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Land suitability studies for the growing of deciduous berries in the Limpopo Province of South Africa.

By

Roger David Stones.

Submitted in partial fulfillment of the requirements for the degree of

M. Inst. Agrar.

In the Faculty of Natural and Agricultural Sciences
Department of Plant Production and Soil Science.

University of Pretoria.

Declaration.

I, the undersigned, declare that the dissertation, which I hereby submit for the degree of M.Inst.Agrar. at the University of Pretoria, is my own work, except where acknowledged in the text, and has not previously been submitted for a degree in any form at this or any other tertiary institution.

Roger David Stones.

Dedication.

I dedicate this to my beautiful bride, Wilna, my companion, who continuously adds dimension and meaning to what I do.

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To The Lord Jesus, who makes everything make sense.

Suitability studies for the growing of berries, with emphasis on Blueberries: Limpopo Province, South Africa.

By

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ABSTRACT

Blueberry, Cherry and Raspberry (berry) production is a potential alternative land use opportunity in the Limpopo Province (LP) of South Africa (RSA). RSA based site selection criterion and literature is limited. Haenertsburg and an area near Pietersburg (Polokwane) were identified for berry production potential. In Haenertsburg, most viable land is held by the timber industry. In Pietersburg, soil and climatic conditions vary greatly, representing a site selection risk.

Using accepted site selection processes, a study was conducted which identified the need to select land qualities and characteristics (QC's) appropriate to berry production. The study revealed key QCs' and secondary QCs'. Key QCs' must be adhered to for site selection, while secondary QCs' have site-specific application. The key land qualities are climate, soil, water, topography and management. In order to design a land rating system (LRS), specific characteristic values were cataloged per quality and per berry. Characteristic values were assigned to a land rating system where S1 (highly suitable), S2 (moderately suitable), S3 (marginally suitable), N1 (currently not suitable) and N2 (not suitable). To test the LRS, a real, but non-representative resource assessment (RA) took place. The RA revealed the further need to incorporate land limits into site selection. QCs' and land limit data was collected from existing sources and measured in situ where the data was insufficient. Finally the RA data was applied to the LRS through the process of matching. The matching precipitated the formation of a site selection process or tool, presented on tables. Each table represents a land quality. Water and soil criteria varied per berry, while topography, water and management were common to all three berries. Additionally, the site selection tool enabled the assessment of secondary QCs'. The assessment process is conservative, allocating the lowest land rating as the overall rating. This allows for the land user to address the most limiting factor from worst to least, thereby ensuring sustainable and good land use.

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Chapter 1

GENERAL INTRODUCTION

1.1 Introduction.

Several questions are raised when the production of Blueberries in South Africa is considered. The questions relate to optimal soil and climatic conditions, markets for berries, business viability, etc. Most of the available information relates to conditions in Europe and North America and not Southern Africa. Crop production conditions differ widely, and what applies to Europe and North America does not necessarily apply to South Africa. Under South African conditions, further questions regarding the right province or production site (along the coast or in mountainous areas) could be asked. Potential Cherry and Raspberry producers are faced with similar uncertainties.

The same questions are asked about the production of Cherries and Raspberries and here some information is available. This is mainly due to the existing production of Cherries in the Eastern Free State. Published information, though, is scarce and the major source of information would be interviews with nurserymen who sell Cherry trees or local farmers in the Ficksburg area. The same applies to the locally available information on Raspberry production. Fortunately there are Raspberry producers in South Africa that are willing to share information but the data needed by farmers to plan a Raspberry production unit with confidence is generally lacking.

Current and prospective farmers face many risks and this is especially so for berry producers. Unlike annuals such as maize and wheat, berries are planted in orchards that take years to establish. Furthermore, berry orchards and especially Raspberries, need to be planted under protection. Significant capital investment, adequate land preparation and correct site selection are therefore necessary to ensure the success of a berry planting. Berry plants typically start producing fruit after three to seven years and mistakes made at site selection often become evident when it is too late. This results in an unacceptable loss of time, production and capital. Prospective berry farmers need a tool in order to minimize the risks associated with site selection.

In the case of prospective berry production, the pressure to change land-use patterns is not the driving factor but rather the lack of land resources and the need to make optimal use of such resources. In this sense, the choosing of an alternative land-use to timber production in the Haenertsburg area and overall land availability becomes an important driving force. As such, it is not known whether berries can be successfully grown in the study areas. It is known though, that Blueberries are currently being produced in Limpopo where the climate is suited to berry production.

Timber is the dominant industry in the Haenertsburg study area, and land is expensive due to its aesthetic value. Two types of landowners are found in the specific area namely 1) those holding large tracts of land necessary for timber production, and 2) those that own relatively smaller tracts of land, which may or may not be economically viable. In most cases smaller landowners use timber to augment an additional income source such as other employment or a business. Neither Raspberries nor Blueberries require large tracts of land (approximately five to ten hectares is considered an economic unit), and even though Cherries require larger lands (approximately ten to 30 hectares is an economic unit); it is insignificant compared with the timber industry on area required. If a deciduous berry industry emerged from both study areas, (available to all land size owners), a greater possibility of wealth and job creation could emerge, as well as the added spin-offs such as pack-house suppliers, cool room maintenance, fertilizer and machinery suppliers etc.

1.2 The Study Area, its Current and Historic Land Uses.

1.2.1 Haenertsburg.

Haenertsburg is a village in Limpopo Province representing the largest area of this study (Refer to Figure K.1). The study area is approximately 10 km wide starting south of Haenertsburg on the farm Leliefontein 1096 LS to approximately Nooyensboom 954 LS in the north. The total Haenertsburg area stretches further north of Nooyensboom by approximately 14 km. However, for practical reasons including cost and time, and because the area chosen for the study is representative of the total area, the additional 14 km was excluded.

From field observation, Haenertsburg falls under the escarpment grassland biome. The area was predominantly Afro-montane indigenous forest and escarpment grassland. High rainfall and deep soils precipitated the planting of timber which is currently the major land use. The area is mountainous, ranging from approximately 1350 m to 2160 m above sea level. The climate is mild and the prevailing climatic conditions include frequent mist, occasional wind and hail and frost in winter.

Haenertsburg averages approximately 1300 mm rainfall per annum. The Haenertsburg Woodbush complex forms part of a catchment supporting the Dap Naude dam, the Ebenezer dam, the Tzaneen dam and the Magoebaskloof dam. These dams supply water to Pietersburg and Tzaneen.

Apples were grown in the early twentieth century, but failed due to false coddling moth (*Cryptophlebia leucotreta)*. Besides the dominant timber industry, current land uses in the area include the production of avocados, kiwi fruit, potatoes, macadamia nuts, trout, dairy products and beef as well as eco-tourism.

1.2.2 Pietersburg.

Pietersburg is the name conveniently used for the area under investigation. However, the study area is approximately 30 km south west of Pietersburg (Polokwane) on the old N1 highway, the farm Turffontein 14KS being the focus of the study (Refer to Figure K.2).

From field observation, the farm is situated at 24°05’ south and 29°17’ east at an altitude of approximately 1400m above sea level. This area is at the foot of the Ysterberg Mountains and supports large-scale peach production. The enterprise Midway Fruit Farm operates on Turffontein. Midway fruit is so named because it is approximately half way between Potgietersrus (Mokopane) and Pietersburg (Neetlingh, 2001).

The target area Turffontein falls within the savannah biome. The climate is hot in summer and cold in winter with frost, with daytime warming in winter. The rainfall averages approximately 600 mm per annum. Hail often causes crop damage.

Previously the area supported dairy and cattle farming as well as mixed vegetables and field crops including maize and tobacco. Irrigation water is obtained from catchment dams and boreholes.

1.3 Land-use Planning.

When deciding on the production of berries, the ideal would be to use a land-use planning tool that would "guide" the way for a prospective producer. No such specialized planning tool currently exists for the production of Blueberries, Cherries and Raspberries in South Africa.

The process of Land-use Planning, as proposed by the FAO, could be used as an approach towards making an informed decision on the production of berries. The Guidelines for Land-use Planning (FAO, 1993), as produced by the Food and Agricultural Organization (FAO) of the United Nations (UN) give an overview of an approach when land use has to be planned. Other FAO documents, such as the FAO Soils Bulletin 55 (FAO, 1985) focus on the planning of specific land-uses such as irrigated crops. The Guidelines (FAO, 1993) list ten steps to be followed in the land-use planning process. For the sake of this study these steps can be grouped into three broad categories namely:

1. Identification of the problem.
2. Determination of alternative solutions.
3. Identification of the best alternative and preparation of the plan.

The three steps can be applied at different levels namely:

1. At a national level, involving an entire political entity presenting broad generalizations for land use for example mining, farming, urban land use.
2. District level (a somewhat subjective assessment), which varies based on the size of the country involved. For the purposes of this study, district level refers to a mapped area involving numerous farms at a scale of approximately 1:50,000.
3. Local level. For the purpose of this study, local refers to an area involving individual farms at a scale of 1:30,000 or less.

A land use planning process is instituted when land users identify a need to change. The circumstances precipitating the change may vary from imminent starvation to discontent with the current status quo. The production of berries represents a novel, and possibly profitable (at farm and local scale) approach that could drive this need for change.

1.4 Aim of the study.

This study aims to provide a site selection methodology and subsequent tool for berry production in the Limpopo province of South Africa.

1.5 Methodology.

Many land assessment tools are available, each with its own merits. However, for the purpose of this dissertation, the framework developed by the FAO (1976), provides the flexibility needed to assess land for the cultivation of berries. Many of the formats used in the guideline document for land use planning FAO (1993), are used in this dissertation. The FAO in its land use planning publications suggests that the land use must determine the bias by which the land is rated. As an example, maize farmers may consider a field that is water logged for most of the year a bad piece of land, but a rice farmer sees the same field as good land. Therefore according to the FAO no land is good or bad, it is the desired land use that gives that land its value.

The Land Resource Section of the KwaZulu-Natal’s (KZN) Department of Agriculture and Environmental Affairs based at Cedara near Pietermaritzburg issued a series of land potential documents in 2000 and 2001 (Anonymous, 2001). The documents present the entire KZN province’s potential for a set of common land uses, for example maize, timber, pasture, sugar, etc. The Cedara documents present methods and field tests that enable farmers to test some of the desired land qualities and apply suitability ratings to the results. Due to their practical nature some of the Cedara field-test methods and rating tables are used in this dissertation.

1.5.1 Overview of the Assessment Process.

In order to develop the desired templates stipulated in the aim, this dissertation is divided into six Chapters and appendices. Chapter 1 aims to 1) create an overall picture of the entire dissertation and 2) act as a point of reference or map to reveal the flow of the document. Some of the information in Chapter 1 is repeated in order to provide a point of reference in the text. Chapter 2 is a study that examines the berries and their management, in order to determine the criteria upon which to base the site selection process. Chapter 3 combines the qualities and characteristics identified in Chapter 2 and assigns values to them through a classification system.

Whereas Chapters 2 and 3 examine the berries, Chapter 4 examines the land. This Chapter is the resource assessment and is sub-divided into three main paths.

- **Path 1:** This path presents existing data, thereby reducing the possibility of duplication.
- **Path 2:** Some of the existing data are not detailed enough to satisfy the classification systems in Chapter 2 and some data are non-existent. Path 2 therefore presents the test and research methods and results needed to satisfy the classification systems.
- **Path 3:** This path addresses land limits that render a site unsuitable for berry production outside the classification system for example it is illegal to use indigenous forest or virgin veld. All the conditions necessary to grow berries may be perfect on the site where the veld grows, but the law of the land prevents it. Path 3 produces a map that eliminates those sites rendered unsuitable due to the specified land limits, and reveals the sites with berry production potential.

Chapter 5 contains the matching process. Matching takes the land qualities and characteristics required by the berries and compares them to actual conditions on the land. The classification process assigns a current rating to the land and gives suggestions on how to improve the land potential for berry production.

Chapter 6 is the general conclusion.

The main content of the Appendices are:

1. Chill Unit and temperature data taken from Chapter 4.
2. The matching tables used to select the site for berry production.
3. The bulk of the matching process taken from Chapter 5.
4. General information on the berries themselves.
5. General maps for reference purposes.
6. The literature, data and information references.

1.5.2 Chapter 2.

The purpose of Chapter 2 is to identify and categorize the criteria upon which the site selection process will be based. Chapter 2 uses a literature study, site visits, interviews and Internet searches. The FAO identifies land qualities and characteristics as a platform for site selection criteria. For clarity, the FAO (1993) divides the properties of land into two groups, namely qualities and characteristics.
1) Land qualities are general land aspects, for example 1) water quality. 2) soil condition, 3) climatic factors.
2) Land characteristics are those attributes of the land quality that can be measured, for example 1) water salinity, 2) water pH, 3) soil pH and 3) soil clay content etc.

Chapter 2 begins by isolating the key land qualities as climate, soil, water, topography and management. The study process is further explained in the method and assumptions. In order to design a land rating system, detailed characteristic tolerance values are necessary. Most of Chapter 2 is dedicated to listing the characteristic values found in the study. This list of values is used in Chapter 3 to design the land classification system. The characteristic values are listed per land quality and per berry respectively. Because management is such a vital part of sustainability, the management section received as much detail as was deemed appropriate. As a useful reference, as many key as well as secondary management site-selection criteria as possible were tabulated. The management section covers a brief overview on marketing and incorporates some relevant socio-economic factors. Chapter 2 ends with two summary tables and a brief conclusion

1.5.3 Chapter 3.

Chapter 3 begins by setting the benchmark and frame of reference upon which the land will be classified. The FAO system of land classification, which classifies land according to its use, is used. In summary, an S1-land is highly suitable, an S2-land is moderately suitable, an S3-land is marginally suitable, an N1-land is currently not suitable and an N-2 land is not suitable. Additionally the Cedara (Anonymous, 2001) system is used to classify internal drainage. In Chapter 3 tables showing characteristic values derived from the literature review in Chapter 2 are presented for each berry. For example, the key climatic characteristic is Chill Units. A Chill Unit count greater than 300 Chill Units (CU) permits all Blueberries types, therefore the site is classified as S1. However, if the Chill Unit count is less than 800 CU, Highbush Blueberries render the land classification less than S1. The characteristic values for 1) soil, 2) water, 3) topography, and 4) management are tabulated in Chapter 3 in a similar manner. A subscript to each table explains other values found within the table, for example, an S2ca rating indicates the need to add calcium to the soil. The values and classifications in Chapter 3 are conservative, influencing the final matching in Chapter 5. Chapter 3 has no conclusion as it consolidates Chapter 2.

1.5.4 Chapter 4.

Chapters 2 and 3 relate to the berries and production requirements of the berries. Chapter 4 focuses on the land itself. This Chapter is the resource assessment, or land inventory, and aims to produce basic maps and tables that depict and summarize the actual conditions found in the study areas. In the traditional scientific sense, research or experimentation is presented in a generally accepted norm, that being the aim, methods and materials, experiment and conclusion. However, this dissertation is concerned with the method rather than the data and this is expressed in Chapter 4. It is sub-divided into three paths, each path representing a different level of data sourcing. All data are tabulated and referenced. For clarity rather than scientific announcement, conclusions are offered in the text of this Chapter. Chapter 4 should further be seen a reference section applicable to the matching, rather than part of the narrative.

1.5.4.1 Path 1.

This path reveals those data and information already researched or measured by sources like the Institute for Soil, Climate and Water (I.S.C.W.) or from laboratory results of farmers' fields.

1.5.4.2 Path 2.

This path takes existing data with insufficient detail and enhances it with the necessary tests or research. Because this dissertation is written primarily for land use planners or farmers, many of the tests are accepted field testing methods used for reconnaissance surveys. The latter parts of path 2 presents detail relevant to two of the most important land qualities pertaining to site selection, those being soil and climate. The soil assessment examines the two study areas in differing degrees of detail. The detail presented is related to the scale used for the maps. The Haenertsburg area is presented using scale 1:50,000, and the Pietersburg area is mapped at scale 1:30,000. Soil is presented in terms of 1) soil drainage, 2) clay content 3) soil pH, and 4) soil taxonomy in the study areas. The soil pH, drainage and clay content are grouped together and presented in tables together with the relevant methods. The method used for the soil taxonomy, soil pH, soil drainage and soil clay content is a amalgamation of field testing methods and existing data (explained in text). Appendix K has two 1:50,000 maps showing general locations of the test and samples sites. Due to the large size of the Haenertsburg area, the ensuing soil taxonomy maps are not detailed. It is assumed that a detailed soil map will be drafted for a farm plan. The Pietersburg soil maps are semi-detailed and show the major soil types on the farm Turffontein.

The soil maps are derived from a combination of field surveys and the land type inventory of Land Type Survey Staff (1989). The land type inventory uses a coding system to identify a specific combination of soil and land qualities. The land type coding is incorporated into the 1) text, 2) tables and 3) maps of Path 2 of Chapter 4. A colour coding system is used in the text to link land types and soil forms with the relevant maps. A referenced section on terrain forms is included, as this has bearing on 1) slope and 2) pedogenesis of the areas.

The final section of Path 2 covers the Chill Unit (CU) data. It must be emphasized that the CU data was collected for one winter only, and cannot be seen as representative. It is advisable to use CU data measured over as many years as possible. Due to resource constraints and a lack of acceptable data, the CU data measured over one season is used for **demonstration** purposes.

The Chill Unit section is introduced with methodology. Some national data are shown, followed by the measured Chill Unit data. The reason the Chill Unit data was measured is because, 1) only one site with CU data was sourced from the I.S.C.W.. 2) Because CUs' directly impact the marketing of berries, it was deemed necessary to investigate Chill Units in some detail. For ease of use and brevity in the text, the bulk of the Chill Unit data are represented in appendix A. Only the Chill Unit summaries and a set of demonstration tables is included in the text of Path 2.

In the methods and materials of Path 2 of Chapter 4, two Chill Unit formulae are presented. One is the Richardson Chill Unit and the other the Positive Chill Unit. The Richardson Chill Unit is used internationally and the positive Chill Unit is a South African adaptation of the Richardson unit. Three sites were used to measure Chill Units in Haenertsburg and one site in Pietersburg. Due to time and resource constraints, temperatures during parts of May and August were not measured. The missing temperature data was extrapolated based on the average Chill Unit accumulation for the month concerned. For example: if the average Chill Unit for May was 4.5 Chill Units per day, and 7 days were not measured in May, the extrapolated Chill Units would be the 4.5 Chill Units x 7 days which is equals 31.5 Chill Units additional to the measured Chill Units. However, the text presents the measured Chill Units and extrapolated Chill Units separately. Because the matching process is taken conservatively, only the measured Chill Units are used. For comparative purposes, both the Richardson and positive Chill Units are presented with the percentage difference or variance. Because the measurement sites were spread over a large geographic area, not all the data was gathered at the same time. Therefore, each data table has a unique method explained as it is presented in the results. Path 2 of Chapter 4 ends with a summary and conclusion of the Chill Unit data.

1.5.4.3 Path 3.

During the course of the fieldwork, it became obvious that some of the land associated with this study had certain limits that render it unsuitable for berry cultivation, for example dams and mountains. This path concerns itself with these limits, which are: 1) Environmental; 2) Residential; 3) Slope and accessibility; 4) Soil types; and 5) Wetlands, dams and rivers. The land limits are introduced, defined and presented with accompanying photos for clarity.

The final section of Path 3 presents four general maps showing land limits in relation to the area and sites with potential for berry farming. The purpose of presenting land limits is to prevent land users from assessing sites with no potential for berry production. Due to the scale of the maps the areas depicted are generalized. It is therefore possible that within areas shown as unsuitable, small areas may have potential and vice versa. The sites shown as having potential for berry production must be further investigated using the principles presented in this dissertation. Chapter 4 closes with land potential maps.

1.5.4.4 Special note on Chapter 4.

At district level, area is measured in square kilometres. To accurately map the desired land characteristics a representative sample would require a very large sample size. It is beyond the scope of this dissertation to measure a representative sample. The resource assessment therefore, cannot be seen as representative of the given areas, but rather as demonstrative. The data presented in the resource assessment, however, is real. To overcome the problem of representation, average values for the land characteristics are calculated. The average values are used in the matching to represent an hypothetical site. It is expected that the land user or planner will take responsibility to assess the given site accurately.

1.5.5 Chapter 5.

Chapter 5 presents the matching process. Matching compares the berry growth requirements, such as acid soils, with what was assessed on the land, such as the measured soil pH. This is done using the criteria given in Chapter 3 and the assessed data of Chapter 4, the resource assessment.

Chapter 5 introduces the matching principles and a set of tables summarizing the necessary data from the resource assessment. The matching tables originate from the blank tables in Appendix E. There are two types of matching tables. The one type of table that uses data common to all three berries (for example water quality), is termed a generic table. The other type of table has qualities specific to the berry, for example Chill Units. The matching method is explained and demonstrated as the text runs concurrently with the matching tables. The main body of the table shows the critical qualities and characteristics. Below the critical qualities and characteristics on the same table are additional factors that the planner may consider, such as soil organic matter content. The additional factors are measured qualitatively and are for reference purposes. The matching tables have subscripts defining codes, for example S3o, indicating a need for organic matter. Below the tables are lines where comments or notes can be written.

After the berry is matched to the site in question, a table summarizes the results and presents a final land rating. The summary table applies a conservative policy. For instance: if all the land qualities such as soil, climate and water are S1 (highly suitable), but the slope has an N3 (marginally suitable) rating, the N3 rating applies overall. If the necessary slope management is implemented, the land is re-assessed and a new rating applied based on the new findings is assigned. Chapter 5 presents a set of matching tables for each berry per study area. The final table summarizes all the ratings in Chapter 5. As with the Chill Unit data of Chapter 4, for ease of use and brevity in the text, the bulk of the matching process tables were placed in Appendix G. Only those matching tables used to demonstrate the matching process and the summary tables are included in the text of Chapter 5.

1.5.6 Chapter 6.

Chapter 6 is the general conclusion. The general conclusion summarizes the flow of the dissertation and tests whether the aim was achieved.

1.5.7 Appendices.

The appendices hold A) the bulk of the Chill Unit data; B,C,D and E) The blank or template matching tables; F and G) the bulk of the matching tables used to demonstrate the matching process. H) general information on the berries and I) additional information on Blueberries and K) general maps.

