
H23	F7	-28 54 16.69709	18 08 45.25837
H24	H7	-28 54 16.74384	18 08 52.64003
H25	J7	-28 54 16.76718	18 08 56.33086
H26	K7	-28 54 16.79048	18 09 00.02169
H27	L7	-28 54 16.81376	18 09 03.71253
H28	M7	-28 54 16.83700	18 09 07.40336
H29	N7	-28 54 16.86022	18 09 11.09420
H30	E8	-28 54 19.92141	18 08 41.54092
H31	F8	-28 54 19.94483	18 08 45.23177
H32	G8	-28 54 19.96822	18 08 48.92264
H33	H8	-28 54 19.99158	18 08 52.61350

Nr	Code	Lat. D M S	Long. D M S
H34	J8	-28 54 20.01491	18 08 56.30436
H35	K8	-28 54 20.03822	18 08 59.99522
H36	L8	-28 54 20.06149	18 09 03.68609
H37	M8	-28 54 20.08474	18 09 07.37696
H38	N8	-28 54 20.10796	18 09 11.06782
H39	F9	-28 54 23.19256	18 08 45.20518
H40	G9	-28 54 23.21595	18 08 48.89607
H41	H9	-28 54 23.23931	18 08 52.58696
H42	J	-28 54 23.26265	18 08 56.27786
H43	K9	-28 54 23.28595	18 08 59.96875
H44	L9	-28 54 23.30923	18 09 03.65965
H45	M9	-28 54 23.33248	18 09 07.35055
H46	N9	-28 54 23.35570	18 09 11.04145
H47	F10	-28 54 26.44029	18 08 45.17858
H48	G10	-28 54 26.46368	18 08 48.86950
H49	H10	-28 54 26.48705	18 08 52.56043
H50	J10	-28 54 26.51038	18 08 56.25136
H51	K11	-28 54 26.53369	18 08 59.94228
H52	L10	-28 54 26.55697	18 09 03.63321
H53	M10	-28 54 26.58022	18 09 07.32414
H54	N10	-28 54 26.60344	18 09 11.01508
H55	F11	-28 54 29.68802	18 08 45.15198
H56	G11	-28 54 29.71141	18 08 48.84294
H57	H11	-28 54 29.73478	18 08 52.53389
H58	J11	-28 54 29.75811	18 08 56.22485
H59	K11	-28 54 29.78142	18 08 59.91581
H60	L11	-28 54 29.80470	18 09 03.60677
H61	M11	-28 54 29.82795	18 09 07.29774
H62	N11	-28 54 29.85118	18 09 10.98870
H63	G12	-28 54 32.95915	18 08 48.81637
H64	K12	-28 54 33.02916	18 08 59.88934
H65	L12	-28 54 33.05244	18 09 03.58033
H66	M12	-28 54 33.07569	18 09 07.27133
H67	N12	-28 54 33.09891	18 09 10.96232
H68	L13	-28 54 36.30017	18 09 03.55389
H69	M13	-28 54 36.32342	18 09 07.24492
H70	N13	-28 54 36.34665	18 09 10.93594

Nr	Code	Lat. D M S	Long. D M S
H71	P13	-28 54 36.36985	18 09 14.62697
H72	L14	-28 54 39.54791	18 09 03.52745
H73	M14	-28 54 39.57116	18 09 07.21850
H74	N14	-28 54 39.59438	18 09 10.90956
H75	P14	-28 54 39.61758	18 09 14.60062
H76	M15	-28 54 42.81889	18 09 07.19209
H77	N15	-28 54 42.84212	18 09 10.88318
H78	P15	-28 54 42.86532	18 09 14.57428
H79	M16	-28 54 46.06663	18 09 07.16568
H80	N16	-28 54 46.08986	18 09 10.85680
H81	P16	-28 54 46.11306	18 09 14.54793
H82	L17	-28 54 49.29111	18 09 03.44811
H83	M17	-28 54 49.31436	18 09 07.13926
H84	N17	-28 54 49.33759	18 09 10.83042
H85	P17	-28 54 49.36079	18 09 14.52157
H86	L18	-28 54 52.53884	18 09 03.42166
H87	M18	-28 54 52.56210	18 09 07.11285
H88	N18	-28 54 52.58532	18 09 10.80403
H89	P18	-28 54 52.60853	18 09 14.49522
H90	J19	-28 54 55.73997	18 08 56.01278
H91	K19	-28 54 55.76328	18 08 59.70399
H92	L19	-28 54 55.78657	18 09 03.39521
H93	M19	-28 54 55.80983	18 09 07.08643
H94	N19	-28 54 55.83306	18 09 10.77765
H95	P19	-28 54 55.85626	18 09 14.46887
H96	C20	-28 54 58.84722	18 08 33.83881
H97	D20	-28 54 58.87070	18 08 37.53005
H98	E20	-28 54 58.89416	18 08 41.22129
H99	F20	-28 54 58.91758	18 08 44.91253
H100	G20	-28 54 58.94098	18 08 48.60377
H101	H20	-28 54 58.96436	18 08 52.29502
H102	J20	-28 54 58.98770	18 08 55.98626
H103	K20	-28 54 59.01101	18 08 59.67751
H104	L20	-28 54 59.03430	18 09 03.36876
H105	M20	-28 54 59.05756	18 09 07.06001
H106	N20	-28 54 59.08079	18 09 10.75126
H107	P20	-28 54 59.10399	18 09 14.44251