1.6 General comments.

- The process of this dissertation places land users on a site where berries have potential to grow. Once on the site, however, the potential land user must initiate a thorough farm plan. The farm plan contains detailed soil tests, water tests, feasibility studies, etc.. The use of a farm plan is however entirely at the land users discretion.
- The templates presented in the appendices, and demonstrated in Chapter 5, are open to further development. All systems evolve and improve from one version to the next. It is hoped that this dissertation marks the beginning of more research that ultimately benefits the land and the land user.

Chapter 2

SITE SELECTION CRITERIA

2.1 Introduction.

This Chapter presents the first step in the formulation of a site selection process for Blueberry, Cherry and Raspberry growth and production. In the site selection process, the FAO (1976 and 1993) recommends, that only those factors that have a substantial effect on the land use, should be used for site selection. In addition, only those values of the land that actually occur in the locale of the study should be considered. The FAO (1985 and 1993) divides the properties of land into two groups.
1) Land qualities for example water quality.
2) Land characteristics, those attributes of the land quality that can be measured, for example water salinity.

According to Crandall (1995), Baker *et al.* (1990), Farringer (2002), Human (2002) Prinsloo (2002), Strik *et al*. (2003) and, Webster and Looney (1996), the **key** land qualities are climate, soil, water, topography and management. In order to use these key land qualities for site selection, the associated characteristic values were ascertained through the study presented and tabulated per berry below.

2.2 Method.

This Chapter is a compilation of information found from primary and secondary sources. Primary sources included interviews with growers, site visits and literature, secondary sources included Internet searches and relevant monographs. A process of elimination was used to test for key land qualities. For example if berries on site A do not incur wind damage, while berries on site B do, windbreaks are advisable on site B. However, both sites cannot support berries if the soil pH is incorrect. Soil pH is therefore a key quality while the importance of windbreaks is secondary or site specific.

2.2.1 Assumptions.

It is beyond the scope of this document to address every requirement relating to land and its suitability for agriculture. Each plant species has specific growth requirements, while agriculture in general has fundamentally accepted norms, for example resource conservation, sustainability, enterprise viability etc. Consequently in the interests of brevity, the following assumptions were made.

1. Most aspects relating to marketing and viability will not be addressed. It is the responsibility of the producer to determine if growing berries is financially and economically viable, and to establish markets.
2. It is assumed that berry production is not subsistence farming, but intensive farming. Therefore, management requirements and skills levels are high.
3. The nutrient status of the soil varies from site to site. Therefore, the producer, once on the selected site, must initiate detailed soil testing and the required soil nutrient adjustment.
4. Irrigation design and management are handled professionally.
5. Water availability is assumed.
6. Whether the land is suitable for agriculture or not, is beyond the scope of this document. For example: generally speaking, one cannot grow permanent crops 1) in a river, 2) on a cliff face, 3) on solid rock, 4) in places where the environment is hostile, 5) where the use of equipment or infrastructure is impractical, etc. Good and sustainable agricultural practice is assumed.
7. This dissertation will not examine detailed environmental implications beyond 1) drainage, 2) slope, 3) wetlands and 4) interference with protected biomes.

2.3 General berry information.

The Blueberry plant is a 2 – 5 m high shrub with its growth point at ground level. Blueberries are grown under hail net or in the open. Blueberry plants can produce fruit for longer than 30 years. Blueberry production is intensive, as it uses relatively little land for high return and is aimed at the export market.

Cherry trees are grown in orchards similar to peaches and apples. For best fruit production Cherries on average require approximately 1000 Chill Units. In South

Africa the main Cherries producing area is in Ficksburg. Approximately 10% of the Cherry fruit produced in Ficksburg is exported; 50% processed and 40% sold as fresh fruit locally (Webster, 1996). However, the export market for Cherries is expanding and new plantings are aiming at meeting the export demand (Sheard, 2000).

Raspberries are grown under protection. The Raspberry plant consists of canes sprouting from ground level that are supported by trellises. Raspberries produce highly perishable fruit. The Raspberry fruit season is longer than that of Cherries and Blueberries.

2.4 Soil requirements.

2.4.1 Blueberries (*Vaccinum sp*).

Blueberries need well drained, acid, sandy-loam soils, with pH values ranging from 4.2 – 5.2 and an organic matter (OM) content of at least 3.0%. (Torrice, 2002; Farringer, 2002). According to Rieger (2002) soil organic matter content must range from 20 - 50% for best growth. It is advised to use ammonium sulphate as Blueberries have a low tolerance for nitrate nitrogen (Rieger, 2002).

Note: currently berry farmers 1) incorporate OM into a ploughed row or 2) place OM into the hole dug for the plant at planting. Together with regular mulching, these methods enable the high soil organic matter contents required by Blueberries.

According to Farringer (2002) Blueberries should be grown in a sandy loam and will tolerate well drained "shale soils". Soil clay content should not exceed 15 – 20% and soils with a clay content greater than 30% should not be considered.

Blueberries grow naturally in peaty soils, and have a strong relationship with *Ericaceous Mycorrhizae* (Sylvia, 1997). This suggests that when growing Blueberries, one should manage both the *Vaccinum sp*. as well as the *Mycorrhizae sp*.

According to Braswell (2002) "Blueberries will not tolerate standing water or grow well in excessively wet areas." Old lands where high level of Ca was applied should be avoided as well as should low-lying areas. However, low-lying areas can be used for Blueberries, provided that the water table stays at least 600 mm below the soil surface all year round. If the water table is less than 600 mm below the soil surface, raised beds of 200 – 300 mm must be used.

Elemental sulphur can be used to reduce the pH of soils having a pH range of 5.2 to 5.9. However when the soil pH is 6.0 to 6.5 and higher, sulphur applications can become impractical, especially in soils with high exchangeable acidity values (Strik *et al.,* 2003). Sandy soils require regular and possibly costly sulphur applications (Strik *et al.,* 2003; Torrice, 2002; Farringer, 2002). Kinsey and Walters (1999) state that in their experience, the best Blueberry production was noted on soils of pH 6.0 – 6.5. However, their results are based on using a system known as Biological Farming™ and will not be described in this document.

2.4.2 Raspberries.

Raspberries need a well-drained loamy soil with a pH of 4.5 – 7.0. (Farringer, 2002; Reiger, 2002).

2.4.3 Cherries.

Cherries need a deep, well-drained, loamy soil with pH 6 – 7 (Reiger, 2002).

2.5 Climatic requirements.

2.5.1 Blueberries.

Blueberries, Cherries and Raspberries, need sufficient chill hours or Chill Units (CU) for normal flower and leaf bud development (University of California, 2001). Blueberries need 350 to 1000 Chill Units (Strik *et al.,* 2003, 1998; Williamson, 2002).

The Chill Units required by each Blueberry species, according to Reiger (2002), are given in table 2.1 below.

Table 2.1. Chill Unit requirement per Blueberry type.

Highbush	800 - 1100 CU
Rabbiteye	350 - 800 CU
Southern Highbush	150 - 400 CU
Lowbush	Approx. 1000 CU

2.5.2 Cherries.

The CU requirement of Cherries is variety dependent, ranging from 500 to 1600 (Reiger, 2002; Webster & Looney, 1996; Sierra Gold, 2000). According to Bernd (2003) no Cherry production should be considered in areas with less than 1000 CU.

2.5.3 Raspberries.

Raspberries require 250 – 1600 CU depending on variety (Crandall, 1995; Reiger, 2002).

Root rot and post harvest *Botrytis sp.* fruit rot are problematic in summer rainfall areas. This is because high humidity and warmth during growth and harvesting provides a medium for fungal growth (Farringer, 2002).

Raspberries are sensitive to sunburn and the use of black hail netting structures is highly recommended (Farringer, 2002).

2.6 Water requirements.

When considering high value intensive product like berries, one should not consider production without irrigation. South Africa is prone to drought and erratic rain distribution whilst Webster and Looney (1996), as well as Gough (1994), confirm that moisture stress in berries reduces yield and plant health. In order for an irrigated system to succeed, water volume, water availability, and water quality must be evaluated.

In the context of this study, plant water demand is influenced by climate, plant size, soil texture, rain and land size. In order to plan an irrigation system correctly, one must determine the plant's water demand as a function of all of the above (Brady, 1984).

Crandall (1995); Loony (1996), Austin (1994) and Gough (1994) all agree that water pH, salinity, sodium, bicarbonate, chlorine and boron are the key water quality parameters to consider when selecting a potential site for berries and are common to all three berry types. However, other water quality parameters such as nitrogen, potassium, dissolved solids, and others, may be limiting. It is therefore recommended that an appropriate professional be consulted for water evaluation.

2.7 Topography.

For Blueberries, Cherries and Raspberries it was recommended that terracing or contouring should be used on slopes greater than 6-10%, and slopes greater than 10% present a management risk. (Anonymous, 2000).

2.8 Management.

It was decided to compile the management section for reference purposes and provide the needed characteristic values pertaining to production and marketing. The socio-economic aspects of berry production are affected by management elements like labor availability and available of land etc., these aspects are addressed in table 2.2 through table 2.4 below.

2.8.1 General marketing information.

Only the marketing information that has an influence on site selection will be presented here. Consequently, this section is brief and does not attempt to be comprehensive in marketing terms.

According to the Northwest Berry & Grape Information Net (Strik *et. al.,* 1998), South Africa has approximately 129 ha of Blueberries under cultivation. This constitutes approximately 0.68% of world production and 9.9% of the 1300 ha under production in the southern hemisphere. According to Dr. E. Farringer of Microprop, Stellenbosch (2002), there was approximately 150-200 ha of Blueberry under cultivation in South Africa in 2002 and indicates an upward trend since 1998. However, 200 ha of Blueberries is insignificant compared to 16 422 ha in production during the year 2000 in the U.S.A. alone, (USDA, 2002). Statistics from Tswane Market Services (2005) show that fresh-fruit sales of Blueberries increased from 1.5 kg in 2002, to 178 kg in 2005. In addition, that most of the South African fresh fruit berries are sold directly to large retailers like *Pick n Pay* and *Woolworths*. Exact sales figures could not be ascertained, as it was found that such retailers are unwilling to release such data.

According to a number of sources (Boyette *et al.,* 1993; Mississippi State University, 1998; Williamson 2002), Blueberries grown in the northern hemisphere are marketed from April to August, with the peak season during July. South Africa produces Blueberries from October to February, with the peak during November and December (Farringer, 2002). Blueberries, Cherries and Raspberries, are summer bearing fruit, and together present an export opportunity for South African farmers.

Currently the largest Blueberry plantings occur in south-western Mpumalanga and the Western Cape. According to Webster and Loony (1996), approximately 1000 tons of Cherries are produced annually in Ficksburg in the Eastern Free State. Currently Cherry production is being investigated in the Underberg area in KwaZulu-Natal, as well as areas in Gauteng, Mpumalanga and Limpopo (Sheard, 2000). Raspberries are grown in the Western and Eastern Cape provinces, the Free State and other areas with cold winters. The major commercial production, however, occurs in the Western and Eastern Cape and Free State provinces.

2.8.2 Blueberry production information.

The structures of tables 2.2 through 2.4 are based on the land use type table of the FAO Guidelines for Land-use Planning (1993). Table 2.2 presents a summary of the production requirements relevant to Blueberry site selection.

Table 2.2. Summary of production requirements for commercial irrigated Blueberry production.

Production.
Marketing and yields. 40 - 50% of production is exported; 50 – 60% is sold locally as fresh or frozen fruit. (Farringer, 2002; Human, 2002; Strik *et al.,* 2003). Berries are transported by refrigerated/insulated truck to the local market and air freighted for export (Farringer, 2002). Average yields are 8 $t.ha^{-1}$ but can range from 6 – 12 $t.ha^{-1}$ under irrigation (Farringer, 2002). With no irrigation, yields are noted at 50 – 60% of irrigated berries where rainfall is greater than 1000 mm per annum. In areas where rainfall is less than 1000 mm per annum, yields are assumed to be less than 50% of irrigated production (Human, 2002). The peak season in South Africa (RSA) is November to 24 December, low season after 25 December to January (price related). A favourable market exists in October but varieties that produce fruit during this month run the risk of late frost damage to flowers (Farringer, 2002).
Management unit.
Size and ownership. In the main, management units are privately owned. Where land units are less than 4 ha supplementary income will be necessary. Units of 4 – 10 ha are manageable by the owner and units of more than 10 ha require management assistance (Prinsloo, 2002). Unit size is also dependant on the proximity to markets/airports and fruit price (Farringer, 2002; Human, 2002; Strik *et al.,* 2003).
Capital intensity and Economic Considerations.
Establishment costs range from medium to high. The average total establishment cost was approximately R20.00 – R45.00 per plant in 2003. Some costs such as pack houses can be deferred to year three. Running costs amount to approximately 10% of the total establishment cost per annum. When the interest rate is less than 22% a

positive cash flow is realized within five years; when more than 22% a positive cash flow is realized after five years (Prinsloo, 2002). Fruit prices vary considerably with process prices approximately R15.00 – R20.00 kg^{-1} and fresh fruit from more than R30.00 up to R370.00 kg^{-1} (Human, 2002).

Cultivation practices and Inputs.

Labour.

Farringer (2002); Human (2002) and Strik *et al.* (2003) agree that 10 – 20 people per ha during harvest and 1 - 2 people per ha for maintenance during the off-season is appropriate, also that pruning skills varies according to Blueberry species, but is not as intensive as peaches and apples Labour remuneration is based on Rand per kilogram picked, and/or on profit share basis (Prinsloo, 2002). Larger plantings in the United States of America use mechanical harvesters (Austin, 1994; Gough, 1994; Strik *et al.,* 2003), there is no such technology in R.S.A. yet (Prinsloo, 2002).

Power/Energy requirements.

Electricity is used for pack houses and cool rooms, and small diesel/petrol vehicles for mowing and transporting. During establishment, heavy diesel driven earth moving vehicles and tractors can be hired. Because Blueberries are a permanent crop, annual tillage is minimal (Baker *et al.*, 1990; Prinsloo, 2002). Blueberries need approximately 11,000 lux to photosynthesize effectively, but approximately 25,000 lux for effective flower bud development (Gough, 1994).

Site preparation.

Austin (1994); Braswell (2002); Farringer (2002); Gough (1994); Human (2002); Prinsloo (2002); Strik *et al.* (1998); Strik *et al.* (2003); Baker *et al.* (1990); Torrice (2002); Malik and Cawthon (1993) all agree that site preparation is very important and that soil drainage must be excellent. Ridging is acceptable in low-lying areas with high water tables (Austin, 1994; Baker *et al.,* 1990; Gough, 1994). Farringer (2002), Strik *et al.* (1998) and Strik *et al.* (2003) recommend removing all weeds to reduce competition. Green manures or cover crops are used in the season prior to planting (Gough, 1994; Malik and Cawthon, 1993). Sulphur is incorporated into the soil to lower pH (Baker *et al.,* 1990; Malik and Cawthon, 1993; Strik *et al.,* 1998; Strik *et al.,* 2003; Torrice, 2002), organic matter like compost or sawdust, is incorporated into the row at establishment. Soil O.M. content is adjusted to as close to 30-50% as possible (Baker *et al.,* 1990; Farringer. 2002; Human, 2002; Malik and Cawthon, 1993; Strik *et al.,* 1998; Strik *et al.,* 2003; Torrice, 2002). Soil tests are essential (Anonymous, 2001). If hail netting is to be used, it is erected at site establishment or just prior to the 3rd season. Generally, white hail net is used (Farringer, 2002; Prinsloo, 2002; Strik *et al.,* 2003). Windbreaks are recommended and irrigation is installed during site preparation (Farringer, 2002; Prinsloo, 2002; Strik *et al.,* 2003).

Site Selection.

The use of north or west slopes is preferred, while south and east slopes have delayed fruiting and the fruit has a reduced sugar content (Human, 2002; Prinsloo, 2002). Soils must be well drained sandy or silt loams with an acidic pH 4.2 – 5.5 and a high O.M content (Austin, 1994; Braswell, 2002; Farringer, 2002; Gough, 1994; Human, 2002; Prinsloo, 2002; Strik *et al.,* 1998; Strik *et al.,* 2003; Baker *et al.,* 1990; Torrice, 2002). Soil clay contents greater than 30% are not recommended by Farringer (2002), unless the clay content can be adjusted, or has good drainage. Sands deeper than 1,500 mm are not recommended, while sandy soils should receive regular organic matter inputs (Anonymous, 2001; Prinsloo, 2002). Strik *et al.* (2003) advises against the use of soils high in salts and Na levels. Austin (1994 and Gough (1994) advise that bottomlands and wet areas should be avoided. However, if the water table is closer that 600 mm to surface, Blueberries should not be planted. If there was previous cropping on the target site, Anonymous (2001); Strik *el al* (1998) and Strik *et al,* (2003) suggest checking for pests and diseases like nematodes and *Botrytis sp,* also test for excessively elevated soil pH or unwanted chemicals in the soil. Baker *et al.* (1990) and Strik *et al.* (2003) agree that free air movement is necessary to prevent cold damage and fungal infestations. Blueberries need Chill Units; the Chill Unit requirement depends on Blueberry type (Austin, 1994; Braswell, 2002; Farringer, 2002; Gough, 1994; Human, 2002; Prinsloo, 2002; Strik *et al.,* 1998; Strik *et al.,* 2003; Baker *et al.,* 1990; Torrice, 2002).

Variety selection.

Species and variety selection depends on 1) last frost, 2) available Chill Units and 3) marketing strategy, that is, late, mid or early season (Austin, 1994; Braswell, 2002;

Farringer, 2002; Gough, 1994; Prinsloo, 2002; Strik *et al.,* 1998; Strik *et al.,* 2003; Baker *et al.,* 1990; Torrice, 2002). Highbush and Southern Highbush Blueberries very generally take 50 – 65 days from flowering to fruiting, whereas Rabbiteye Blueberries take 70 – 100 days depending on variety (Krewer and Scott NeSmith, 2000). South African knowledge in this respect is inconclusive.

Planting.

Dependant on mechanical or manual harvesting. Spacing must facilitate easy air movement. Spacing varies from 800 – 1,800 mm in the row and 3,000- 3,600 mm between rows (Austin, 1994; Braswell, 2002; Gough, 1994; Strik *et al.,* 1998; Strik *et al.,* 2003; Baker *et al.,* 1990).

Pruning.

Pruning is variety dependant and of low intensity. Pruning aims to open the plant canopy and remove dead, diseased and unproductive wood. Baker *et al.* (1990) and Strik *et al,* (2003) suggest the removal of flowers in 1st and 2nd year to encourage vegetative growth

Plant Nutrition.

Plant nutrition needs are determined through soil tests, sap analysis and leaf tests. Nutrients applied through fertigation, direct application to soil or foliar feed. Appropriate Ca applications can reduce berry burst during heavy rains. Blueberries prone to Fe deficiency (Baker *et al.,* 1990; Strik *et al.,* 2003).

Weed control.

Because Blueberries are poor competitors it is suggested that all weeds be removed. Mulching helps reduce weed infestations, and applications 50 – 75 mm deep are suggested. Mulching materials include sawdust and pine bark. Sod and cover crops such as clover and fescue are alternative green mulches. Recommended chemical weeding can be used; also hand weeding (Austin, 1994; Braswell, 2002; Gough, 1994; Strik *et al.,* 1998; Strik *et al.,* 2003; Baker *et al.,* 1990; Torrice, 2002).

Pest control. Pests include insects, birds, monkeys, antelope, fungi, virus and bacteria. Blueberries are a "new" crop in South Africa and currently have relatively few natural enemies except *Botrytis sp,* birds and monkeys. Hail net shade houses reduce animal and bird damage, while commercial or organic pest control is adequate for insects and disease control. (Austin, 1994; Braswell, 2002; Farringer, 2002; Gough, 1994; Human, 2002; Strik *et al.,* 1998; Strik *et al.,* 2003; Baker *et al.,* 1990; Torrice, 2002). **Pollinators.** Blueberries need pollinators for best fruit set (see figure 1). Blueberry flowers respond best to bumble bees but common bees in sufficient numbers bring adequate results. Hives must be introduced just prior to flowering. Highbush Blueberries are intra species pollinating; while all other species require inter variety pollination, meaning that two or more varieties must be planted together (Austin, 1994; Braswell, 2002; Farringer, 2002; Gough, 1994; Strik *et al.,* 1998; Strik *et al.,* 2003; Baker *et al.,* 1990; Torrice, 2002).
Cropping characteristics.
Blueberries are a permanent monoculture grown with or without hail netting (Farringer, 2002; Human, 2002; Prinsloo, 2002; Strik *et al.,* 2003). Blueberries are intensive and have a productive life span exceeding 30 years (Baker *et al.,* 1990; Prinsloo, 2002). Blueberries are mulched or an inter-row sod or cover crop can be grown (Austin, 1994; Braswell, 2002; Gough, 1994; Strik *et al.,* 1998; Strik *et al.,* 2003; Baker *et al.,* 1990; Torrice, 2002; Malik and Cawthon, 1993).
Water.
Blueberries are grown dry land and irrigated. Water sources include catchment dams, rivers and boreholes. Blueberries require very pure water with low salts, low to neutral pH; low Na, B, HCO_3 and Cl (Strik et al., 2003; Malik and Cawthon, 1993). Blueberries use approximately 25 – 35 mm of water a week split into 3 applications with a maximum of 15 mm per application (Austin, 1994; Braswell, 2002; Gough, 1994; Strik *et al.,* 2003; Baker *et al.,* 1990; Torrice, 2002; Malik and Cawthon, 1993). Low season water demand during September and March is approximately 30% of peak, intermediate use during October and April is approximately 75% of peak use and winter irrigation should be enough to prevent water stress (Baker, *et al.,* 1990).

Too much water can quickly "drown" the plant and cause fruit splitting (Austin, 1994; Gough, 1994; Strik *et al.,* 2003). Water generally delivered by micro sprinklers, drippers or over-head sprinkler. Effective rooting depth is 450 – 600 mm. (Austin, 1994; Braswell, 2002; Gough, 1994; Strik *et al.,* 1998; Strik *et al.,* 2003; Baker *et al.,* 1990).

Figure 2.1. Honey bee pollinating Blueberry flowers (Photo: Scott NeSmith).

2.8.3 Cherry production information.

Table 2.3 presents a summary of the production requirements relevant to Cherry site selection.

Table 2.3. Summary of production requirements for commercial irrigated Cherry production.

Production.
Marketing and yields. Approximately 50% of fresh fruit sweet Cherry production is exported and 50% is sold to local markets (Webster and Looney, 1996). Theoretical yields are 10 $t.ha^{-1}$. Fruit is marketed at the end of October to February (Bernd, 2003).
Management unit.
A privately owned unit is viable if greater and equal to 10 ha. Units' less than 10 ha may require additional income (Bernd, 2003).

Capital intensity and Economic Considerations.
Total initial establishment is capital intensive. In 2003 the total establishment cost was approximately R87.00 per tree. In 2002 - 2003 the mean export price was approximately R40.00 kg^{-1} and the estimated process fruit price R10.00 kg^{-1} (Bernd, 2003). A positive cash flow realized in year 5 when interest rates are less than 12 - 15%; when interest rates less than 28-30% a positive cash flow realized in year 6. Annual running cost approx 13% of establishment cost (Prinsloo, 2002).
Cultivation practices and Inputs.
Labour. 10 – 20 people are required per ha during picking season, 2 people per ha for maintenance during off season. Labour paid per kg. Pruning may require specialized staff (Bernd, 2003). **Power /energy.** Site establishment is done with diesel driven tractors and earth moving equipment. It can be sub-contracted. Transport is required on the farm and to market and airports. Also may need mowers for cover crops and sod. Large plantings may require sprayers for pest/disease control. Cool rooms and pack houses generally use electricity. Cherry orchards are permanent and do not require annual tillage (Bernd, 2003; Webster and Looney, 1996). **Site preparation.** Bernd (2003) encourages good drainage by ripping, sub soiling, and delve ploughing as well as planting trees in individually prepared holes together with compost if possible. Webster and Looney (1996) recommed ridging in low-lying areas with high water tables; where ridge width = 2,000 mm, height = 450 mm. Bernd (2003); Hirst and Hayden (2001 and Webster and Looney (1996) suggest the following: a) Green manures or cover crops planted in season prior to planting. b) Soil pH adjusted as needed. c) Soil tests essential. d) If hail/shade netting is to be used it can be erected immediately or just prior to 4th season. e) Black netting assists with Chill Unit accumulation. f) Wind breaks are recommended. g) Irrigation installed during site preparation

Site Selection.

Sites with afternoon shade are recommended (Bernd, 2003). Bernd (2003); Farringer (2002); Reiger (2002); and Webster and Looney (1996) say that soils must be well drained sandy loams, even loose rocks and shale soils are acceptable, optimum soil pH 5.5 – 6.5, O.M. content greater and equal to 3%, clay contents greater than 30% not recommended, optimum clay content is 15 – 20%. Soils must not have high salts and Na levels. Bottomlands and wet areas should be avoided. If there was previous cropping on the site Anonymous (2001) advises to check for residual pests, diseases chemicals and unfavourable soil pH. Bernd (2003) and Hirst and Hayden (2001) advise free air movement to prevent cold damage and fungal infestations To adequately break dormancy, and for best production, Cherries need adequate Chill Units; the Chill Units required is variety specific (Bernd, 2003; Webster and Looney, 1996). A major limiting factor to Cherry production is day time warming in winter (Bernd, 2003). Dormancy can be broken artificially using Gibberellic acid (Nugent, 2001).

Variety selection.

Variety selection depends on last frost, and market demand (Bernd, 2003; Webster and Looney, 1996). Variety selection is primarily based on Chill Unit availability. Common varieties are Van, Stella, Vista and Bing. Select correct rootstock for area (Webster and Looney, 1996; Reiger, 2002).

Planting.

Bernd (2003); Hirst and Hayden (2001) and Webster and Looney (1996) advise that: a) tree spacing facilitate easy air and equipment movement. b) Trees are planted with graft or bud union 25 - 50 mm above soil surface. c) Planting depends on tree density, pruning method and support; ranging from 4.5 – 10 m between rows and 1.5 – 9.0 m in the row

Pruning.

Summer pruning opens the canopy, removes dead wood and branches that cross each other. Pruning focuses on healthy fruit numbers rather than fruit selection. Pruning depends on orchard design. Orchard designs include tipping, hedging, thinning and

trellising (Webster and Looney, 1996). **Plant Nutrition.** Plant nutrition needs determined through soil tests, sap analysis and leaf tests. Nutrients applied through fertigation, direct application to soil or foliar feed. Mg and Bo uptake slow in young plants. Excessive N can delay fruiting (Bernd, 2003; Webster and Looney, 1996) **Weed control.** Malik and Cawthon (1993) suggest that mulching helps reduce weeds, achieved by applying mulch 50 – 75 mm deep, (sawdust, pine bark etc). Sod and cover crops are also used as green or living mulch. Recommended chemicals can be used; also hand weeding **Pest/disease control.** As needed. Pathogens can be transported through water; common problems are bacterial and fungal cancer, also *Pseudomonas sp* (Bernd, 2003; Webster and Looney, 1996). **Pollinators'.** Cherries need pollinators, bee hives are introduced during flowering (Reiger, 2002).
Cropping characteristics.
Cherries are a permanent monoculture, grown with or without hail netting (Bernd, 2003). Cherries are semi-intensive (viable units greater and equal to 10 ha) and have a productive life span of up to and sometimes exceeding 11 - 15 years. (Bernd, 2003; Webster and Looney, 1996)
Water.
Too much water can drown trees and during fruiting cause fruit cracking (Webster and Looney, 1996). High quality water needed similar to Blueberries. Water requirements are similar to apples and can demand as much as 1,400 mm per season. Effective rooting depth is greater and equal to 1,000 mm (Bernd, 2003; Webster and Looney, 1996). Irrigation applied via drippers, micro sprayers or overhead sprayers. Over-head sprayers used to reduce frost damage. (Bernd, 2003).

2.8.4 Raspberry production information.

Table 2.3 presents a summary of the production requirements relevant to Raspberry site selection.

Table 2.4. Summary of production requirements for commercial irrigated Raspberry production.

Production.
Marketing and yields. Raspberries produce approximately 6 – 8 $t.ha^{-1}$ depending on plant spacing; in exceptional cases records of 17.5 $t.ha^{-1}$ exist (Crandall, 1995; Farringer, 2002). Summer bearing Raspberries produce November – February on 2nd year wood, autumn bearing Raspberries produce in May on 1st year wood and again in spring together with summer Raspberries (unless pruned back in winter) (Farringer, 2002). 50% of fruit is market fresh (generally exported) and 50% sold for processing (Ames *et al.,* 2000). Raspberry fruit is highly perishable, therefore needs pre-chilling and must reach markets within 48 hours. Market/airport proximity is an important marketing consideration (Crandall, 1995; Farringer, 2002).
Management unit.
Size, ownership. Privately owned viable units are greater and equal to 4 ha. Units' less than 4 ha may require additional income (Prinsloo, 2002).
Capital intensity and Economic Considerations.
Total initial establishment costs medium to high intensity. In 2003 the total establishment cost was approximately R70.00 – R90.00 per plant. In 2002 - 2003 export fruit price was approximately R30.00 – R60.00 kg^{-1} and estimated price of process fruit R9.00 kg^{-1}. When interest rates are less than and equal to 24%, a positive cash flow realized in year 4. Annual running cost approx 10% of establishment cost (Prinsloo, 2002).
Cultivation practices and Inputs.
Labour. 10 - 20 people are required per ha during picking season, 2 people per ha for maintenance during off season. Labour paid per kg. Pruning may require specialized

staff (Farringer, 2002; Prinsloo, 2002).

Power/energy.

Site establishment done through diesel driven tractors and earth moving equipment. It can be sub-contracted. Transport needed on the farm and to market and airport. Also may need mowers for cover crops and sod. Cool rooms' pre-chillers and pack houses generally use electricity. Raspberry plantings are permanent and do not require annual tillage (Farringer, 2002; Prinsloo, 2002).

Site preparation.

Ames *et al.* (2000) suggest good soil drainage by ripping, also by applying ridging in low lying areas with high water tables. Green manures or cover crops are planted in the season prior to planting. Soil pH adjusted as needed. If P levels less than 60 parts per million, Crandall (1995) recommends P applications as needed, also where possible, 20 – 30 $t.ha^{-1}$ of compost applied, further compost applications strictly according to seasonal soil tests. Soil tests essential (Ames,et al., 2000). Farringer (2002) highly recommends the use of black hail/shade netting, and in high summer rainfall areas, low cost plastic coverings may be considered Wind breaks are recommended (Prinsloo, 2002). Irrigation can be installed during site preparation. Raspberries are supported by trellising systems. Trellises designs are dependant on variety selection, cost and personal preference/management (Ames, *et al.,* 2000; Crandall, 1995, Farringer, 2002; Prinsloo, 2002).

Site Selection.

Ames *et al.,* (2000); Crandall (1995) and Farringer (2002) advise that: a) Soils must be well drained sandy loam, even loose rocks and shale soils are acceptable, b) optimum soil pH 6 – 7 (5.3 KCl), d) O.M. soil content greater and equal to 3%, e) clay contents greater than 40% are not recommended, f) optimum clay content is 15 – 20%, g) Soils must not have high salts especially Cl and Na levels. Crandall (1995) states that bottomlands and wet areas should be avoided as Raspberries "hate wet feet". Ames *et al.* (2000) advise against using sites previously planted to fruits like peaches, grapes apples, brambles etc, as well as Solonaceous crops like tomatoes, potatoes, peppers etc. Where such occurrences exist it is suggested that the site be left fallow for 4 – 5 years. This reduces the risk of residual pests, diseases, chemicals and unfavourable soil pH. Ames *et al,* (2000) and Farringer (2002) promote the removal of all wild brambles within 150 – 200 m of Raspberry sites, and that free air movement is ensured to prevent cold damage and fungal infestations. Raspberries need 250 – 1600 Chill Units depending on variety for best production and to break dormancy (Ames, 2000, Reiger, 2002).

Variety selection.

Variety selection depends on last frost, Chill Unit requirement and marketing strategy, that being summer or autumn bearing (Ames, 2000; Farringer, 2002).

Planting

Spacing varies with 1) variety, 2) whether under shade net or open planting (Ames, 2000). Generally plantings vary from 1,157 – 11,000 plants per ha (Ames, 2000 and Sandpoint, 2002). Farringer (2002) advises to irrigate after planting and to plant during June - August and no later than September in colder areas. Also to complete all planting in one day, as roots must not dry out.

Pruning

After fruiting, second year wood can be removed during winter. Just before spring budding, the top 150 – 200 mm of the floricanes can be removed. Autumn fruiting varieties can be "mowed" back completely if needed in winter (Ames, 2000; Prinsloo, 2002).

Plant Nutrition.

Plant nutrition needs determined through soil tests, sap analysis and leaf tests. Nutrients applied through fertigation, direct application to soil or foliar feed. Ames (2000) and Crandall (1995) advise against a) excessive applications of Phosphate, associated with zinc deficiencies, b) that Raspberries are also sensitive to fertilizers with high levels of chlorine salts especially potassium chloride and c) Raspberries are known to demonstrate Mg and Bo deficiencies.

Weed control. 50 – 75 mm deep mulch helps reduce weeds, (sawdust, pine bark and other mulching materials). Sod and cover crops are also used. Recommended chemicals used for weeding; also hand weeding (Ames *et al.,* 2000). **Pest/disease control.** Pests and diseases controlled as needed; common problems are root rot and post harvest fruit *Botrytis sp*. Sunburn can be prevented through site selection or shade nets (Ames, 200; Crandall, 1995, Penn State, 1997) **Pollinators.** Raspberries need pollinators, bee hives must be introduced during flowering (Prinsloo, 2002).
Cropping characteristics.
Raspberries are a permanent monoculture, grown with hail netting. Raspberries are intensive (viable unit greater and equal to 4 ha) and have a productive life span of approx 10 years. (Ames, 2000; Crandall, 1995; Farringer, 2002)
Water.
Too much water will drown plants and cause root rot (Ames, 2000). High quality water needed similar to Blueberries. Water requirements are approximately 600 – 900 mm depending on how dry and hot the climate is (Crandall, 1995). Effective rooting depth approximately 1,200 mm (Crandall, 1995, Farringer, 2002). Irrigation applied via drippers, micro sprayers. Sprayers can help reduce frost damage. Use 3 – 5 litres per hour drippers spaced approximately 300 mm apart (Prinsloo, 2002).

2.9 Summary of land qualities and characteristics.

Tables 2.5 and 2.6 contain a summary of critical land qualities and land characteristics respectively. These tables aim to provide a valuable reference to potential and current berry producers.

Table 2.5. Summary of land qualities with a substantial effect on berry production.

Land Qualities.	**Land Characteristics and limitations.**
Climate	Chill Units, unwanted rain/mist, hail, wind, late frost.
Soil	Drainage, depth, clay content, pH, organic matter, Cl, Na, salts, water table, previous/current land use.
Water	Availability, quantity, pH, salinity, sodium, bicarbonate, chlorine, boron, water table.
Topography	Aspect, slope, accessibility.
Management	Market proximity, available land, labour, energy sources, post harvest handling, and ease of cultivation.
Socio-economic	Wealth and job creation.

Table 2.6. Explanation of land characteristics and limitations as well as some considerations in respect of finding solutions

Land characteristics and limitations.	**Explanation and clarification.**	**Considerations, corrective interventions and reference.**
Chill Units	Minimum Chill Units required to break dormancy for best production; different berry types have different Chill Unit requirements.	Variety selection.
Unwanted rain and mist	Excessive rain can limit access to fields by labour and equipment. Too much water in the soil profile can cause fruit burst and root rot. Rain and mist during harvest can leave excess moisture on fruit causing post harvest fungus (see figure 2.2).	Appropriate farm access and runoff management, farm lay out and maintenance. Soil drainage class. Appropriate pack house machinery and process. Build waterproof structure for example plastic tunnel over plants to protect them from rain/moisture.
Hail	Hail damage to plants, fruit and flowers.	Hail netting.

Wind	Wind can damage plants; fruit and flowers also inhibit bee (pollinator) activity.	Hail netting and windbreaks can reduce impact of wind.
Late frost	Late frost can threaten early flowers (see figure 2.3).	Overhead sprinklers, hail netting provides some protection (see figure 2.4).
Soil drainage	All berries need drainage associated with silts or sandy loams, too little water causes drought stress and too little drainage causes excess moisture stress/damage.	Soil drainage class, apply OM, appropriate land preparation, appropriate artificial drainage for example ridging.
Soil organic matter content	Most soils in South Africa do not have OM contents higher that 3 – 5%. Blueberries need to be planted with peat, compost or some appropriate OM. It is advisable to add OM when planting Cherries and Raspberries.	Applications of appropriate OM.
Clay content	Excess clay content affects root hair/*Mycorrhizal sp* development and drainage.	OM applications, mulching.
Soil depth	Each berry has an effective rooting depth; soil depth also affects erosion risk and moisture holding capacity.	Ridging on shallow or wet soils. Soil criteria.
Previous/current land use	Assess old lands in order to determine the presence of unfavourable chemicals and pests. It is best to use sites fallow for 4 or more years.	Soil testing.
Soil pH	Each berry has a unique range of preferred soil pH values.	Soil criteria.
Soil Cl, Na and salts.	Berries require low levels of soil Cl, Na and salts. Soils with an EC greater than 300 – 400 mSiemens.m^{-1}, should be avoided.	Soil criteria.
Water salinity, sodium, bicarbonate, chlorine and boron.	Berries have unique tolerances to water quality and water affects on soil.	Water criteria.
Water table	High water tables can cause water stress. Ridge where water tables reach within the rooting depth.	Soil criteria.

Water availability.	It is assumed that water is available in the context of irrigated land us. Due consideration must be given to water legislation. Due consideration must be given to the required water quantity per ha per berry.	Match water demand to water availability, consult irrigation design professionals like supply companies or engineers.
Aspect	North or south slopes have different sunshine hours, light intensity and temperature regimes.	Site selection.
Slope.	Slope affects 1) erosion hazard, 2) irrigation performance and installation, 3) mechanization and 4) labour productivity.	Land preparation and management, also site selection.
Accessibility	1) Remote areas, 2) steep lands, 3) no access roads, 4) water logged, 5) too far from water, 6) too far from electricity or 7) is unpractical. This assessment is a qualitative or subjective value and may change over time.	N2 rating. Not presently suitable to produce berries.
Available land.	The size of the land available may not be sufficient to support a viable unit. Where land size is limiting, producers may consider co-operative production or additional sources of revenue.	Management.
Labour.	Labour may be too costly or not available.	Mechanization, management.
Energy sources.	Also relates to accessibility. The energy source must be cost effective and available. Energy sources are mainly 1) electricity and 2) diesel. Plant energy sources are 1) light and 2) ambient temperature.	Management, return on investment.
Post harvest handling and market proximity.	Relates to infrastructure for example fruit chilling, packing and transport costs. If post harvest marketing is limited, producers may consider co-operative farming options, niche marketing or value adding for example “U pick” or jam.	Management, marketing, return on investment.
Ease of cultivation.	Relates to all aspects of accessibility and topography measured in terms of rockiness or rock outcrops. Fields that become waterlogged or have heavy vertic clays are also problematic in this context.	Cost, management.
Socio-economic.	Community impact w.r.t. wealth and job creation.	Management.

Figure 2.2. Typical mists in Haenertsburg.

Figure 2.3. Heavy frost in Haenertsburg, a possible threat to berries that flower early.

Figure 2.4. Sprayers used for frost protection. (Photo: Scott NeSmith).

2.10 Conclusion.

This Chapter, through relevant studies, has compiled much of the relevant information pertaining to the key site selection criteria for berry production. The key land qualities for berry production are climate, water, topography and management. The detailed characteristic values given in this Chapter will be used to develop the land classification system and matching process in the Chapters to follow.

Chapter 3

LAND CLASSIFICATION SYSTEM

3.1 Introduction.

In order to classify land, one needs a suitable classification system. This Chapter presents such a system using a set of tables. The data in the tables originates from the study presented in Chapter 2 and the dissemination of the data are explained in the method below. This Chapter serves to: 1) catalogue the general land classification system adapted from the FA0 (1993) and Baker (2001). 2) Define the characteristic values associated with soil drainage (Anonymous, 2001 and Baker, 1990) and, 3) present the dissemination of the characteristic values in land rating per berry.

3.2 General land classification system.

The FAO land classification system (FAO, 1993) describes a set of classes that can be used for the description of land suitability for a specific purpose. These land suitability classes can be ascribed to specific land characteristics and can be categorized from highly suitable to unsuitable. Table 3.1 presents these classes as suggested by the FAO and adapted to suit this study.

Table 3.1 Broad suitability classes attributed to plant requirements (Based on FAO, 1993, and Anonymous, 2001).

Class.	Suitability.	Definition.
S1	Highly suitable	This land has few or no limitations or hazards, with good management this land is suitable for berry production with no or minimal adjustments or inputs. Low risk.
S2	Moderately suitable.	Land that is suitable but has some limitations or hazards that can reduce productivity or may require more inputs or require some conservation practices to ensure sustainability. Some risk.

S3	Marginally suitable.	Land with moderate limitations or risk of loss or damage. This land can still be suitable but will require special management or practices or high inputs to ensure productivity. Risky.
N1	Currently not suitable	Land with limitations or hazards that need specialized and continuous management, limitations that need intervention or inputs to remove the limitations. Moderate to high risk.
N2	Not Suitable	Land that has permanent limitations that renders it unsuitable to grow berries.

3.3 Internal drainage classification.

Chapter 2 revealed that soil drainage is a key land quality; however, the study speaks only of "well drained" soils as a berry requirement. Anonymous (2001) and Baker *et al.* (1990) describe in more detail a soil-drainage classification system presented in table 3.2.

Table 3.2. Internal drainage classes and definitions of the total soil profile (After Anonymous, 2001, and Baker, 1990)

Class.	Description.
W0	Well drained. No grey colour with mottling within 1.5 m of the surface. Grey colour without mottling is acceptable. Can be sandy loam.
W1	Moderately drained. There is no evidence of wetness within the top 0.5 m. Occasionally wet. Grey colours and mottling begin between 0.5 m and 1.5 m of soil surface. Or, sandy soils less than and equal to 500 – 600 mm deep.
W2	Poorly drained. Rapidly drained. Temporarily wet during wet season. No mottling in the top 0.2 m but grey colours and mottling occur between 0.2 m and 0.5 m from the surface. Included are: G horizons (highly gleyed and often clayey) at depths greater than 0.5 m. Soils with and E horizon overlying a B

	horizon with strong structure. Soils with E horizons over G horizons where the depth to the G is more then 0.5 m.
W3	Restricted drainage. Extremely rapid drainage. Periodically wet. Mottling occurs in the top 0.2 m, and includes soils with heavily gleyed or G horizons at a depth of less than 0.5 m. Found in bottomlands. Or, sandy soils or E horizons less than 1500 mm and greater than 500 mm deep. Over-drained to drought prone.
W4	Impermeable. Excessively drained. Semi-permanently to permanently wet at, or above the soil surface throughout the wet season. Usually organic topsoil or an un-drained vlei. Found in bottomlands. Or, sandy soils or E horizons deeper than 1500 mm.

3.4 Land quality and characteristic values associated with berry production.

The land characteristic values for the different berries presented in this section were derived from the study given in Chapter 2. The dissemination of the characteristic values into the suitability classes was achieved by logical elimination and by using an approximate linear progression. For example, the best and worst soil clay content values of less than 15% and greater than 50%, yields the ratings highly suitable (S1), and not suitable (N2) respectively. Further, interviews and a literature search revealed that soil with a clay content of approximately 30% may be improved by adding organic matter. Thus, a land value of N1**o** – "currently not suitable in need of OM" is appropriate. The remaining 15% to 30% clay content range was divided equally and assigned to the S2 and S3 ratings linearly.

Some land classes do not have practical characteristic values, for example due to shallow roots (less than 600 mm), Blueberries require relatively shallow soil. However, in keeping with good and sustainable land use, shallow soils (less than 455 mm deep) should not be cultivated, leaving a range of 150 mm soil depth. It therefore makes little sense to consider soils shallower than 450 mm and deeper than 600 mm, therefore the soil is either suitable (S1) or not suitable (N2). A similar approach was applied in assigning values to soil pH and water salinity etc.

Tables 3.3, 3.4 and 3.5 present the data created for Blueberries, Cherries and Raspberries respectively.

3.4.1 Blueberries.

Table 3.3. Key land requirements for Blueberries and the class determining land characteristic values.