Nr	Code	Lat. D M S	Long. D M S
H108	C21	-28 55 02.09494	18 08 33.81210
H109	D21	-28 55 02.11843	18 08 37.50337
H110	E21	-28 55 02.14188	18 08 41.19464
H111	F21	-28 55 02.16531	18 08 44.88592
H112	G21	-28 55 02.18871	18 08 48.57719
H113	H21	-28 55 02.21208	18 08 52.26847
H114	J21	-28 55 02.23543	18 08 55.95975
H115	K21	-28 55 02.25874	18 08 59.65103
H116	L21	-28 55 02.28203	18 09 03.34231
H117	M21	-28 55 02.30529	18 09 07.03359
H118	N21	-28 55 02.32852	18 09 10.72487
H119	P21	-28 55 02.35173	18 09 14.41616
H120	C22	-28 55 05.34266	18 08 33.78539
H121	D22	-28 55 05.36615	18 08 37.47669
H122	E22	-28 55 05.38961	18 08 41.16800
H123	F22	-28 55 05.41304	18 08 44.85930
H124	G22	-28 55 05.43644	18 08 48.55061
H125	H22	-28 55 05.45981	18 08 52.24192
H126	J22	-28 55 05.48316	18 08 55.93323
H127	K22	-28 55 05.50647	18 08 59.62454
H128	L22	-28 55 05.52976	18 09 03.31585
H129	M22	-28 55 05.55302	18 09 07.00717
H130	N22	-28 55 05.57626	18 09 10.69848
H131	C23	-28 55 08.59039	18 08 33.75868
H132	D23	-28 55 08.61387	18 08 37.45001
H133	E23	-28 55 08.63733	18 08 41.14135
H134	F23	-28 55 08.66076	18 08 44.83269
H135	G23	-28 55 08.68417	18 08 48.52403
H136	H23	-28 55 08.70754	18 08 52.21537
H137	K23	-28 55 08.75420	18 08 59.59806
H138	L23	-28 55 08.77749	18 09 03.28940
H139	M23	-28 55 08.80076	18 09 06.98075
H140	N23	-28 55 08.82399	18 09 10.67209
H141	C24	-28 55 11.83811	18 08 33.73197
H142	D24	-28 55 11.86160	18 08 37.42334
H143	E24	-28 55 11.88506	18 08 41.11470
H144	F24	-28 55 11.90849	18 08 44.80607

Nr	Code	Lat. D M S	Long. D M S
H145	G24	-28 55 11.93189	18 08 48.49745
H146	N24	-28 55 12.07172	18 09 10.64570
H147	C25	-28 55 15.08583	18 08 33.70526
H148	D25	-28 55 15.10932	18 08 37.39666
H149	E25	-28 55 15.13278	18 08 41.08806

Appendix 3

Soil Chemical Properties

Table 1 Soil chemical properties with Ammonium Acetate extraction results

Ref No	pH (KCl)	PBray1	K	Na	Ca	Mg	EA.KCl	%Ca	%Mg	%K	%Na	ACID SAT
		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	cmol(c)/kg	%	%	%	%	%
H7.1	6.83	7.145071	50.49598	4.183616	634.1808	25.19239	0	89.9615	5.858456	3.663984	0.516057	0
H7.2	7.04	3.669485	48.20827	4.209286	493.1132	22.02844	0	88.44372	6.477006	4.422778	0.656494	0
H7.3	6.861	1.231644	93.19393	9.333477	1502.059	25.22359	0	93.92596	2.585687	2.980847	0.50751	0
H27.1	7.78	19.89091	249.99	473.6908	1018.36	25.26961	0	63.66489	2.589807	7.994196	25.75111	0
H27.2	6.4	3.66849	27.02717	100.4806	847.5338	19.0523	0	86.48603	3.18718	1.410726	8.916068	0
H27.3	6.741	1	25.24963	71.1024	2386.515	18.41547	0	95.78828	1.211717	0.51839	2.481616	0
H50.1	6.26	8.670007	170.7654	19.13359	1456.639	44.17125	0	89.19817	4.434186	5.34881	1.018832	0
H50.2	6.663	1	21.87032	186.9253	1858.987	21.42162	0	89.90016	1.698269	0.540994	7.860573	0
H50.3	6.55	1	39.95407	547.5294	2153.739	24.47136	0	80.05258	1.491113	0.75962	17.69668	0
H68.1	5.749	5.994965	231.5422	86.22459	1282.439	43.72613	0	82.86979	4.632023	7.653197	4.84499	0
H68.2	7.03	1	85.59639	156.6483	1772.739	33.19024	0	88.32127	2.710823	2.181369	6.786539	0
H68.3	7.22	1	38.6866	16.56009	1969.301	18.87062	0	96.7989	1.520599	0.972685	0.707821	0
H91.1	8.05	6.389249	43.3887	4.622166	357.3796	22.19345	0	85.09539	8.663059	5.284527	0.957026	0
H91.2	8.01	2.859978	74.1404	6.95785	1306.851	26.99711	0	93.67555	3.172398	2.718369	0.433688	0
H91.3	7.24	1	110.1542	21.50367	2053.902	26.84938	0	94.52088	2.025594	2.592999	0.860524	0
H97.1	8.181	5.342519	59.47273	6.408946	566.3229	23.03359	0	88.47735	5.899291	4.752686	0.870676	0
H97.2	7.18	3.280338	117.0655	10.50164	1741.498	26.01561	0	93.97459	2.301397	3.231243	0.492773	0
H97.3	7.815	2.475156	113.1355	12.30308	2046.945	27.25308	0	94.75762	2.068206	2.678922	0.49525	0
H101.1	6.242	5.673309	249.4129	453.0496	2212.439	45.72715	0	78.76434	2.668718	4.541826	14.02511	0

Ref No	pH (KCl)	PBray1	K	Na	Ca	Mg	EA.KCl	%Ca	%Mg	%K	%Na	ACID SAT
H101.2	7.39	3.857271	45.81006	806.1804	2086.641	23.81955	0	73.21167	1.37005	0.822142	24.59614	0
H101.3	7.84	3.457724	48.74662	811.1725	2730.568	29.93968	0	77.79504	1.398351	0.71039	20.09622	0
H121.1	7.633	10.62722	138.1596	23.24383	1450.277	45.51095	0	89.7578	4.617505	4.373765	1.250925	0
H121.2	7.75	4.34061	101.6444	96.12258	1682.255	30.37833	0	90.0742	2.666506	2.783847	4.475444	0
H121.3	7.28	1	79.43811	947.8962	2147.174	23.92205	0	70.36958	1.285246	1.33168	27.01349	0
H123.1	8.032	8.141065	91.90869	32.3538	1113.91	24.7874	0	90.58455	3.304496	3.823084	2.287871	0
H123.2	7.07	5.359019	98.33889	32.76974	1492.277	28.34894	0	92.25554	2.873094	3.109721	1.761644	0
H123.3	7.502	1	48.35199	282.7393	2326.716	8.886125	0	89.08217	0.557738	0.946924	9.413165	0
H137.1	6.81	8.134987	90.46214	9.004787	1136.227	32.68375	0	91.34323	4.307381	3.719901	0.629487	0
H137.2	6.398	1	191.4086	69.03224	1967.702	32.56124	0	90.30231	2.449688	4.493185	2.754823	0
H137.3	7.32	3.650294	61.59043	216.4974	1890.476	21.52347	0	88.11259	1.644558	1.468363	8.774484	0
H139.1	7.61	7.716316	108.4588	7.867293	438.6879	54.8032	0	74.24717	15.20549	9.389498	1.157849	0
H139.2	7.708	2.690885	107.8107	35.55513	1767.401	42.82489	0	91.87655	3.649523	2.866715	1.607215	0
H139.3	7.9	1	86.56066	331.5914	1987.794	43.24745	0	83.12579	2.964798	1.851562	12.05785	0