Land Quality.	**Land Characteristic.**	**Characteristic values associated with land class.**				
		S1	**S2**	**S3**	**N1**	**N2**
Climate Variety	**Chill Units** Highbush Rabbiteye Southern Highbush	800 – 1100 >550 >300		600 – 800 350 – 550 150 – 300		<600 <350 <150
Soil	**Drainage** Use table 8.	W0	W1		W2	W3 – W4
	Clay content	<15%	15 – 20%	20 – 30% **S 3o**	>30% **N 1o**	>50%
	Depth	≥600mm	450 – 600mm			<450mm
	pH (H_2O)	4.2 – 5.2	3.0 – 4.2 or 5.2 – 6.0 **S 2s** and **S 2ca**			0.0 – 3.0 or >6.0 – 6.5
Water	**Salinity** EC; mS.m^{-1}* mg.l^{-1}**	≤25 ≤160	>25 ≤75 >160 <800		**N 1w** >75 >800	
	SAR* **	≤10	>10 <18		>18	
	Bicarbonate (mg.l^{-1})	≤92	>92 <123		>123	
	Chlorides (mg.l^{-1})	≤142	>142 <284		>284	

	Boron (mg.l^{-1})	≤0.75	>0.75 <0.96		>0.96	
	pH	≥4 <6-7	7 – 8		>8	
Topography	**Slope**	0 – 3%	3 – 6%	6 – 10%	10 – 25%	>25 – 30%
Management	**Ease of cultivation** (% rockiness)†	No rockiness or rock outcrops	1 – 5%	5 – 10%		>10%
	Infrastructure and transport to market.	Possible			Co-operative or additional revenue.	Not possible†† .

S2s – indicates the addition of Sulphur to reduce soil pH.

S2ca – indicates the addition of Ca where the soil pH is too low.

S3o and N1o – indicates the need to add OM to soil.

N1w – some form of water treatment is indicated.

***** - Electrical conductivity (EC) measured in milli Siemens per meter (mS.m^{-1}).

****** - Concentration measured in milligrams per litre (mg.l^{-1}); salinity represented by the sum of Na^+, Ca^{2+}, Mg^{2+}, K^+, CO_3^{2-}, HCO_3^-, SO_4^{2-} and Cl^-.

******* - Sodium adsorption ratio (SAR). SAR = $Na^+ / \sqrt{((Ca^{2+}+Mg^{2+})/2)}$.

Where:

Na^+ = conc. me.l^{-1} Na^+ = mg.l^{-1}Na^+ / 23.

Ca^{2+} = conc. me.l^{-1}Ca^{2+} = mg.l^{-1}Ca^{2+} / 20.

Mg^{2+} = conc. me.l^{-1} Mg^{2+} = mg.l^{-1}Mg^{2+} / 12.

† - berries can be grown in soils high in loose shale as they have good drainage; apply drainage class on table 3.2.

†† - niche marketing or U pick.

> = greater than.

< = less than.

≥ = greater and equal to.

≤ = less than and equal to.

~ = equivalent or approximately.

3.4.2 Cherries.

Table 3.4. Key land requirements for Cherries and the class determining characteristic values.

Land Quality.	**Land Characteristic.**	**Characteristic values associated with land class.**				
		S1	**S2**	**S3**	**N1**	**N2**
Climate	**Chill Units**	1000 - 1600			>500 <1000 **N1cu**	<500
Soil	**Drainage** Use table 8.	W0	W1		W2	W3 – W4
	Clay content	<15%	≤15 – 20%	20 – 30% **S3o**	>30% **N1o**	>50%
	Depth	≥1000mm		>600 <1000mm		<600mm
	pH (H_2O)	6.0 – 6.5	>6.5 <7.5		>7.5 or <6.0	
Water	**Salinity** EC; $mS.m^{-1}$* $mg.l^{-1}$**	≤25 ≤160	>25 ≤75 >160 <800		**N1w** >75 >800	
	SAR***	≤10	>10 <18		>18	
	Bicarbonate ($mg.l^{-1}$)	≤92	>92 <123		>123	
	Chlorides ($mg.l^{-1}$)	≤142	>142 <284		>284	
	Boron ($mg.l^{-1}$)	≤0.75	>0.75 <0.96		>0.96	
	pH	≥4 <6-7	7 – 8		>8	
Topography	**Slope**	0 – 3%	3 – 6%	6 – 10%	10 – 25%	>25 – 30%
Management	**Ease of cultivation** (% rockiness)†	No rockiness or rock outcrops	1 – 5%	5 – 10%		>10%

	Infrastructure and transport to market.	Possible			Co-operative or additional revenue.	Not possible††.

N1cu – indicates Chill Unit limitations, select low Chill Unit Cherry varieties or correct aspect or shading/chilling techniques.

S3o and N1o – indicates the need to add OM to soil.

N1w – some form of water treatment is indicated.

* **-** Electrical conductivity (EC) measured in milli Siemens per meter ($mS.m^{-1}$).

** **-** Concentration measured in milligrams per litre ($mg.l^{-1}$); salinity represented by the sum of Na^+, Ca^{2+}, Mg^{2+}, K^+, CO_3^{2-}, HCO_3^-, SO_4^{2-} and Cl^-.

*** **-** Sodium adsorption ratio (SAR). SAR = $Na^+ / \sqrt{((Ca^{2+}+Mg^{2+}) / 2)}$.

Where:

Na^+ = conc. $me.l^{-1}$ Na^+ = $mg.l^{-1}Na^+$ / 23.

Ca^{2+} = conc. $me.l^{-1}Ca^{2+}$ = $mg.l^{-1}Ca^{2+}$ / 20.

Mg^{2+} = conc. $me.l^{-1}$ Mg^{2+} = $mg.l^{-1}Mg^{2+}$ / 12.

† - Berries can be grown in soils high in loose shale as they have good drainage; apply drainage class on table 3.2.

†† - Niche marketing or value adding.

$>$ = greater than.

$<$ = less than.

$\geq$ = greater and equal to.

$\leq$ = less than and equal to.

~ = equivalent or approximately.

3.4.3 Raspberries.

Table 3.5. Key land requirements for Raspberries and the class determining characteristic values.

Land Quality.	**Land Characteristic.**	**Characteristic values associated with land clas.s**				
		S1	**S2**	**S3**	**N1**	**N2**
Climate	**Chill Units**	>250 - ~1600 **S1v**				<250
Soil	**Drainage** Use table 8.	W0	W1		W2	W3 – W4
	Clay content	<15%	≤15 – 20%	20 – 30% **S3o**	>30% **N1o**	>50%
	Depth	600 – 1200mm		450 – 600mm		<450mm
	pH (H_2O)	5.5 – 6.5			<5.5 or >6.5 – 8.0 **N1ca; N1s**	<4.0 >8.0
Water	**Salinity** EC; $mS.m^{-1}$* $mg.l^{-1}$ **	≤25 ≤160	>25 ≤75 >160 <800		**N1w** >75 >800	
	SAR* **	≤10	>10 <18		>18	
	Bicarbonate ($mg.l^{-1}$)	≤92	>92 <123		>123	
	Chlorides ($mg.l^{-1}$)	≤142	>142 <284		>284	
	Boron ($mg.l^{-1}$)	≤0.75	>0.75 <0.96		>0.96	
	pH	≥4 <6-7	7 – 8		>8	
Topography	**Slope**	0 – 3%	3 – 6%	6 – 10%	10 – 25%	>25 – 30%
Management	**Ease of cultivation** (% rockiness)†	No rockiness or rock outcrops	1 – 5%	5 – 10%		>10%

	Infrastructure and transport to market.	Possible			Co-operative or additional revenue.	Not possible††.

N1ca – indicates the need to add Ca to increase soil pH.

N1s – indicates the need to add Sulphur to reduce soil pH.

S1v – Chill Unit requirement is variety dependent.

S3o and N1o – indicates the need to add OM to soil.

N1w – some form of water treatment is indicated.

* - Electrical conductivity (EC) measured in milli Siemens per meter ($mS.m^{-1}$).

** - Concentration measured in milligrams per litre ($mg.l^{-1}$); salinity represented by the sum of Na^+, Ca^{2+}, Mg^{2+}, K^+, CO_3^{2-}, HCO_3^-, SO_4^{2-} and Cl^-.

*** - Sodium adsorption ratio (SAR). $SAR = Na^+ / \sqrt{((Ca^{2+}+Mg^{2+}) / 2)}$.

Where:

Na^+ = conc. $me.l^{-1}$ Na^+ = $mg.l^{-1} Na^+ / 23$.

Ca^{2+} = conc. $me.l^{-1} Ca^{2+}$ = $mg.l^{-1} Ca^{2+} / 20$.

Mg^{2+} = conc. $me.l^{-1}$ Mg^{2+} = $mg.l^{-1} Mg^{2+} / 12$.

† - berries can be grown in soils high in loose shale as they have good drainage; apply drainage class on table 3.2.

†† - niche marketing or value adding.

> = greater than.

< = less than.

≥ = greater and equal to.

≤ = less than and equal to.

~ = equivalent or approximately.

Chapter 4

RESOURSE ASSESSMENT

4.1 Introduction.

By examining the berries in some detail, Chapter 2 identified the key production factors or the qualities and characteristics required by each berry. Chapter 3 assigned values to each land characteristic with a corresponding land rating. The target land can thus be classified or rated based on how close or far it is from the given best characteristic value. In order to test and demonstrate the land classification system, land data was necessary. This resource assessment Chapter provides the relevant characteristic data taken from the land itself.

Whilst conducting the fieldwork, it became obvious that certain areas were completely inappropriate for berry cultivation, for example cliff faces or dams. Because these areas directly affect site selection, a separate section (path three) was dedicated to the land limits experienced in the study areas. Indeed land limits are useful site selection criteria, in that they eliminate areas from the site selection process. The elimination process yields two types of land 1) land unsuitable for use and 2) land with potential for use. These two types of land can be mapped (figure 4.23 and figure 4.25) and help potential land users focus the site selection criteria on land with potential, rather than waste resources on unsuitable land.

The information sources and methods used to obtain the land data are explained per study area and per berry. In the interests of ordered and logical presentation, this Chapter is sub divided into three main sections, named path one, path two and path three. Unlike the other Chapters in this document, this Chapter should be seen as a reference section, where relevant land data are recorded rather than text per se. Some of the data given in this Chapter was taken by real measurement; however, because the data are insufficient to be representative of the entire study area, it is used purely for demonstration.

4.2 Aim.

This Chapter (the resource assessment), will present the characteristic values and land limits as they were measured on site.

4.3 Method.

Under the context of this study, the assessment follows three paths, namely.

1. **Path one** collates the relevant information and data that already exists. Entities like the I.S.C.W., landowners and existing tests etc have the necessary information, thereby removing the need for duplication.

2. **Path two** uses existing data. However, because the extent or content of the data are not sufficient, or non-existent, it was necessary to collect or research the outstanding data and information, for example Chill Unit data.

3. **Path three** examines the land limits that render the land unsuitable for berry production; further explanation is given under the land limits section.

For clarity and brevity, where additional research or testing took place, the phrase 'field-testing' is used.

4.4 Note on detail.

This study was conducted predominantly at district level, meaning that land units are represented in square kilometres rather than hectares. At this scale, farm level detail is not relevant, however, where farm level detail is used, it is for clarity and demonstration only, for example slope, rockiness and aspect. Similarly, resource constraints and the scales used, prevented the formulation of a detailed soil map. The resultant soil data are therefore generalised on figures 4.8, and 4.10, and semi-detailed on figure 4.11 of this Chapter.

4.5 Path One - Existing Information.

The data and information presented below is referenced and presented per study area.

4.5.1 Geology.

Haenertsburg.

Based on information supplied by the CG (2002), the rock in Haenertsburg is intrusive and metamorphic by nature. The two major types of rock in the area are:

1. Zgo – Goudplaas Gneiss, predominating in the north west of the area including the farm Koppie Aleen.

A small area of this rock approximately 4 km in diameter is also found directly south of Ebenezer dam with Allandale at its western margin.

2. In the southern parts of the area including Haenertsburg and Ebenezer Dam area: Rbg – unnamed biotitic granite, or leucocratic biotitic granite

Pietersburg.

The predominant rock formation in the Turffontein area is the Houtrivier Gneiss.

1. Biotitic granite-gneiss, migmatite, pegmatite, lava and pyroclasts. CG (2002)

4.5.2 Rainfall.

The rainfall data on table 4.1 below was adapted from data supplied by the I.S.C.W. (2002).

Haenertsburg.

Table 4.1. Summary of rainfall data in Haenertsburg area. I.S.C.W. (2002).

Station.	Altitude (m).	Years.	Mean Annual rainfall (mm).	Mean Rain Days (mm).
Haenertsburg - police	1402	97.83	862.4	62.3
Glenshiel	1524	61.50	1057.9	89.7
Allendale	1600	12.25	1111.5	87.2
Weltevreden	1494	54.17	1143.1	89.1
Magoebaskloof	1433	11.83	1253.2	106.6
Woodbush	1528	55.75	1359.4	92.8
Stampblokfontein	1350	14.5	1473.4	93.8
Dehoek-bos	1219	73.17	1660.7	92.1
Broederstroom-bos	1555	86.58	1948.2	95.9

Pietersburg.

The rainfall data on table 4.2 was measured on the farm Turffonten 14 KS and kindly supplied by Neetlingh (2002).

Table 4.2. Total and mean annual rainfall figures for the last 8 years Neetlingh (2002).

Year.	Total Rainfall (mm).
1994 - 1995	451
1995 - 1996	714.5
1996 - 1997	613.5
1997 - 1998	500
1998 - 1999	475
1999 - 2000	961.5
2000 - 2001	475.5
2001 - 2002	755.5
Mean	**618.3**

4.5.3 Frost.

The frost data in table 4.3 was supplied by I.S.C.W. (2002), and depicts average frost patterns in the Haenertsburg area. No data was available for the Pietersburg study area. Table 4.3 shows a summary of average frost figures for approximately 10 years. However, by observation, Haenertsburg had first frost on 12th May 2005 and 8th May 2006, while the last frost for winter 2002 occurred on the 8th November.

Table 4.3. Seasonal frost data at Magoebaskloof for 9.58 years I.S.C.W. (2002).

First Frost.	Last Frost.	Average First Frost.	Average Last Frost.	Average Frost Days per Season.
6/June	29/September	12/June	28/August	11

4.5.4 Hail.

No hail data was available for Haenertsburg or Pietersburg. However, through observation and verbal contact with local producers, the following information emerged. 1) Insurance companies are hesitant to issue hail insurance in the Pietersburg area. 2) Farmers currently use hail netting in both study areas for crops like peaches, grapes and berries. 3) Both areas experience hailstorms during November – February.

4.5.5 Water.

Haenertsburg.

Table 4.4 shows the results of a water analysis prepared by the I.S.C.W. (2003). One water sample was taken at random from the Broederstroom River in Haenertsburg.

Table 4.4. Results of a water test taken in Haenertsburg. (I.S.C.W. 2003).

ANIONS.	**mg l^{-1}.**	**mmol l^{-1}.**
Fluoride (1.5)	0.00	0.00
Nitrite (4.0)	0.00	0.00
Nitrate (44.0)	0.91	0.01
Chloride (250)	3.86	0.11
Sulphate (500)	0.44	0.01
Phosphate	0.00	0.00
Carbonate (20.0)	0.00	0.00
Bicarbonate	33.55	0.55
Subtotal	**38.76**	**0.68**
CATIONS	**mg l^{-1}**	**mmol l^{-1}**
Sodium (400)	3.86	0.17
Potassium (400)	1.16	0.03
Calcium (200)	5.66	0.28
Magnesium (100)	2.33	0.19
Boron (1.5)	0.02	0.01
Subtotal	**13.03**	**0.68**
Total	**51.00**	
Less volatile substances for example $HCO_{3/2}$	**16.78**	
Total dissolved Solids	34.23	
Sodium Carbonate	0.00	0.00
Sodium Bicarbonate	5.87	0.07
Alkalinity	27.50	0.55
Temp. Hardness	24.01	0.48

Perm. Hardness	0.00	0.00
pH	**6.2**	
SAR	**0.34**	
EC	**6.00 mS m^{-1} @ 25ºC**	

() Figures in parendissertation are recommended maximum values for human use in mg/l.

Pietersburg.

Table 4.5 below shows the results of water samples taken from Turffontein, and is currently used by the landowner to irrigate peaches. (Neetlingh, 2002). Polokwane Municipality Laboratory performed the water analysis, (October, 2002).

Table 4.5. Results of water tests taken at Turffontein. (Neetlingh, 2002).

Sample.	Units.	Results.
Ammonia N	mg l^{-1}	0.1
Chloride	mg l^{-1}	15.9
Conductivity	mS m^{-1}	54
p-alkalinity	mg l^{-1} $CaCO_3$	0
m-alkalinity	mg $l^{-1}CaCO_3$	284.7
Nitrate	mg l^{-1} as N_2	0
Fluoride	mg l^{-1}	0.12
Total hardness	mg $l^{-1}CaCO_3$	306
Calcium Hardness	mg $l^{-1}CaCO_3$	142
Magnesium Hardness	mg $l^{-1}CaCO_3$	164
pH		6.80
Calcium	mg l^{-1}	57
Magnesium	mg l^{-1}	40

4.6 Path two - Existing data and information enhanced by field-testing.

4.6.1 Soil clay content, soil drainage and soil pH.

Chapter 2 revealed that the key soil qualities and limitations necessary to produce berries are 1) pH, 2) drainage and 3) clay content. The methods used to ascertain these parameters, and the resultant values are tabulated below.

4.6.1.1 Materials and Methods.

For context, the maps shown on figures 39 and 40 in appendix K depict the sites where samples were collected. The sample sites are represented on the maps as.

GV = Georges Valley.

H = Hove.

KA = Koppie Aleen.

LF = Leliefonten.

PF = Palmietfontein.

SL = Stanford lake.

TF = Turffontein.

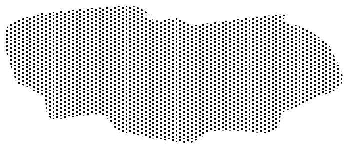
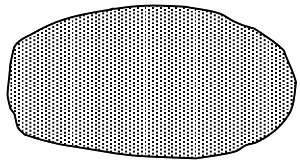
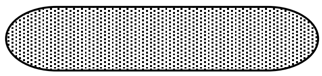
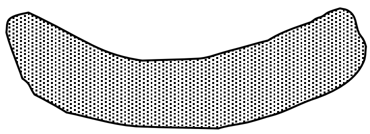
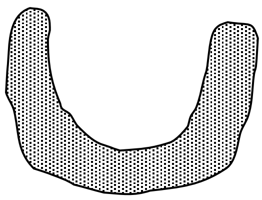
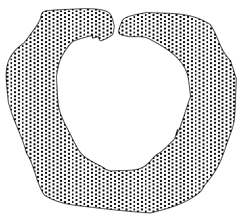
Some samples were analysed by the cited laboratories, the remaining samples were processed using field test methods (see table 4.8 for details).

4.6.1.2 Field Test Methods.

Percentage soil clay content.

"Remove all stones and roots from a handful of soil. Add a small amount of water to the sample if necessary, knead the sample to consistency. Roll the sample to form a spindle, either in ones hands or on a hard flat surface. The spindle or 'sausage' is rolled to a diameter of approximately 10 mm and placed on an even surface. Bend the spindle into a circle. The relationship between soil texture and the ability of the spindle to bend is illustrated in table 4.6." (Anonymous, 2001).

Table 4.6. Field determination of clay percentage. Anonymous (2001).

Clay Percentage.	Shape of Spindle.	Description.
0 - 5		Cannot form a shape.
5 -10		Can form a shape, but a spindle will not form.
10 - 15		Will form a spindle, but will not bend without cracking.
15 - 35		Spindle will bend before cracking.
35 - 55		Will bend into a U before cracking.
>55		Will form a circle with no cracking.

Soil Drainage.

Soil drainage refers to the overall drainage of the soil profile, while **soil permeability** refers to the internal drainage of an individual horizon within a profile. It is worth noting, that a profile may be rendered impermeable or poorly drained if, for example, a well drained topsoil overlays an impermeable horizon like a gleyed horizon (G horizon), (Macvicar and De Villiers, 1991). It is assumed that profiles with drainage limitations such as those described in table 3.2 of Chapter 3 are eliminated during preliminary scoping, for example 1) river sand, 2) profiles with vertic or prismacutanic horizons, (Macvicar and De Villiers, 1991). Once an horizon with potential is identified, the permeability rate of the horizon is estimated using the following method:

"Place three drops of water on a clod that best represents the profile, the seconds are counted for which the water takes to disappear (for the shininess, or glisten, to disappear). Estimate permeability ratings based on table 4.7 below." (Anonymous, 2001).

Table 4.7. Permeability rates and ratings. (Anonymous, 2001).

Rate (seconds).	Description.
< 1	Extremely rapid
1 - 3	Rapid
4 - 8	Good
9 - 20	Slightly restricted
21 - 40	Restricted
41 - 60	Severely restricted
greater than 60	Impermeable

Soil pH, water test method.

Mix 50 g of soil with 100 ml of distilled water, stir vigorously for 5 seconds. After 10 minutes stir sample again for 5 seconds. After 50 minutes measure the supernatant with an electrode. The electrode used was a Eutech Cybernetics WP2 pH Scan, calibrated to pH 7.0. The water test is presented as H_2O with the pH value in the text. Some laboratories use the KCl method to test soil pH; the resultant soil pH is presented with KCl in the text. As a rule of thumb, add 1 to the KCl soil pH value in order to equate it with the H_2O test.

Table 4.8. Details of testing method per sample site.

Sample site.	**Details of analysis.**		
	Clay percentage.	**Permeability.**	**pH.**
Palmietfontein (PF)*	Fertility Advisory Service Cedara (FAS)	Field testing	Fertility Advisory Service Cedara (FAS)
Koppiealeen (KA)	Field testing	Field testing	Field testing
Leliefontain (LF)	Field testing	Field testing	Field testing
Stanford Lake (SL)	Field testing	Field testing	Field testing
Georges Valley (GV)	Field testing	Field testing	Field testing
Turffontein (TF)**	Field testing	Field testing	Central Agricultural Laboratories (CAL)

* 2 samples from the Palmietfontein site were analyzed by FAS (2001).