countinued

Ref No	Ca:Mg	(Ca+Mg)/K	Mg:K	S-Value	Na:K	T	Density	S AmAc	CEC
	1.5-4.5	10.0-20.0	3.0-4.0	cmol(+)/kg		cmol(c)/kg	g/cm3	mg/kg	cmol(c)/kg
H7.1	15.35584	26.15185	1.59893	3.524735	0.140846	3.524735	1.613	4.117899	1.29
H7.2	13.65503	21.46179	1.464466	2.787723	0.148435	2.787723	1.6084	2.164289	1.47
H7.3	36.32534	32.37726	0.867434	7.995971	0.170257	7.995971	1.5118	5.144853	2.61
H27.1	24.58287	8.28785	0.323961	7.997812	3.221226	7.997812	1.6684	4.887232	3.34
H27.2	27.1356	63.56527	2.259247	4.899831	6.320197	4.899831	1.6271	15.03086	1.52
H27.3	79.05167	187.1179	2.337464	12.45724	4.787163	12.45724	1.6246	34.35464	4.68
H50.1	20.11602	17.50527	0.829004	8.165184	0.190478	8.165184	1.6564	7.136751	1.93
H50.2	52.93635	169.3151	3.139164	10.33918	14.52987	10.33918	1.5405	10.48077	2.16
H50.3	53.68647	107.348	1.962971	13.45203	23.29675	13.45203	1.5937	173.4547	2.67
H68.1	17.89062	11.43337	0.60524	7.737674	0.633067	7.737674	1.5493	8.725358	1.45
H68.2	32.58098	41.73162	1.242716	10.03574	3.111137	10.03574	1.592	9.832277	2.19
H68.3	63.65839	101.0805	1.563301	10.17212	0.727698	10.17212	1.5948	9.603357	2.42
H91.1	9.822788	17.74207	1.639325	2.099877	0.1811	2.099877	1.6221	2.41541	1.08
H91.2	29.52831	35.62723	1.167023	6.97541	0.15954	6.97541	1.6626	4.354463	1.71
H91.3	46.66328	37.23351	0.781178	10.86481	0.331864	10.86481	1.5883	6.787942	2.24
H97.1	14.99796	19.85754	1.241254	3.200384	0.183197	3.200384	1.5459	5.427942	0.87
H97.2	40.83371	29.79534	0.712233	9.265793	0.152503	9.265793	1.6102	7.789115	1.63
H97.3	45.81635	36.14358	0.772029	10.80095	0.184869	10.80095	1.5094	7.886194	1.71
H101.1	29.51392	17.92959	0.587587	14.04467	3.087989	14.04467	1.5305	15.60402	4.52
H101.2	53.43723	90.71638	1.66644	14.25074	29.91716	14.25074	1.6675	104.6113	3.26
H101.3	55.6334	111.4788	1.968428	17.54975	28.289	17.54975	1.573	779.4346	3.81
H121.1	19.43859	21.57759	1.055728	8.078834	0.286006	8.078834	1.6294	4.27724	2.74
H121.2	33.77985	33.31387	0.95785	9.338163	1.607647	9.338163	1.6629	1.829594	3.06
H121.3	54.75182	53.80783	0.965131	15.25641	20.28527	15.25641	1.5693	88.3975	3.28

Ref No	Ca:Mg	(Ca+Mg)/K	Mg:K	S-Value	Na:K	T	Density	S AmAc	CEC
H123.1	27.41252	24.55845	0.864353	6.148454	0.598436	6.148454	1.6418	5.544452	1.95
H123.2	32.11017	30.59072	0.923907	8.087738	0.566496	8.087738	1.6559	3.97418	2.02
H123.3	159.7206	94.66436	0.589	13.05938	9.940787	13.05938	1.5573	9.971569	3.94
H137.1	21.20621	25.71322	1.157929	6.219547	0.169221	6.219547	1.6209	4.39554	1.95
H137.2	36.86278	20.64282	0.545201	10.89508	0.613111	10.89508	1.6207	3.847352	2.82
H137.3	53.57827	61.12737	1.119995	10.72761	5.975693	10.72761	1.6511	4.39654	4.59
H139.1	4.882919	9.526883	1.619414	2.95424	0.123313	2.95424	1.759	-0.26346	2.43
H139.2	25.17495	33.32248	1.273068	9.618346	0.560647	9.618346	1.6489	4.588344	2.96
H139.3	28.03758	46.49619	1.601242	11.95654	6.512259	11.95654	1.5954	50.24767	3.34