** 11 soil samples taken from upper and mid slopes by Neetlingh (2001) and processed by CAL, (2001).

4.6.1.3 Other soil tests.

Based on an unrelated building project, a foundation indicator test is included in table 4.10. These data bring additional perspective to general pedogenesis in the area. TPT Lab (2004) conducted the tests, samples were collected from a depth of 2,200 mm on the farm Hove (H), (see figure K.1 in appendix K).

4.6.1.4 Results of soil pH, clay content and permeability tests.

Haenertsburg study area.

Table 4.9 below shows the results of random soil tests conducted in the Haenertsburg area.

Table 4.9. Results of soil pH, clay content and permeability tests at specified sites in the Haenertsburg study area.

Test Site.	pH.	Clay content (%).	Permeability test (seconds).	Description of permeability.
Palmietfontein 1 (PF1)	5.84 KCl	56	2	Rapid
PF 2	6.06 KCl	59	2	Rapid
Koppiealeen (KA)	4.7 H_2O	10 – 15	2	Rapid
Leliefontein (LF)	5.8 H_2O	15 – 35	2	Rapid
Stanford Lake (SL)	6.1 H_2O	35 – 55	3	Rapid
Georges valley (GV)	5.1 H_2O	10 - 15	4	Good

Other test results from Haenertsburg.

As explained under materials and methods, table 4.10 below shows an extract from the results of a foundation indicator test, (PTP Lab, 2004).

Table 4.10. An extract from a foundation indicator test taken from 2,200 mm at Hove. (PTP Lab, 2004).

Test.	Clay (%).	Silt (%).	Sand (%).	Gravel (%)	Classification.
Astm	38.7	25.6	29.5	6.2	Sandy Clay
Jennings	38.7	30.2	28.6	2.6	Silty Clay
British Standard	31.0	35.6	27.2	6.2	Silty Clay
Heave Classification					LOW

Pietersburg study area.

Table 4.11 below shows soil clay content determined through field-testing. Table 4.12 shows the soil pH test results from CAL (2001).

Table 4.11. Soil clay percentages per terrain type on Turffontein.

Terrain.	**Clay percentage.**
Upper slope	15 – 35
Mid slope	15 – 35
Bottom lands	> 55%

Table 4.12. Soil pH test results on farm Turffontein (CAL, 2001).

Sample reference number.	**pH (KCl).**
2, 3, 4, 5, 7, 8	5.44
9	4.58
10	4.48
1, 6, 11	4.9
Mean	**4.85**

4.6.2 Soil Types.

4.6.2.1 Introduction.

In the context of this study, a soil-type-assessment was necessary to map areas with potential for berry production. Soil types have a close relationship with soil potential and are categorized as soil forms (Macvicar, 1991). In general terms, berries need deep, well drained soils, therefore a well drained Hutton, Clovelley or Inanda soil form has berry production potential (see table 4.14 for soil form descriptions). Conversely, shallow soils or soils with limiting horizons have little or no potential to support berries, therefore soil forms like Mispha or Glenrosa should be avoided. Ultimately, site selection is based on more than soil form. In this study, the soil forms together with the I.S.C.W. land type inventories were used to identify sites with berry production potential, and are shown on the site potential maps (figure 4.23 and 4.25).

Land Type Survey Staff (1989) describe land types as, "an area that can be shown at 1:250,000 scale and that displays a marked degree of uniformity with respect to terrain form, soil pattern and climate."

The I.S.C.W. land inventories have a land type code, for example Ab90. Each land type is mapped and has an associated inventory description. The land type inventory is a table showing factors that include a) climate zones, b) terrain units, c) soil depth, d) soil texture, e) area, f) soil forms etc. The soil form data relevant to this study was taken from the land type inventory and is listed in table 4.13. For clarity, the land types on figures 4.8, 4.10 and 4.11 have an associated colour code, which is reflected on table 4.13. The maps on figures 4.8, 4.10 and 4.11 are presented in two levels of detail. Namely:

1. Haenertsburg (figure 4.8), was assessed at district level, using a scale of 1:50,000, using the I.S.C.W. inventory together with field verification. The total result is summarized on table 4.13. The soil map of the Haenertsburg study area lacks individual soil form detail because the soil forms are grouped together into the I.S.C.W. land type.

2) Turffontein was mapped at a scale of 1:30,000, (figures 4.10 and 4.11) the soil map therefore has more detail than the Haenertsburg map (semi detailed). Although the I.S.C.W. land form map is included in the description of the Pietersburg area (Turffonten), it is not used to the same extent as the Haenertsburg soil map

Because the relationship between slope and terrain form is an important function of pedogenesis, a short explanation of terrain is included under this section. The terrain type sketches depicted below (figures 4.1 through 4.7 and 4.9), were scanned from the I.S.C.W. land type inventory (the author apologizes for the poor quality of the scan).

Land Type Survey Staff (1989) best describe terrain units as such:

"A terrain unit is any part of the land surface with homogeneous form and slope. Terrain can be thought of as being made up of all or some of the following kinds of terrain units: crest, scarp, mid-slope, foot-slope and valley bottom or flood plain. A terrain type (adapted after Kruger, 1973; Hammond, 1964; King, 1953) in this context denotes an area of land over which there is a marked uniformity of surface form and which, at the same time, can be shown easily on a map at a scale of 1:250 000. Land shown on a map as belonging in a terrain type may cover only a single terrain unit (for example a flood plain), it may cover a single crest-valley bottom sequence (for example an escarpment) or it may cover a large number of crest to valley bottom sequences that repeat themselves three-dimensionally (for example a large area of rolling hills). Although the terrain type has genetic implications, morphology and not genesis is the basis of its delineation and description.

In the following diagrams (Figure 4.1 and 4.2), 1 represents a crest, 2 a scarp, 3 a mid-slope, 4 a foot-slope and 5 a valley bottom. $3^{(1)}$ indicates a second phase mid-slope and $3^{(2)}$ a third phase mid-slope. Whether a terrain unit is a foot-slope or a mid-slope depends on its position (a mid-slope lies immediately below a crest or scarp) and, to an extent, upon the steepness of the slope. In contrast with a mid-slope, a scarp is steeper than 100% (45°) and usually steeper than about 70°".

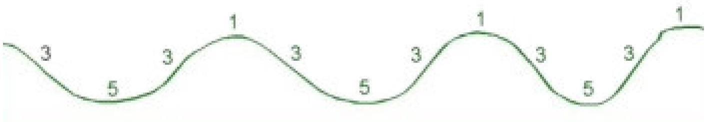


Figure 4.1. Single-phase terrain type.

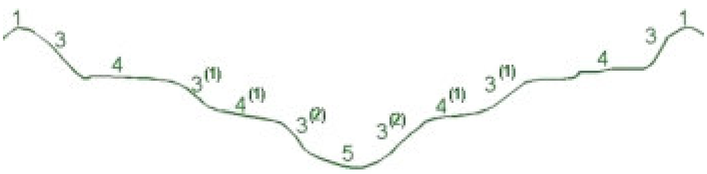


Figure 4.2. Multi-phase terrain type.

4.6.2.2 Soil tables and maps.

Haenertsburg Area.

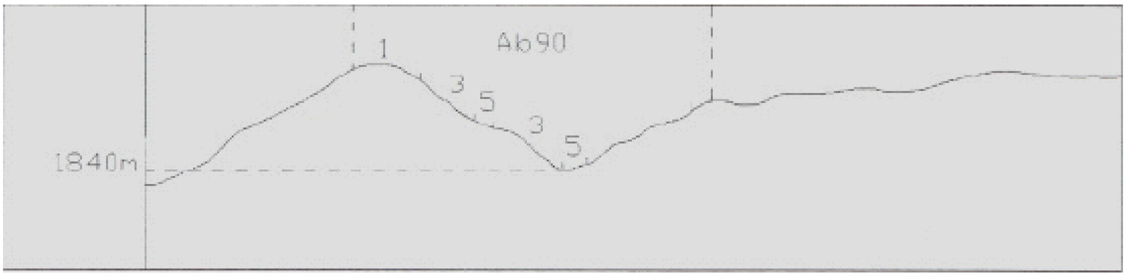


Figure 4.3. Terrain form sketch of land type Ab 90 (Land Type Survey Staff, 1989).

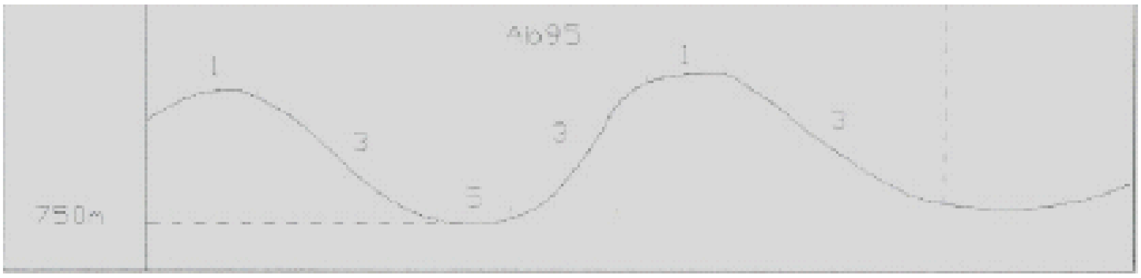


Figure 4.4. Terrain form sketch of land type Ab 95 (Land Type Survey Staff, 1989).

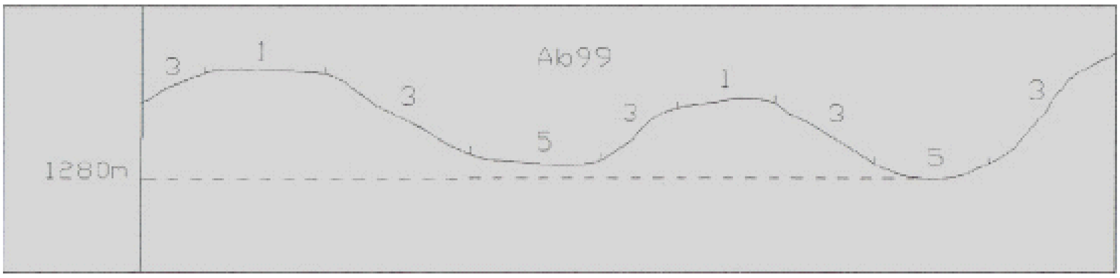


Figure 4.5. Terrain sketch of land type Ab99 (Land Type Survey Staff, 1989).

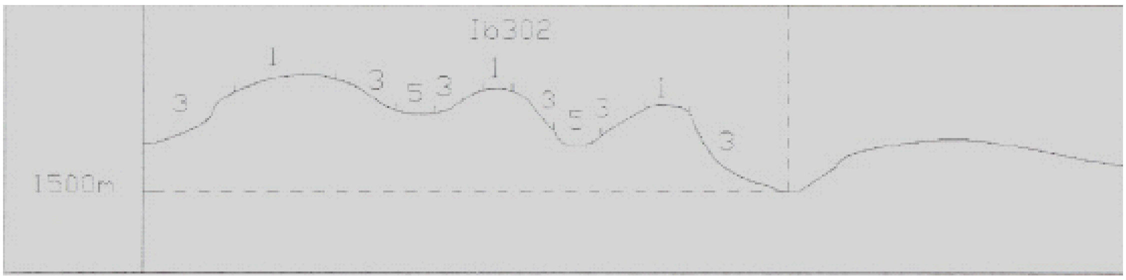


Figure 4.6. Terrain sketch of land type Ib302 (Land Type Survey Staff, 1989).

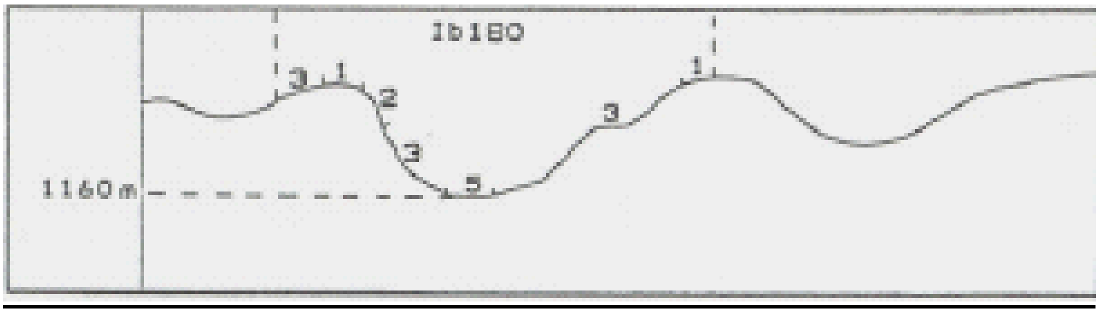


Figure 4.7. Terrain sketch of land type Ib180 (Land Type Survey Staff, 1989).

Table 4.13 shows a summary of the I.S.C.W. land types relevant to the Haenertsburg area. Each land type is colour coded to match the colours used on the map in figure 4.8. Table 4.13 further sub-divides the land types into the soils forms, the percentage of the area per soil form and the depth range of the soil forms. Table 4.14 shows each soil form's diagnostic horizon.

Table 4.13. Soil form divisions in figure 11, with sub-division into land type, percentage composition and depth class in the Haenertsburg area. (I.S.C.W., 2002).

Land Type.	Percentage of area.	Soil form.	Depth (mm).
Ab 90	30%	Rock	
	45%	Hutton*	400 - 850
	11%	Glenrosa*	15 – 300
Ab 95	75%	Inanda*	900 – 1200
	8%	Glenrosa	600 – 900
	6.5%	Rock	
	4%	Hutton	900 – 1200
Ab99	57.3%	Hutton	500 – 1200
	13%	Shortlands*	900 – 1200
	9.5%	Glenrosa	200 – 400
	8.9%	Oakleaf*	700 – 1200
	5%	Streams	
	2.6%	Mispha*	100 – 200
	1.6%	Magwa*	1000 – 1200
	1.6%	Clovelley*	700 – 900
	0.5%	Champagne*	1000 – 1200
Ib 180	69%	Rock	
	10%	Mispha	100 – 250
	9%	Glenrosa	150 – 300
	6%	Hutton	150 – 300
Ib 302	62%	Rock	
	14%	Glenrosa	100 – 250
	14%	Hutton	150 – 300
	10%	Mispha	50 - 150

* - See Table 4.12 for the diagnostic horizons of the soil forms.

Table 4.14. The diagnostic horizons for the soil form used in table 25 according to Macvicar (1991).

Soil Form.	Diagnostic Horizon.
Champagne	Organic / Unspecified
Clovelley	Orthic / Yellow-Brown Apedal B / Unspecified
Glenrosa	Orthic / Lithocutanic
Hutton	Orthic / Red Apedal B / Unspecified
Inanda	Humic / Red Apedal B / Unspecified
Magwa	Humic / Yellow-Brown Apedal B / Unspecified
Mispha	Orthic / Hard Rock
Oakleaf	Orthic / Neocutanic B / Unspecified
Shortlands	Orthic / Red Structured B

Additionally, according to the Agricultural Geo-referenced Information System (AGIS) the general soil types in Haenertsburg are:

1. Depth class **d** – greater and equal to 750 mm.
2. greater and equal to 15% and less than 35% clay content.
3. Dystrophic to mesotrophic soil.
4. Red and yellow, massive or weak structured soils with low to medium base status.
5. Red – yellow well-drained soils lacking a strong textural contrast.

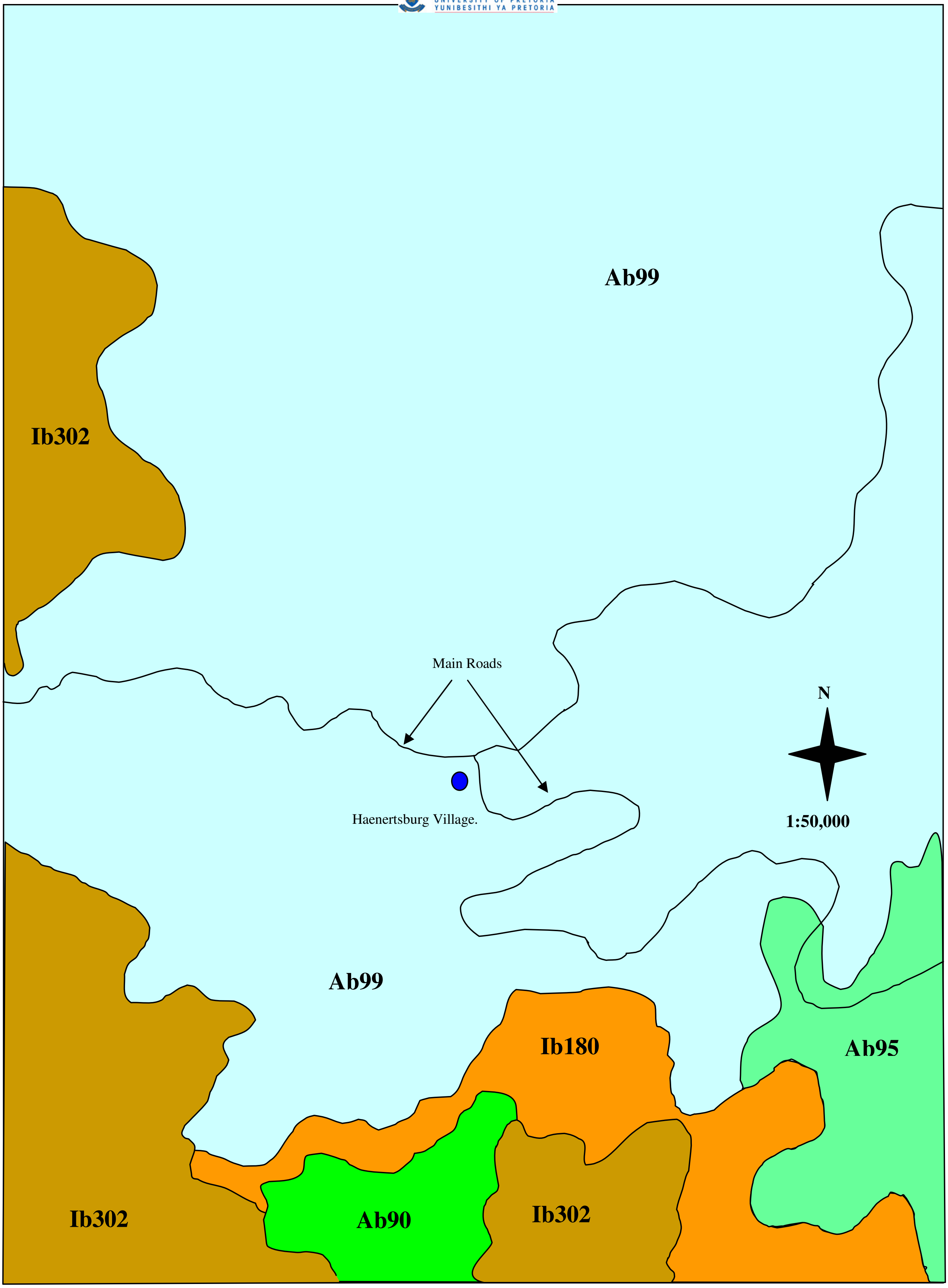


Figure 4.8. Land types in the Haenertsburg study area according to the I.S.C.W. (2002).

Pietersburg.

From information supplied by the I.S.C.W. (2002), the productive areas on the farm Turffontein fall under landform Ae225 (figure 4.9). Landform Ae233 also forms part of Turffontein, however, the areas under Ae233 are mountainous with shallow and rocky soils and were therefore not considered in this study.

The I.S.C.W. (2002), describes the terrain units on Ae225 as 3, 4 and 5, (figure 4.9). The soils are described as: 1) Red – yellow apedal; 2) freely drained soils; 3) red, high base status > 300mm deep. (No dunes). On Turffontein, most of the lands under cultivation are Hutton forms. According to the I.S.C.W., Hutton depths range from 400 mm – 1200 mm on land type code Ae225.

From field testing:

Terrain unit 3 = slopes 5 - 10% upper slopes.

Terrain unit 4 = slopes 2 – 6% mid slopes.

Terrain unit 5 = slopes 1 – 4% bottomlands. (figure 4.9).

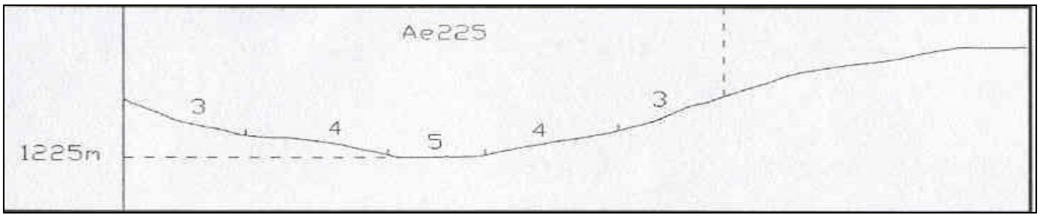


Figure 4.9. Terrain form sketch of land unit Ae225, (Land Type Survey Staff, 1989).

Compared to the Haenertsburg study area, Turffontein is smaller in area, thereby making it possible to assess the site in more detail, see fig 4.11**.** Table 4.15 below describes the major soil forms, their diagnostic horizons and actual area composition.

Table 4.15. Soil forms and diagnostic horizons (Macvicar, 1991) on the farm Turffontein in the Pietersburg area.

Soil Form.	Diagnostic Horizon.	% Of Total Area.
Hutton	Orthic / Red Apedal	34.1
Mispah *	Orthic / Hard Rock	41.0
Willowbrook **	Melanic / Gley	21.3
Willowbrook and Hutton	Residential and farm buildings.	3.6
Glenrosa	Orthic / Lithocutanic	Included with Mispha.

* Also includes Hutton, Glenrosa and Willowbrook but due to extremely rocky conditions (greater than 80% rockiness), area excluded from desired land use.

** Includes river courses, dams and areas classified as wetland.

Additionally, according to the Agricultural Geo-referenced Information System the predominant soils in the Pietersburg area are:

1. Red and yellow well drained soils lacking a strong textural contrast.
2. Red and yellow massive or weak structured soils with high base status.
3. Eutrophic soils.
4. Clay content greater and equal to 15% and less than 35%.

Depth greater and equal to 450 mm and less than 750 mm.

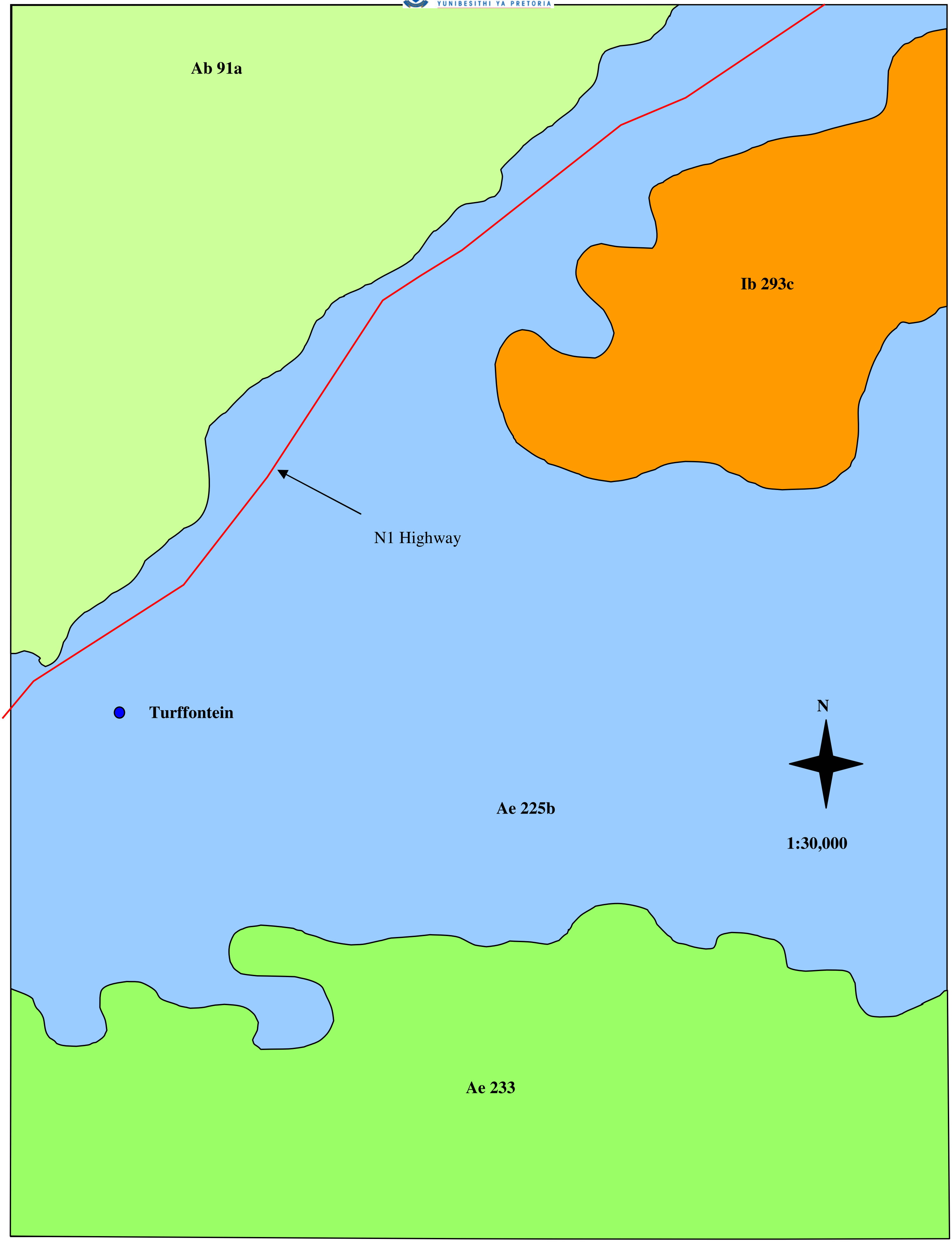
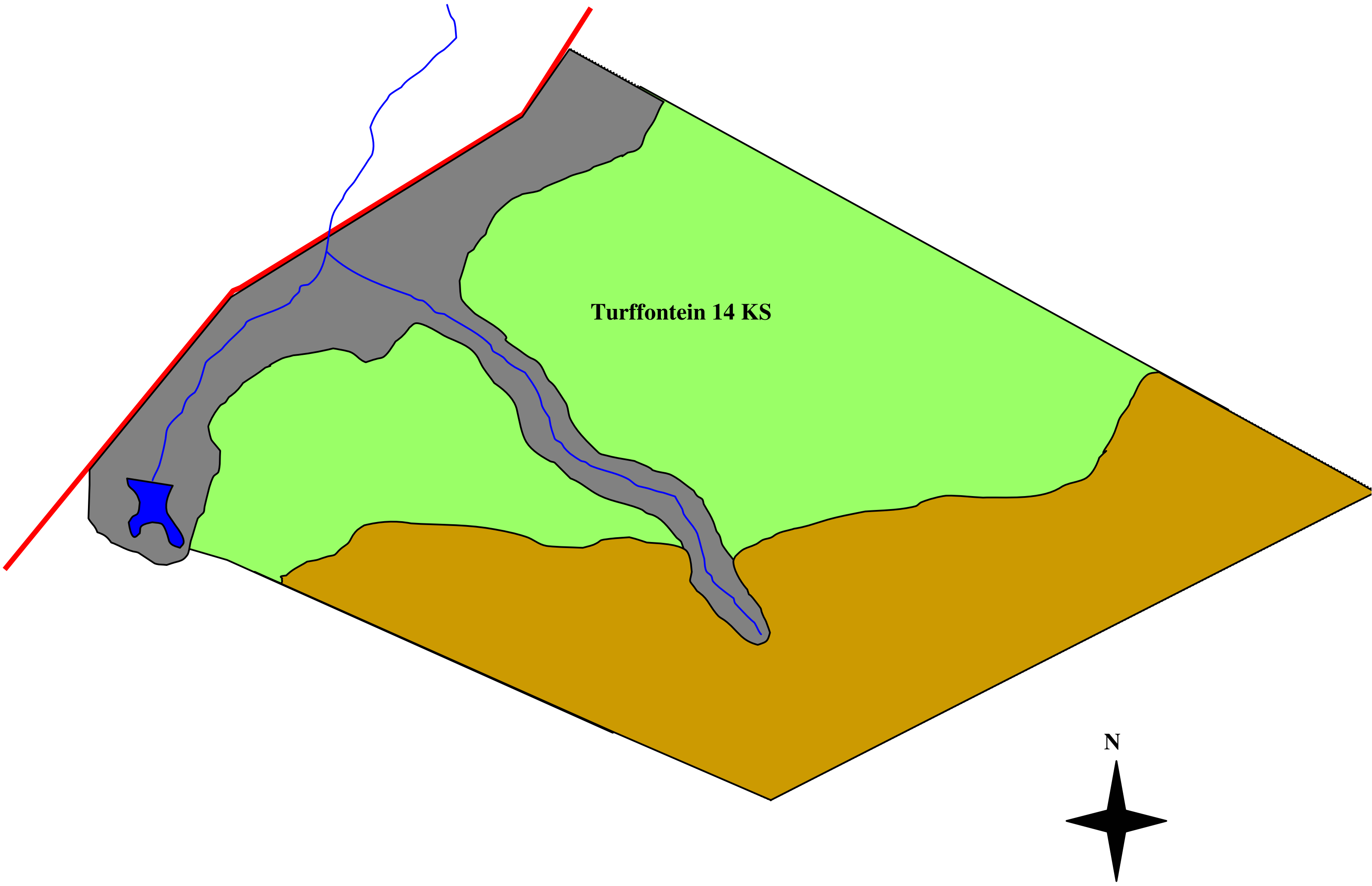


Figure 4.10. General land type map of the Pietersburg study area, adapted from I.S.C.W. (2002).



Willowbrook; >500 mm. Bottomlands.

Hutton and Shortlands; >500 mm. Mid slope.

Rivers and dams.

Mispah, Rock and Glenrosa; 100 – 300 mm. Upper slope.

N1 National road.

1:30,000

Figure 4.11. Semi-detailed soil map of Turffontein, the focus of the Pietersburg study area.

4.6.3 Chill Units.

4.6.3.1 Introduction.

Chill Units are calculated using temperature data, and are important to site selection in terms of berry viability, variety selection and marketing. This part of the resource assessment focuses on how one season's temperature data was accumulated and converted into Chill Units. For ease of reading and brevity in the text, most of the Chill Unit data results are shown in appendix A. However, to demonstrate how the total Chill Unit data summarized in table 4.19 was achieved, tables 4.16 though 4.18 demonstrates how the Chill Unit data are presented for one sample site.

The most accurate way to calculate Chill Units is to apply the Chill Unit formulae to hourly or hourly average temperatures over the cold season. After an extensive search, the I.S.C.W. (2002) found only Chill Unit data for Magoebaskloof (tables A.15, A.16 and figure K.1 of appendix A and K respectively), all other Chill Unit data was irrelevant as it was outside the appropriate study areas. To compensate for this lack of data, winter temperatures were measured at 3 sites in Haenertsburg, and one site in Pietersburg during April through to August 2002. Note: it is not advisable to site select based on one seasons Chill Unit data only. As with the previous soil data, this Chill Unit data although real, is suitable for demonstration purposes only.

The only other available Chill Unit information is shown on the maps depicted in figures 4.12 and 4.13 below, a result of studies done by Prof. R. E. Schulze and Maharaj (2006). This information is general in nature, and shows the Chill Unit distribution over South Africa and the Limpopo Province respectively. Note: Positive Chill Unit (PCU).

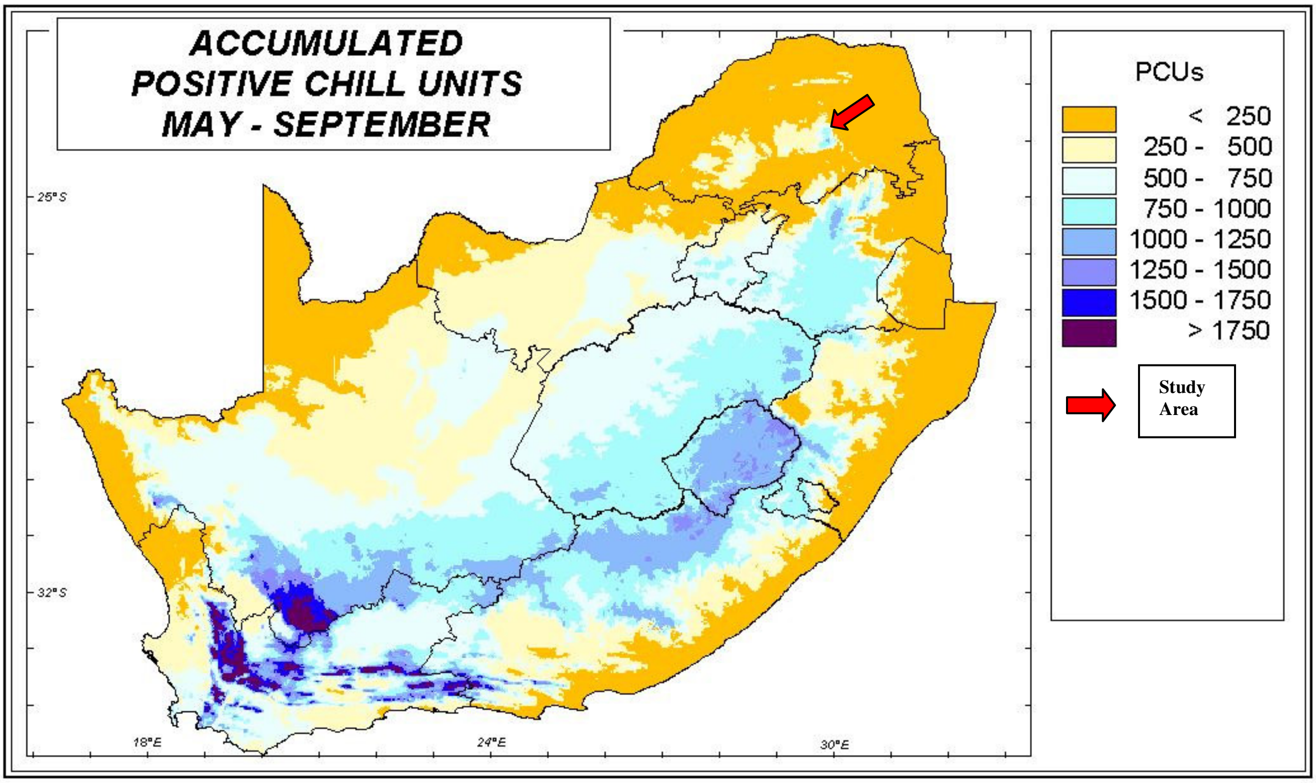


Figure 4.12. Chill Unit accumulation in South Africa and the position of the study area, (Schulze and Maharaj, 2006).

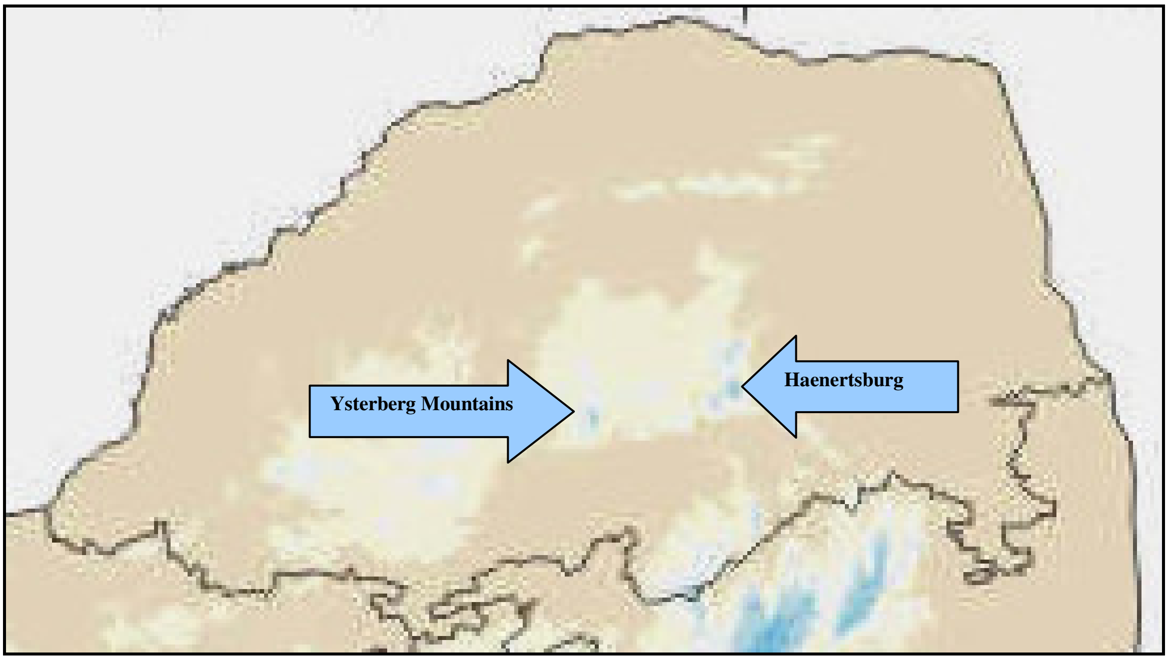


Figure 4.13. Zoom view of the Limpopo Province and areas where higher Chill Units accumulate, (Schulze and Maharaj, 2006).

4.6.3.2.Methods and materials.

Richardson or Utah Chill Units (CU) formula.

Richardson, Schuyler, Seeley and Walker, of the Utah State University, U.S.A., derived the following Chill Unit formula based on research presented in 1974. Richardson *et al,* (1974) calculated Chill Units by totalling hourly temperatures over a 24-hour period. The resultant formula is:

Temperatures < 1.5° C = 0 CU

Temperatures 1.5 – 2.4° C = 0.5 CU

Temperatures 2.5 – 9.1° C = 1 CU

Temperatures 9.2 – 12.4° C = 0.5 CU

Temperatures 12.5 – 15.9° C = 0 CU

Temperatures 16 - 18° C = -1.5 CU

Temperatures > 18° C = -1.0 CU.

Positive Chill Units (+CU) formula.

The Utah model is generally accepted. However, in South Africa, despite low or negative Chill Unit accumulation (caused mainly by daytime warming in winter), deciduous fruits like peaches show normal cold induced dormancy and bud break. Therefore, the Chill Unit model needed adapting to South African conditions. Linsley-Noakes, Allan, Matthe and Louw in 1994 and 1995, proposed and developed an adapted Chill Unit model. Different sources name the model the 1) Modified Utah Chill Unit, 2) Positive Daily Richardson Unit, 3) Daily Positive Utah Chill Unit, and 4) the Equivalent Infruitec Chill Unit, (used by the Stellenbosch Institute for Fruit and Fruit Technology) however, the formula remains the same, (Sheard, 2000). Unless specified otherwise, this study uses the term Positive Chill Units (+CU).

To calculate the positive Chill Unit, Chill Units are assigned a value of 1 or a portion thereof depending on the hourly temperature. The +CU is calculated as such:

Temp $<1.45^0$C = 0 ^{0}C Chill Units

Temp $\geq 1.5^0$C but $<2.45^0$C = 0.5 Chill Units

Temp $\geq 2.45^0$C but $<9.15^0$C = 1.0 Chill Unit

Temp ≥9.15^{0}C but <12.45^{0}C = 0.5 Chill Units

Temp ≥12.45^{0}C but <15.95^{0}C = 0 Chill Units

Temp ≥15.95^{0}C but <17.95^{0}C = -0.5 Chill Units

Temp >18.0^{0}C = -1.0^{0}C Chill Units

The Chill Units are summed for each 24-hour period. If the total for the day is negative, then it is assigned the value of 0 Chill Units for the day. If the value is positive, it is added to the seasonal total (Sheard, 2002).

Due to physical and time constraints, the time of data collection could not be identical. To compensate for loss of data, CU calculation was extrapolated based on an arbitrary date and based on the average CU for the relevant month. The calculation of the extrapolated CU was unique for each sample site. Therefore the method of calculation is defined above each CU results table. However, in keeping with conservative matching, the measured Chill Unit data, not the potential or theoretical Chill Unit data are used for the matching process.

4.6.3.3 Sample Sites.

The four sample sites used to measure winter temperatures were:

1. **Koppiealeen**; S 23º 53’ 04.5”; E 29º 55’ 30.2”; 1438 m altitude; (KA on Fig K.1).
2. **Leliefontein**: S 23º 57’ 33.3”; E 29º 54’ 38.7”; 1444 m altitude; (LF on Fig K.1).
3. **Stanford lake**; S 23º 54’ 40.7”; E 29º 58’ 50.1”; 1368 m altitude; (SL on fig K.1).
4. **Turffontein** (Pietersburg); S 24º 04’ 27.6”; E 29º 15’ 35.5”; 1417 m altitude; (TF on Fig K.2).

4.6.3.4 Equipment.

HOBO® H8 sensors were used to measure the temperatures. The sensors were placed in homemade containers based on the Stevenson Screen principle. The information was downloaded using Box Car® 3.7 software and further processed on Microsoft XL 2000 Professional.

4.6.3.5 Chill Unit Results.

The following results are presented on three sets of tables per sample site. The first table in the set shows the **measured** Utah CU and Positive CU, with the respective mean CU per day. The second table in the set shows the extrapolated or theoretical extra CUs', with an explanation of the calculation method above the table. The third table of the set shows the theoretical or additional **total** CU per sample site. Tables 4.16 through 4.18 below, show the Chill Unit results for Koppiealeen, the remaining Chill Unit results are depicted in appendix A. Table 4.19 summarizes the total Chill Unit findings.

Although the Positive CU will be used for the matching process, the Utah Chill Units are included for interest sake, and give some indication of day-time warming when compared to the + CU. The Chill Units on table A.15 and A.16 in appendix A are Utah Chill Units measured by the I.S.C.W at Magoebaskloof. Table A.13 in appendix A summarizes the measured temperature data.

Koppiealeen.

Table 4.16. Chill Units and mean Chill Units measured 22 April to 23 August 2002, at Koppiealeen.

No	Month.	Samples	Days	Chill Units (+CU)	Mean (+CU.day^{-1})	Richardson (CU)	Mean Richardson (RCU)
1	April - May	3971	33	100	3.03	100	3.03
2	May - June	3592	29	195	6.73	203.5	7.02
3	June - July	3361	28	176	6.3	195	5.79
4	July - August	3971	33	219	6.6	162	5.9
5	**Total**	**14895**	**124**	**690**		**660.5**	

Table 4.15 below shows the additional Chill Units calculated by using the mean CU for April – May, and May – August shown in table 4.14 above.

Table 4.17. Additional Chill Units extrapolated from calculated mean, Koppiealeen.

Period	Mean (+CU.day^{-1})	Additional Dates	Days	Additional +CU	Additional (RCU)
April - May	3.03	15 Apr. – 21 Apr.	7	21.21	21.21
July - Aug	6.54	24 Aug. – 31 Aug.	8	52.32	47.2
Total			**15**	**73.53 say 74**	**68.41**

By adding the additional Chill Units on Table 4.15 to the measured Chill Units on table 4.14, table 4.16 below shows the seasons theoretical or potential total CU accumulation.

Table 4.18. Measured CU and additional extrapolated CU for season 15 April – 31 August 2002, Koppiealeen.

No	Month	Samples	Days	Chill Units (+CU)	Mean (+CU.day^{-1})
1	April - May	3971	33	100	3.03
2	May - June	3592	29	195	6.73
3	June - July	3361	28	176	6.3
4	July - August	3971	33	219	6.6
5	**Total**	**14895**	**124**	**690**	
6	**Additional extrapolated CU total**		**15**	**764** **729 (RCU)**	**5.5**

Table 4.17 below compiles all the mean temperature data, the Chill Unit data, and the percentage variance between the +CU and the RCU taken from tables 4.14 through 4.16 above, and all the tables in appendix A.

Table 4.19. Overall average temperature data, +CU, RCU and the % difference between the +CU and RCU per sample site from April – August 2002.

Sample site.	Mean Min (ºC)	Mean Max (ºC)	Overall Mean (ºC)	Measured Chill Units (+CU)	Extrapolated (+CU)	Extrapolated (RCU)	% difference (+Cu – RCU)
Leliefontein	1.44	27.51	11.77	720	783	529	32.44%
Stanford Lake	- 1.88	28.92	10.28	793	850	790	7.05%
Koppiealeen	- 2.45	27.52	8.05	690	764	729	4.58%
Turffontein	- 0.85	27.33	11.51	641	699	662	5.29%

4.6.3.8 Conclusions on Chill Units.

The purpose of this exercise is not to analyse Chill Unit dynamics, but rather to measure one seasons Chill Units in order to demonstrate the matching process realistically in Chapter 5. However, some conclusions and observations are noteworthy.