Table 2 Mehlich III results

Ref No	P	K	Na	Ca	Mg	EA.KCl	%Ca	%Mg	%K	%Na	ACID SAT
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	cmol(c)/kg	%	%	%	%	%
H7.1	43	59	9	1096	87	0.00	85.87	11.18	2.36	0.59	0.00
H7.2	24	56	7	789	59	0.00	85.77	10.47	3.11	0.64	0.00
H7.3	7	103	11	1823	50	0.00	92.65	4.17	2.68	0.50	0.00
H27.1	72	262	466	1323	79	0.00	66.42	6.51	6.73	20.34	0.00
H27.2	17	24	103	974	34	0.00	86.14	4.87	1.07	7.92	0.00
H27.3	7	23	73	3686	36	0.00	96.50	1.53	0.31	1.66	0.00
H50.1	30	178	24	1861	125	0.00	85.48	9.39	4.18	0.95	0.00
H50.2	15	22	193	8425	47	0.00	97.05	0.89	0.13	1.93	0.00
H50.3	11	37	536	8884	54	0.00	93.93	0.94	0.20	4.93	0.00
H68.1	22	242	79	1762	119	0.00	81.97	9.06	5.76	3.21	0.00
H68.2	20	89	161	3863	81	0.00	92.39	3.18	1.09	3.34	0.00
H68.3	12	37	20	6898	65	0.00	97.97	1.51	0.27	0.25	0.00
H91.1	42	58	14	810	67	0.00	84.17	11.48	3.10	1.25	0.00
H91.2	17	76	12	2295	70	0.00	93.32	4.65	1.59	0.44	0.00
H91.3	16	121	22	3354	49	0.00	95.41	2.28	1.76	0.54	0.00
H97.1	21	63	10	721	48	0.00	85.86	9.30	3.84	1.01	0.00
H97.2	15	126	9	1986	41	0.00	93.48	3.13	3.03	0.35	0.00
H97.3	11	109	14	2061	47	0.00	93.45	3.46	2.53	0.56	0.00
H101.1	25	268	448	3297	100	0.00	82.68	4.12	3.44	9.77	0.00
H101.2	17	53	792	2859	50	0.00	78.18	2.25	0.74	18.83	0.00
H101.3	13	52	821	3199	54	0.00	79.43	2.18	0.66	17.73	0.00
H121.1	43	144	27	1798	114	0.00	86.33	9.01	3.54	1.12	0.00
H121.2	18	105	93	2300	83	0.00	89.50	5.27	2.08	3.15	0.00
H121.3	15	86	924	6131	71	0.00	86.41	1.65	0.62	11.32	0.00

Ref No	P	K	Na	Ca	Mg	EA.KCl	%Ca	%Mg	%K	%Na	ACID SAT
H123.1	30	103	33	1314	76	0.00	86.46	8.21	3.47	1.87	0.00
H123.2	22	102	28	1824	55	0.00	91.64	4.51	2.62	1.22	0.00
H123.3	22	75	277	2561	61	0.00	87.10	3.39	1.31	8.19	0.00
H137.1	15	98	12	1863	34	0.00	94.15	2.79	2.53	0.53	0.00
H137.2	33	203	73	2143	100	0.00	86.61	6.63	4.20	2.57	0.00
H137.3	25	74	224	3146	82	0.00	89.53	3.85	1.08	5.54	0.00
H139.1	13	121	12	682	68	0.00	78.77	12.88	7.15	1.21	0.00
H139.2	13	118	34	2090	93	0.00	89.62	6.51	2.59	1.28	0.00
H139.3	9	85	328	3241	101	0.00	86.76	4.44	1.17	7.64	0.00