1. The I.S.C.W. Chill Unit data for Magoebaskloof (table A.15 and A.16) is 249 RCU higher than the average measured Chill Units for the area. Upon investigation, it was noted that the Magoebaskloof weather station favours the accumulation of Chill Units in that it faces northeast, thereby receiving shade early in the day. In addition, the station was on the cusp of an escarpment, which receives regular moist cool winds. However, the I.S.C.W. data was measured over nine years, compared with one year for this study.

   These and other arguments are valid, but not relevant to this exercise. The most significant conclusion is that the disparity in the CU data emphasizes the need to measure CU at site specific level, and conduct thorough research.

2. During the period of measurement, in excess of 650 Chill Units accumulated in the Haenertsburg area.

3. There is no I.S.C.W. Chill Unit data for Pietersburg, however.
   1. The maps on figures 4.12 and 4.13 show that the Pietersburg study area falls within a 500 – 750 CU zone.
   2. Deciduous fruits like peaches (which require Chill Units) are produced in the area.

   Points i. and ii. above are consistent with the greater than 600 Chill Units measured in the Pietersburg study area. However, further research is advisable.

4. Table 4.19 shows a 32.44% varience between the +CU and RCU at Leliefontein. Observation reveals that:

i. The mean temperature at Leliefontein on table A.13 in appendix A for the trial period was 2º C higher than the other Haenertsburg sites. This warmer climate increases the negative Chill Units on the Richardson model, and favours zero Chill Unit days on the positive Chill Unit model.
ii. Leliefontein falls within the boundary area associated with a warmer biome.
iii. Daytime warming contributes to negative, or zero Chill Unit accumulation.

4.7 Path three - Land Limitations.

4.7.1 Introduction.

This part of the resource assessment will separate the study areas into two main land types, 1) those areas **with** berry production potential, and 2) areas **with no** potential for berry production. The matching process concerns itself with the areas that have berry production potential, whereas this section concerns itself with the definitions and process of eliminating unsuitable areas.

This section will produce two sets of maps per study area, one map showing the land limits and one map showing areas with, and areas with no potential for berry production. The Haenertsburg maps have a 1:50,000 scale, whereas Pietersburg (Turffontein) has a 1:30,000 scale. These larger scales classify large areas of land as having berry production potential or not, however, this does not necessarily apply at a smaller scale. For instance, within an area mapped as having potential for berry production, may be smaller areas of shallow or rocky soil, rendering the smaller areas not suitable, and vice versa. Farm level studies should reveal this type of detail, but are not relevant at the level of this study.

4.7.2 Method.

With the kind assistance of Trevor Phillips of *Steven's Lumber Mills*, the land limits maps (figures 4.22 and 4.24), were compiled from field data using a GIS program, Arc View® 3.3.

The land potential maps (figures 4.23 and 4.25) were achieved by combining the land limit maps on figures 4.22 and 4.24, with the soil and land type maps on figures 4.8, 4.10 and 4.11 of path 2 of this Chapter.

4.7.3 Defining the land limits.

In the context of this study, the following land limits render an area unsuitable for berry production.

1. Environmental limits.
2. Residential limits.
3. Slope, and access limits.
4. Soil type limits.
5. Wetlands, dams, and rivers.

4.7.4 Environmental limitations.

4.7.4.1 Open veld, virgin land or old lands.

According to Bothma (2005), it is unlawful under item 10 of the National Environmental Management Act (NEMA) (1998), "to cultivate or use in any other way, virgin ground on or after 10th of May 2002". Virgin ground is defined as: "land (open veld: disturbed or undisturbed, figure 4.14), which has at no time during the preceding 10 years been cultivated, irrespective of the zoning or property rights of the site".

Figure 4.14. The Haenertsburg common, an example of natural grassland, open veld (photo Frans Rousseau, 2005).

4.7.4.2 Indigenous forests.

According to the National Forestry Act (1998) “no person may cut, disturb, damage, destroy, remove or receive any indigenous flora, and no person may kill any animal, bird, insect or fish from an indigenous forest (figure 4.15) unless; the person has a license or exemption from the minister”.

Figure 4.15. Black Forest, an example of an indigenous forest in Haenertsburg (photo Frans Rousseau, 2005).

4.7.5 Residential limitations.

Residential limitations are areas where people currently live or work (figure 4.16). Residential limitations include buildings; town lands access roads and servitudes.

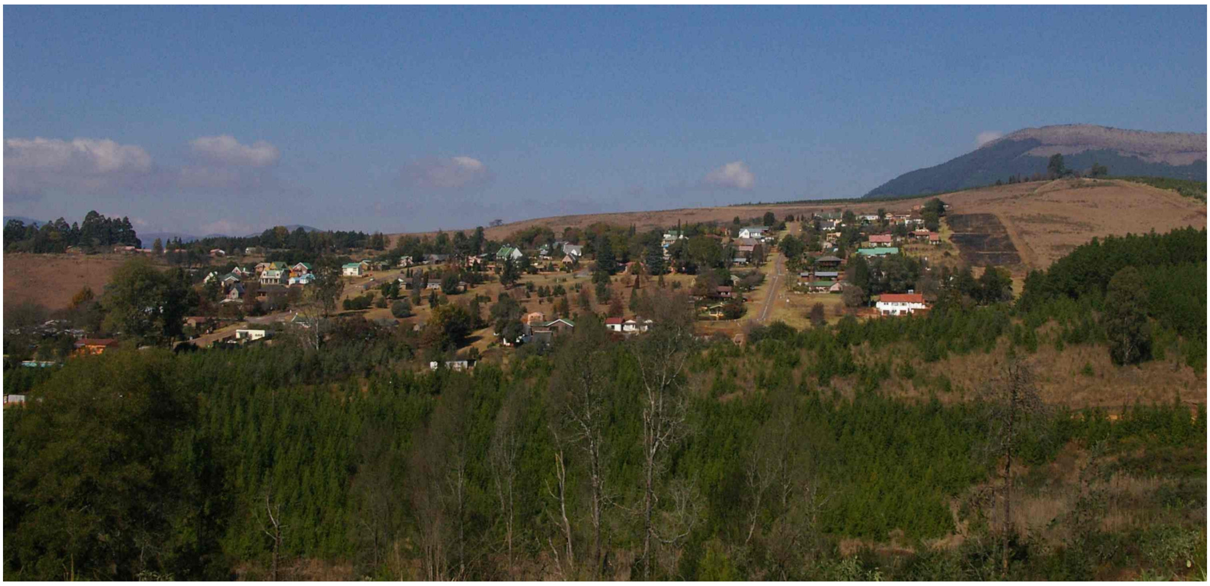


Figure 4.16. Haenertsburg village, an example of residential limits (photo Frans Rousseau, 2005).

4.7.6 Slope and access limits.

Slope limitations are those slopes classified as N2 - Not Suitable, which are slopes in excess of 20 – 25%. However, careful assessment is advised as target sites may possess multiple gradients.

Access limits include, 1) reasonable road access, 2) the practicality of irrigation, 3) access to electricity and 4) access to infrastructure. In the context of this study, access and slope limits are grouped together as the steep slopes of the study areas render the areas inaccessible (figure 4.17).

Figure 4.17. Asgard peak above Haenertsburg, typifying slope and accessibility limits (photo Frans Rousseau, 2005).

4.7.7 Soil Types.

Field-surveys revealed two major soil limitations. 1) Soil depth, that is shallow soils with limiting B-horizons, like rock for example Mispha, and Lithocutanic B horizons for example Glenrosa (figure 4.18). 2) Soil clay content, that is heavy clays with gleyed horizons or gleyic properties.

Figure 4.18. A shallow soil profile (Glenrosa) in Haenertsburg, suitable for grazing only.

4.7.8 Wetlands, dams and rivers.

Wetlands (figure 4.19) are protected environments, and unsuitable for berry production as berries are terrestrial and do not grow in waterlogged soils. Figures 4.20 and 4.21 below represent dams and rivers in the Haenertsburg area respectively.

Figure 4.19. A wetland in Haenertsburg, not suitable for berry production.

Figure 4.20. Ebenezer dam Haenertsburg, (photo Frans Rousseau).

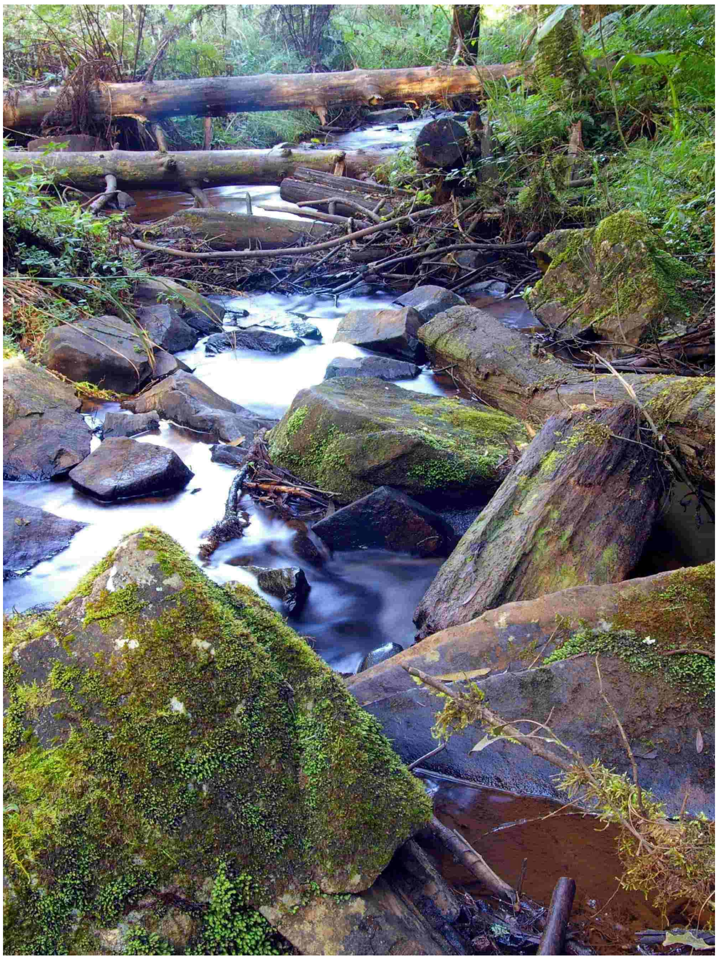


Figure 4.21. The Broederstroom river near Dap Naude Dam Haenertsburg, (photo Frans Rousseau).

4.8 Land limits, and land potential maps.

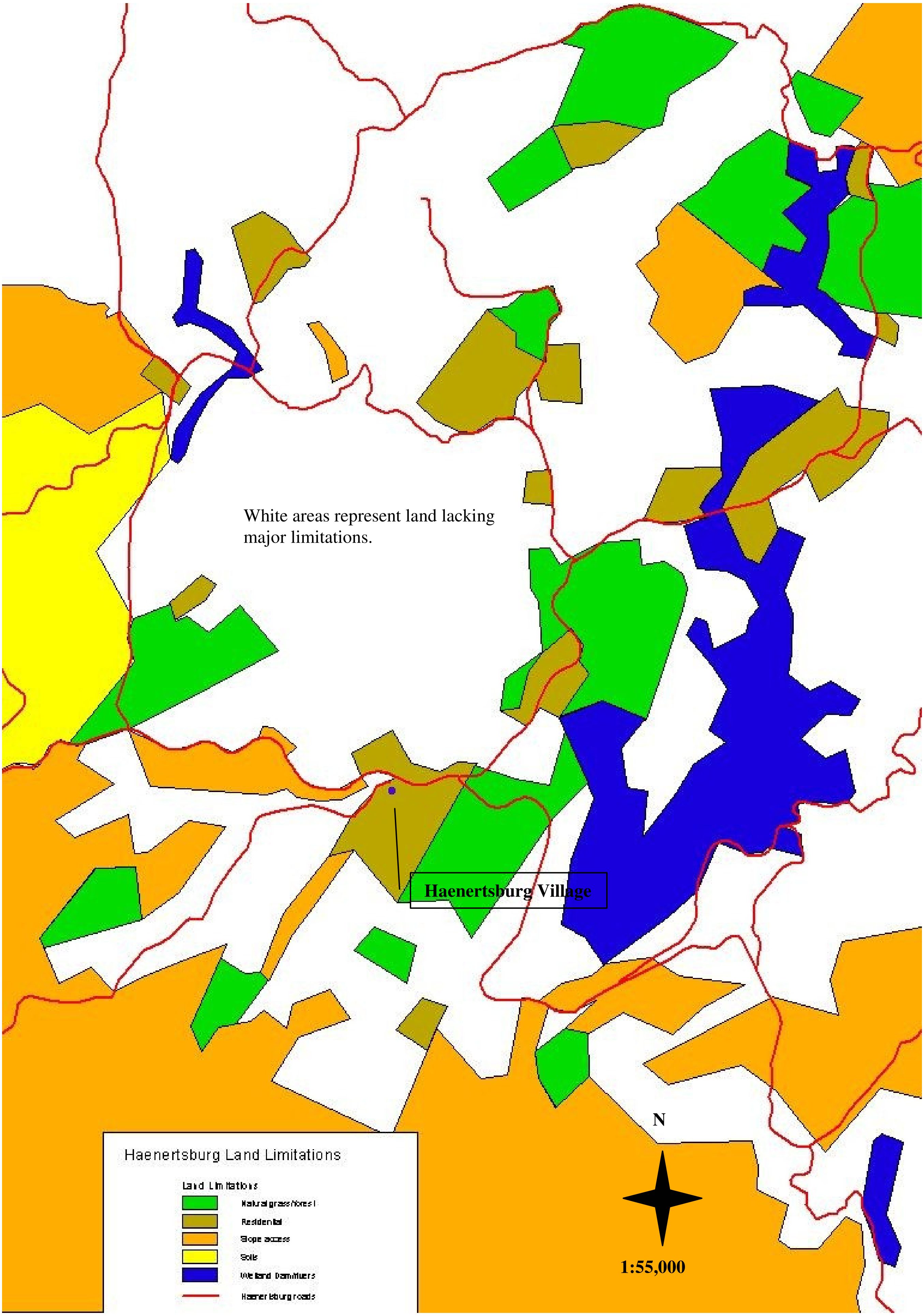


Figure 4.22. The compiled land limitations in the Haenertsburg area (mapping Trevor Phillips).

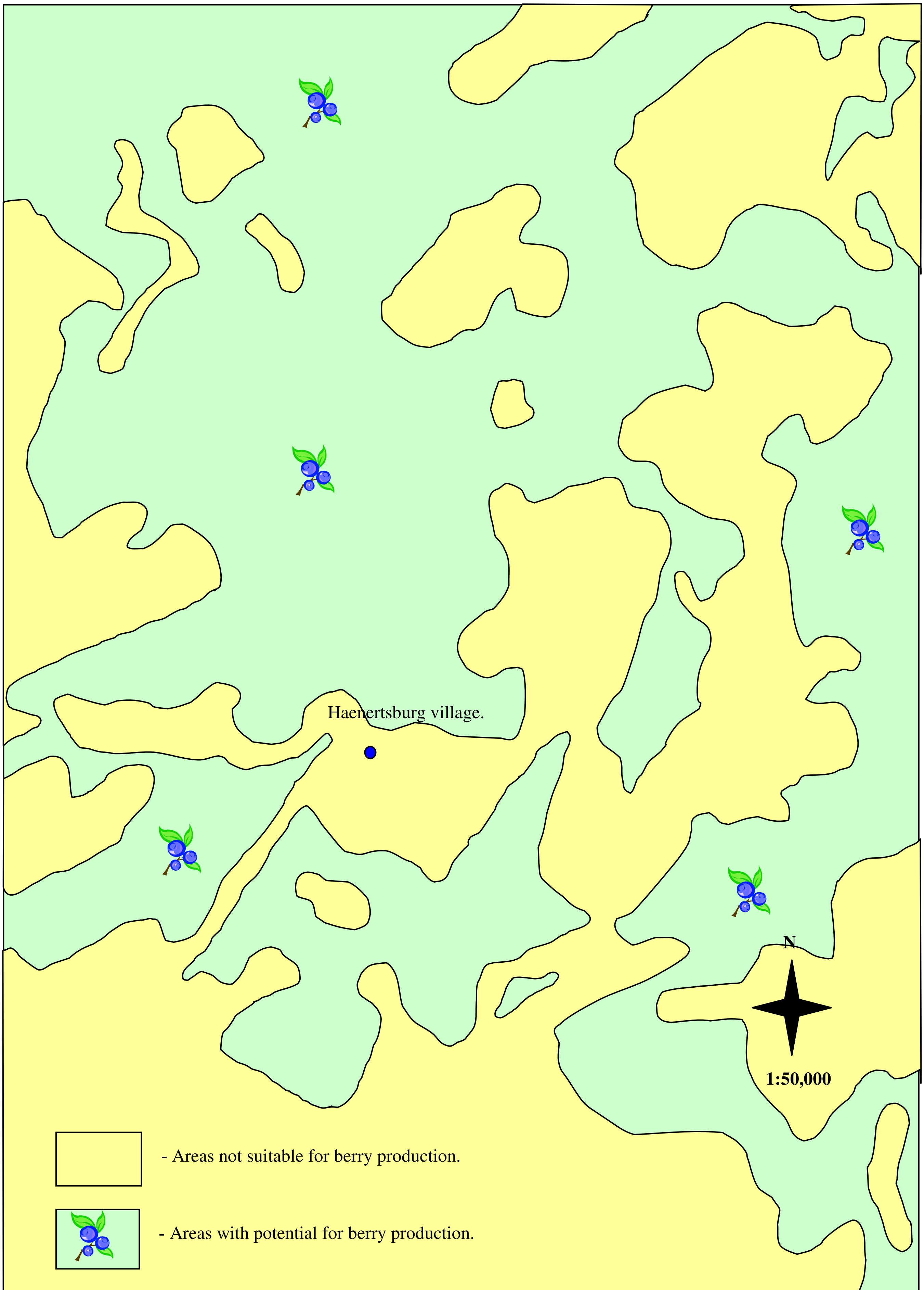


Figure 4.23. Final potential land use map Haenertsburg.

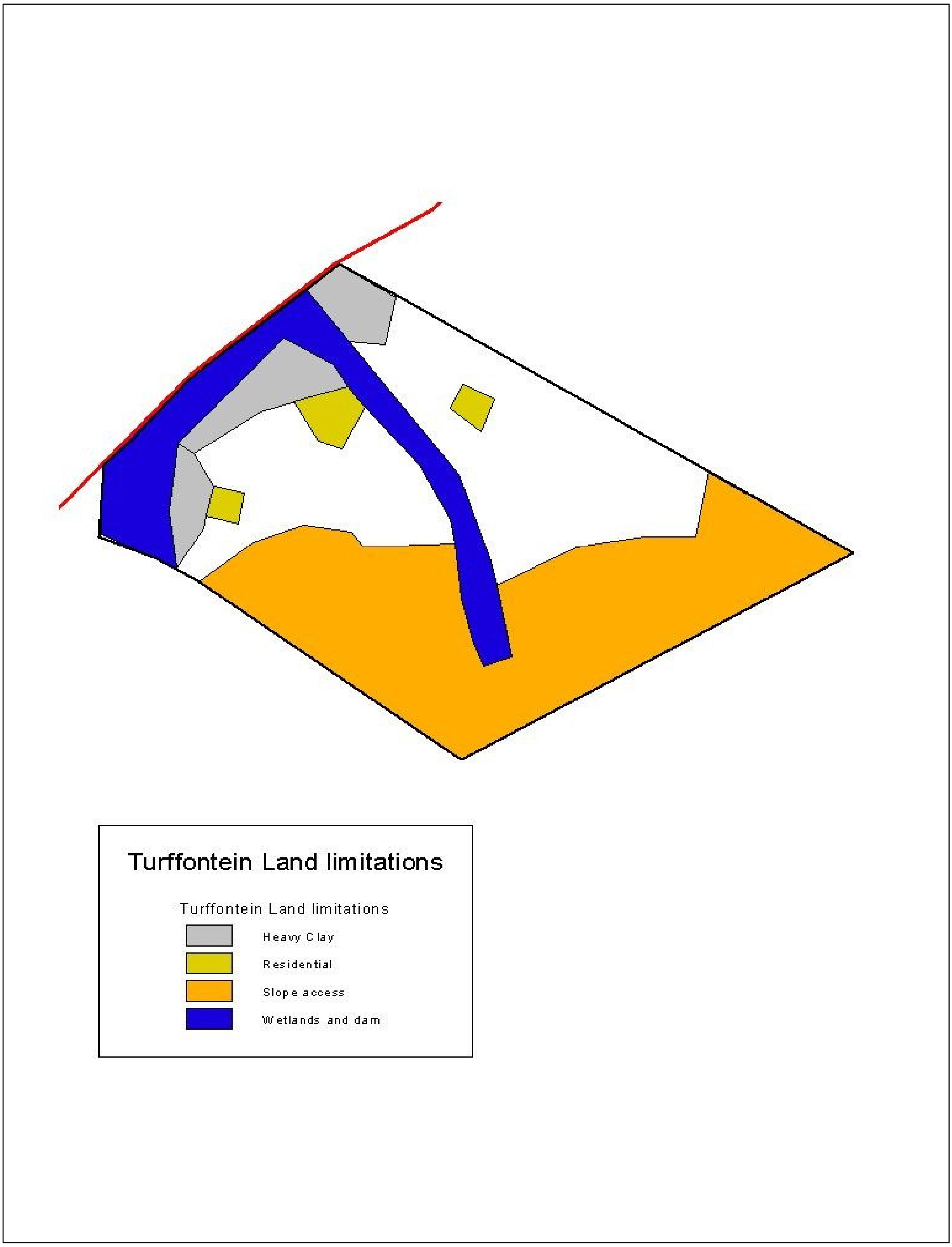


Figure 4.24. Compiled land limits map for Turffontein, Pietersburg, (mapping Trevor Phillips).