continued

Ca:Mg	(Ca+Mg)/K	Mg:K	S-Value	Na:K	T	Density	Fe	Mn	Cu	Zn	S	B	Al
1.5-4.5	10.0-20.0	3.0-4.0	cmol(+)/kg		cmol(c)/kg	g/cm3			mg/kg				
7.68	41.13	4.74	6.38	0.25	6.38	1.61	24.37	18.27	0.81	0.54	7.04	0.47	114.34
8.19	30.91	3.36	4.60	0.21	4.60	1.61	21.56	20.52	0.42	0.28	5.19	0.75	76.24
22.22	36.17	1.56	9.84	0.19	9.84	1.51	10.23	21.00	0.44	0.18	5.10	0.39	75.89
10.20	10.84	0.97	9.96	3.02	9.96	1.67	30.76	31.62	0.64	1.49	7.09	0.45	194.07
17.68	84.77	4.54	5.66	7.38	5.66	1.63	18.17	19.03	0.40	0.23	12.77	0.34	78.97
63.15	313.68	4.89	19.10	5.30	19.10	1.62	10.41	18.96	0.39	0.20	41.63	0.45	51.10
9.10	22.69	2.25	10.89	0.23	10.89	1.66	27.91	26.16	0.53	0.45	6.72	0.37	145.95
109.30	753.42	6.83	43.41	14.87	43.41	1.54	2.46	4.91	0.51	0.30	20.62	0.47	3.63
99.91	477.42	4.73	47.29	24.82	47.29	1.59	2.78	5.20	0.49	0.23	204.68	1.88	2.34
9.04	15.81	1.57	10.75	0.56	10.75	1.55	20.01	19.34	0.60	0.48	7.19	0.64	85.27
29.05	87.78	2.92	20.91	3.07	20.91	1.59	11.20	25.01	0.81	0.32	12.54	0.51	24.44
64.80	370.85	5.64	35.21	0.92	35.21	1.59	3.13	9.49	0.43	0.22	18.87	0.38	3.17
7.33	30.88	3.71	4.81	0.40	4.81	1.62	21.78	13.88	0.45	0.35	6.62	0.30	95.33
20.07	61.67	2.93	12.30	0.28	12.30	1.66	12.82	24.27	0.68	0.25	5.94	0.28	57.88
41.79	55.49	1.30	17.58	0.31	17.58	1.59	6.60	15.28	0.71	0.29	5.56	0.34	1.97
9.24	24.80	2.42	4.20	0.26	4.20	1.55	16.51	8.14	0.32	0.27	5.16	0.30	51.80
29.84	31.85	1.03	10.62	0.11	10.62	1.61	16.25	19.51	0.51	0.19	4.55	0.23	65.28
26.98	38.34	1.37	11.03	0.22	11.03	1.51	15.10	29.09	0.81	0.26	8.26	0.32	61.73
20.09	25.24	1.20	19.94	2.84	19.94	1.53	25.35	45.05	0.91	0.40	6.75	0.44	190.41
34.70	108.51	3.04	18.29	25.40	18.29	1.67	17.14	34.88	0.72	0.25	142.75	3.42	69.03
36.36	123.57	3.31	20.14	26.84	20.14	1.57	14.00	27.19	0.44	0.15	892.76	1.06	33.30
9.58	26.96	2.55	10.41	0.32	10.41	1.63	27.21	35.86	0.86	0.33	5.81	0.38	191.48
16.98	45.52	2.53	12.85	1.51	12.85	1.66	19.56	36.14	0.87	0.26	4.11	0.33	148.63

Ca:Mg	(Ca+Mg)/K	Mg:K	S-Value	Na:K	T	Density	Fe	Mn	Cu	Zn	S	B	Al
52.52	142.03	2.65	35.48	18.27	35.48	1.57	4.51	9.31	0.48	0.21	102.44	1.62	4.26
10.53	27.32	2.37	7.60	0.54	7.60	1.64	24.75	15.86	0.59	0.37	6.94	0.30	104.00
20.30	36.68	1.72	9.95	0.47	9.95	1.66	16.94	15.62	0.43	0.19	4.20	0.27	77.18
25.67	69.05	2.59	14.70	6.25	14.70	1.56	17.61	17.92	0.48	0.21	5.18	0.28	85.97
33.74	38.27	1.10	9.89	0.21	9.89	1.62	2.16	3.86	0.99	0.40	27.90	0.41	4.46
13.06	22.22	1.58	12.37	0.61	12.37	1.62	21.59	17.74	0.50	0.35	5.09	0.27	117.81
23.28	86.69	3.57	17.57	5.15	17.57	1.65	15.88	25.54	1.17	0.25	7.35	0.47	57.06
6.12	12.82	1.80	4.33	0.17	4.33	1.76	15.76	27.71	0.70	0.14	4.73	0.41	87.86
13.78	37.13	2.51	11.66	0.49	11.66	1.65	19.13	34.26	1.28	0.23	7.70	0.27	143.06
19.55	78.26	3.81	18.68	6.55	18.68	1.60	9.14	20.74	0.94	0.24	77.66	0.90	3.83

Appendix 4

Site layout and contour map