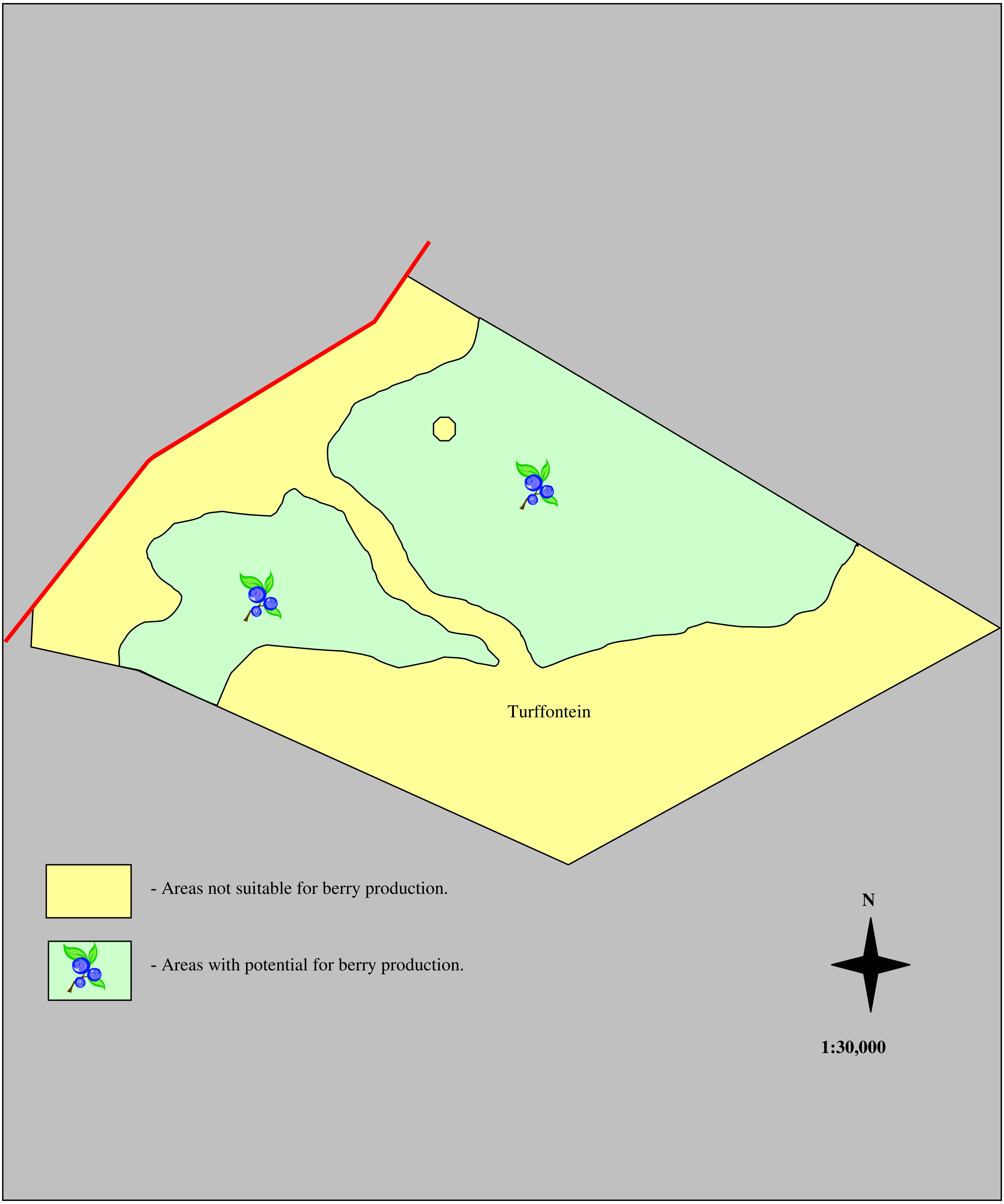


Figure 4.25. Final land potential map of Pietersburg.

Chapter 5

MATCHING

5.1 Introduction.

Matching is a comparing and rating process. Ratings are achieved by comparing the production requirements of the berries with the measured conditions on the land. Inevitably, the land will not match the conditions required by the berries. Therefore, the classification system presented in Chapter 3 is used to assign ratings that show the land's divergence from the berry requirement. To review, the FAO (1993) land suitability classes are, S1 = highly suitable, S2 = moderately suitable, S3 = marginally suitable, N1 = currently not suitable and, N2 = not suitable. Matching not only rates the land, but also provides a strategic goal per land quality aimed at achieving production sustainability.

This matching Chapter will, 1) establish the matching process principles; 2) present a data source table that summarises the land assessment results, and 3) provides the matching method and demonstrates the matching process per study area and per berry. In this study, the matching is achieved by using tables; the tables are listed in appendix B through E. Each matching table represents one land quality, for example one table for soil and one table for water. The land characteristic values and the corresponding land ratings are specified down and across the tables respectively. All three berries have the same water, topography and management requirements, and therefore are grouped together as generic matching tables in appendix E. However, each berry has unique soil and climatic requirements, and is therefore tabulated separately per berry in appendix B through D. The results of the matching are presented on a summary table per berry, and a final overall summary delivered at the end of this Chapter.

For ease of reading and brevity, all the matching process tables are placed under appendix F, except for the Haenertsburg Blueberry tables 5.3 through 5.6 which are used to demonstrate the matching process in the text. For ease of use and reference to the text, the summary tables 5.7 through 5.12 as well as the overall summary table 5.13 are included in the text in this Chapter.

5.2 Matching principles.

1. Land ratings are assigned conservatively. This means that the characteristic that yields the lowest land rating determines the final rating. For example, if all land ratings are S1, but one quality is S3, the land is rated S3. In keeping with the conservative approach, the **measured** Chill Units were used in the climatic matching and not the **extrapolated** CU values.

2. The data presented in the land assessment, although real, is not representative but demonstrative.

3. For simplicity sake, where for a given land characteristic, multiple samples exist, the average values were calculated and used.

4. In addition to the key land qualities, it is well advised to consider the "other factors" presented on the matching tables. Although the "other factors" are secondary, they have the potential to render a site unsuitable.

5. Some discretion is acceptable when assigning land values. For example with Blueberries a soil pH of 5.5 is highly suitable, however if the soil tests reveal a soil pH of say 5.6, an S1 land value may be considered. In the event of uncertainty regarding land assessment values, further tests or additional information sources should be sought.

6. The matching process places the land user on a site with potential for berry production. However, once on the site, it is assumed that the land user will conduct an appropriate farm plan. Farm plans vary in level of detail, but should include factors such as 1) soil sampling and mapping, 2) water testing, 3) climate analysis, 4) financial and viability analysis etc.

5.3 Land assessment data.

Table 5.1. Summary of the average land assessment results.

Land qualities.	**Haenertsburg land characteristic values.**	**Pietersburg land characteristic values.**
Soil.		
Drainage / permeability class	W0	W0
Clay content	35%	25%
Depth	≥ 750 mm Shortlands 900 – 1200 mm. Hutton 500 – 1200 mm.	> 400 - < 1200 mm. Hutton
pH	5.3	4.85
Climate		
+Chill Units	734 measured	641 measured
Rain	1318.86 mm for 90 days/year	620 mm
Hail	November – February	November – February
Last frost	29 September	Unknown
Water		
Salinity	106.59 $mg.l^{-1}$ and 6.00 $mS.m^{-1}$	54 $mS.m^{-1}$
SAR	0.3438	Not known
Bicarbonate	33.55 $mg.l^{-1}$	142 $mg.l^{-1}$
Chloride	3.86 $mg.l^{-1}$	15.9 $mg.l^{-1}$
Boron	0.02 $mg.l^{-1}$	Unknown
pH	6.2	6.8
Topography		
Slope	8%	5%
Management		
Rockiness	0.0% rockiness	0.0% rockiness
Infrastructure	Possible	Possible

5.4 Method.

To demonstrate the matching process, the matching is executed per study area and per berry. For that reason, Haenertsburg and Pietersburg each have a set of tables for Blueberries, Cherries and Raspberries with a summary table for each berry. Besides the critical land qualities and characteristics, the matching tables have two additional elements. 1) A section of qualitative assessments, given as secondary land qualities and named "other factors". 2) A blank table for additional notes.

The relevant land data presented on table 5.1 above is inserted into the light turquoise cells labelled **actual value** on the matching tables. The row to the left of the actual value offers comparative characteristic values or ranges. When a range or value matches the measured or actual value, the land rating above the value or range in the column is inserted into the light turquoise cell to the right of the actual value, labelled as the **rating.** This process continues down the table. The final rating is derived and inserted into the **final rating** cell. The derivation of the final rating is explained in point one under the matching principles above.

Each matching table has a number of additional considerations called **other factors.** Other factors are qualitative assessments or prompts used to remind the land assessor of the secondary land qualities identified in Chapters 2 and 3. Each secondary factor is listed per column, with suggested corrective action, and a place where the land assessor can inset yes or no relating to relevance or action taken. Beneath each matching table is a key, the key explains specific land ratings for example S2s indicates the need to treat the soil with sulphur. A blank text table is supplied below each matching table for personal notes. Once all the matching tables relating to a berry are completed, the results are inserted into a summary table. The summary table condenses all the land qualities, the final ratings and comments into an overall final rating with key considerations. This matching method is further explained and expanded upon in the demonstration given below.

5.5 Demonstration of matching method.

5.5.1 Haenertsburg.

5.5.1.1 Blueberries.

1. The Haenertsburg land characteristic data on table 5.1 is inserted into the light turquoise cells (blue font), of the matching tables below (tables 5.3 through 5.6).

2. The first row of the soil-matching table (table 5.2), reads as drainage class. In order to rate the land's drainage class, the actual drainage class value is taken from the Haenertsburg column of table 5.1. In this case, the drainage class rating is W0. The W0 value is inserted into the light turquoise **actual value** cell of table 5.2. By reading left across the soil drainage row, W0 correspond to the S1 column, S1 is therefore inserted into the light turquoise cell under the **rating** column.

3. This rating process continues down the table until a final rating is derived.

4. Because the Blueberry has different chill requirements per species, the Chill Unit portion of the climate-matching table (table 5.3), is sub divided per species. A similar approach is possible when selecting for berry variety, however, variety selection is not considered in this study.

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Table 5.2. Soil ratings for Blueberries in Haenertsburg.

Soil.	**S1.**	**S2.**	**S3.**	**N1.**	**N2.**	**Actual value.**	**Rating.**
Drainage class (Table 3.2)	W0	W1		W2	W3 – W4	W0	S1
Clay content	< 15%	15 – 20%	20 – 30% **S3o**	>30% **N1o**	> 50%	35%	N1o
Depth	450 – 600 mm				< 450 mm	≥ 750	S1
pH	4.2 – 5.2	3.0 – 4.2 or 5.2 – 6.0 **S 2s** and **S 2ca**			0.0 – 3.0 or > 6.0 – 6.5	5.3	S2s
						Final rating	N1o
Other factors	**Organic matter content**	**Previous / Current land use**					
Corrective action	Apply OM	Test					
Yes (Y) or No (N)?	Y	Y					

S3o and N1o – indicates the need to add OM to soil.

S2s – indicates the addition of Sulfur to reduce soil pH.

S2ca – indicates the addition of Ca where the soil pH is too low.

Conclusions on soil:
The most limiting factor for this soil is a high clay content, second limiting factor is
soil pH. All other soil characteristics are highly suitable.
It is recommended to apply OM and adjust soil pH.

Table 5.3. Climatic ratings for Blueberries in Haenertsburg.

Climate.		Chill Units.			Actual value.	Rating.
		S1.	S3.	N2.		
	Highbush	800 – 1100	600-800	< 600	734	S3
Variety	Rabbiteye	> 550	350 - 550	< 350	734	S1
	Southern High Bush	> 300	150 – 300	< 150	734	S1
Other factors	Early Frost	Hail	Wind	Rain & Mist		
Corrective action	Sprinklers / variety selection.	Hail net	Wind break	Pack house, land drainage, waterproof structure.		
Yes (Y) or No (N)?	Y	Y	N	Y		

Conclusions on climate:
With regards to Chill Units; it is marginally suitable to grow Highbush Blueberries in Haenertsburg and highly suitable to grow Rabbiteye and Southern Highbush Blueberries. Select the correct varieties to reduce early frost damage and where finance permit, consider the installation of anti-frost sprinklers. Install hail netting to reduce the risk of hail damage, hail netting also reduces risk associated with climate extremes and fruit loss from birds, monkeys and other animals.

Table 5.4. Generic water ratings for Blueberries in Haenertsburg.

Water.	S1.	S2.	N1.	Actual Value.	Rating.
Salinity			N 1w		
EC; $mS.m^{-1}$*	≤ 25	> 25 ≤ 75	> 75	6 $mS.m^{-1}$	S1
$mg.l^{-1}$**	≤ 160	> 160 < 800	> 800	106.59 $mg.l^{-1}$	S1
SAR* **	≤ 10	> 10 < 18	> 18	0.3438	S1
Bicarbonate ($mg.l^{-1}$)	≤ 92	> 92 < 123	> 123	33.55 $mg.l^{-1}$	S1
Chlorides ($mg.l^{-1}$)	≤ 142	> 142 < 284	> 284	3.86 $mg.l^{-1}$	S1
Boron ($mg.l^{-1}$)	≤ 0.75	> 0.75 < 0.96	> 0.96	0.02 $mg.l^{-1}$	S1
pH	≥ 4 < 6-7	7 – 8	> 8	6.2	S1
				Final rating	S1
Other factors	**Water availability**	**Water table**			
Corrective action	Measurement / consultation.	Ridging			
Yes (Y) or No (N)?	Y	Y			

N1w – some form of water treatment is indicated.

* - Electrical conductivity (EC) measured in milli Siemens per meter ($mS.m^{-1}$).

** - Concentration measured in milligrams per liter ($mg.l^{-1}$); salinity represented by the sum of Na^+, Ca^{2+}, Mg^{2+}, K^+, CO_3^{2-}, HCO_3^-, SO_4^{2-} and Cl^-.

*** - Sodium adsorption ratio (SAR). $SAR = Na^+ / \sqrt{(Ca^{2+}+Mg^{2+}) / 2}$.

Where:

Na^+ = conc. $me.l^{-1}$ Na^+ = $mg.l^{-1} Na^+ / 23$.

Ca^{2+} = conc. $me.l^{-1} Ca^{2+}$ = $mg.l^{-1} Ca^{2+} / 20$.

Mg^{2+} = conc. $me.l^{-1}$ Mg^{2+} = $mg.l^{-1} Mg^{2+} / 12$.

Conclusions on water:
Barring limits associated with water table depth and the availability of water; this
water is highly suitable for Blueberry production.

Table 5.5. Generic topography ratings for Blueberries in Haenertsburg.

Topography.	S1.	S2.	S3.	N1.	N2.	Actual value.	Rating.
Slope	0 – 3%	3 – 6%	6 – 10%	10 – 25%	> 25 – 30%	8%	S3
						Final rating	S3

Other factors	Aspect	Accessibility
Corrective action	Management / Marketing	Management / Planning / Infrastructure
Yes (Y) or No (N)?	Y	Y

Conclusions on topography:
The steepness of this land is cause for concern, however, appropriate contouring and slope management will reduce risk, also the fact that Blueberries are a permanent crop where mulching and inter row sodding can be used to reduce risk associated with slopes.

Table 5.6. Generic management ratings for Blueberries in Haenertsburg.

Management.	S1.	S2.	S3.	N1.	N2.	Actual vale.	Rating
Ease of cultivation (% Rockiness)†	No rockiness or rock outcrops	1 – 5%	5 – 10%		> 10%	0.0%	S1
Infrastructure and transport to market.	Possible			Co-operative or additional revenue.	Not possible ††	Possible	S1
						Final rating	S1
Other factors	Available land	Labor	Energy	Socio-economic.			
Corrective action	Acquire, lease, supplement income	Availability	Availability, accessibility, affordability.	Positive or negative.			
Yes (Y) or No (N)?	Y	Y	Y	Positive			

† - Berries can be grown in soils high in loose shale as they have good drainage; apply drainage class on table 3.2.

†† - Niche marketing or U pick (customers pick their own berries in the fields)

Conclusions on management:
In terms of management, this land is highly suitable.
Because land is expensive in Haenertsburg land availability is somewhat limited, in
these cases some form of supplemental and/or co-operative farming may be a
consideration. Socio economic aspects are positive as Blueberries offer an alternate
source of income to the predominant timber industry.

Table 5.7. Summary of final land ratings for Blueberries in Haenertsburg.

Land qualities.	Final ratings.	Summarized considerations.
Soil	N1o	Organic matter, possibly apply Sulphur to adjust soil pH
Climate	S1 and S3	Rabbiteye and Southern Highbush recommended, variety selection imperative, hail netting recommended.
Water	S1	Consider water availability.
Topography	S3	Manage land risk associated with slopes.
Management	S1	High levels of management.
Final Rating	**N1o**	**Soil, species/variety and slope.**

As explained above in the introduction to this Chapter, tables 5.8 through 5.12 below summarize the matching process taken from the matching tables per berry and per area in appendix F. Table 5.13 summarizes the entire matching process.

5.5.1.2 Cherries.

Table 5.8. Summary of final land ratings for Cherries in Haenertsburg.

Land qualities.	Final ratings	Summarized considerations.
Soil	N1o	Apply OM and adjust soil pH
Climate	N1cu	Climate highly limiting, cultivar selection may lessen risk.
Water	S1	Consider water availability.
Topography	S3	Manage land risk associated with slopes.
Management	S1	High levels of management.
Final Rating	**N1o, cu**	**Soil, climate, cultivar selection, slope.**

5.5.1.3 Raspberries.

Table 5.9. Summary of final land ratings for Raspberries in Haenertsburg.

Land qualities.	**Final ratings**	**Summarized considerations.**
Soil	**N1s, o.**	Apply OM and adjust soil pH with Sulphur
Climate	**N1cu**	Climate highly limiting, cultivar selection may lessen risk.
Water	**S1v**	Variety selection, plastic cover, water availability.
Topography	**S3**	Manage land risk associated with slopes and consider slope w.r.t. tunnel construction.
Management	**S1**	High levels of management and marketing.
Final Rating	**N1s, o, cu.**	**Soil, climate, cultivar selection, slope.**

5.5.2 Pietersburg matching tables

5.5.2.1 Blueberries.

Table 5.10. Summary of final land ratings for Blueberries in Pietersburg.

Land qualities.	**Final ratings.**	**Summarized considerations.**
Soil	**S3o**	Highly suitable soils, high clay content indicates the need to apply OM
Climate	**S3, S1**	S3 for Highbush, S1 for Rabbiteye and Southern Highbush, hail netting and variety selection of major concern.
Water	**N1w**	Water treatment and further testing indicated.
Topography	**S2**	Slope management.
Management	**S1**	High levels of management.
Final Rating	**N1w**	**Water, soil, climate, slope**.

5.5.2.2 Cherries

Table 5.11. Summary of final land ratings for Cherries in Pietersburg.

Land qualities.	Final ratings	Summarized considerations.
Soil	**N1**	Soil pH major limiting factor, apply OM.
Climate	**N1cu**	Cultivar selection of major concern, hail protection needed.
Water	**N1w**	Water treatment and further testing indicated.
Topography	**S2**	Slope management.
Management	**S1**	High levels of management.
Final Rating	**N1cu, w.**	**Climate, cultivar selection, water.**

5.5.2.3 Raspberries.

Table 5.12. Summary of final land ratings for Raspberries in Pietersburg

Land qualities.	Final ratings	Summarized considerations.
Soil	**N1ca**	Apply Ca and OM.
Climate	**S1v**	Variety selection and hail netting of major concern.
Water	**N1w**	Water treatment and further testing indicated.
Topography	**S2**	Slope management.
Management	**S1**	High levels of management and marketing.
Final Rating	**N1ca, w.**	**Soil, water, climate, variety selection.**

Table 5.13. Overall summarized final land ratings with influencing factors per berry and per study area.

Haenertsburg.		
Fruit	**Final Rating**	**Factors influencing final rating.**
Blueberries	N1o	Soil, species/variety and slope.
Cherries	N1o, cu	Soil, climate, cultivar selection, slope.
Raspberries	N1s, o, cu.	Soil, climate, cultivar selection, slope
Pietersburg.		
Blueberries	N1w	Water, soil, climate, slope
Cherries	N1cu, w.	Climate, cultivar selection, water.
Raspberries	N1ca, w.	Soil, water, climate, variety selection, slope.

5.6 Conclusion on matching.

Table 5.13 above reveals that both Haenertsburg and Pietersburg rate N1 – currently not suitable for berry production. In Haenertsburg, 1) soil condition, 2) climatic conditions and 3) management are the limiting factors. In Pietersburg, 1) soil condition, 2) climatic conditions and 3) water quality are limiting.

The N1 – **currently** not suitable rating offers opportunity for change and adaptation. 1) With respect to soil conditions, the soil may be improved through soil testing and corrective action for example applying OM and or prescribed fertilizers. 2) With regard to climatic conditions, the berry species and or variety selection must favour the Chill Unit accumulation in the study areas. Protective structures can reduce the risk associated with wind, hail, frost and excess free moisture during harvest. Over-head sprinklers can reduce frost damage and by using appropriate technology, wet fruit can be suitably dried. 3) With respect to slope, where appropriate, slope management is necessary for example contouring. 4) With respect to water, improving water quality through water treatment and or finding alternate water sources should be considered.

Chapter 6

GENERAL CONCLUSION

Blueberry, Cherry and Raspberry production offers an alternative land use opportunity in the Limpopo Province of South Africa. Haenertsburg and areas associated with Pietersburg were identified as having berry production potential. In Haenertsburg, most of the viable land is held by the timber industry. In Pietersburg, soil and climatic conditions vary greatly, and therefore present a site selection risk when considering berry production. Berry production needs relatively little land, approximately 20.0 ha for Cherry production and 5.0 ha for Blueberry and Raspberry production. This represents an opportunity for small landowners; however, the site selection process is unclear, and South African based literature for Blueberries, Raspberries and Cherries is limited, especially for the Limpopo Province.

Using accepted land use planning techniques, a site selection system or tool was developed. The means by which the tool was developed was separated into four main steps.

1) Identify the key and secondary berry land requirements.
2) Consolidate the land requirements into a land classification or ranking system.
3) In order to test the land ranking system, real but non-representative characteristic data was collected through a resource assessment.
4) Combine the resource assessment data with the ranking system through the process of matching.

A literature search, site visits, interviews and Internet searches, revealed that the key land requirements for berry production are 1) climate, 2) soil, 3) water, 4) topography and 5) management. Each of these requirements is called a land quality, while the actual values associated with the land quality are called land characteristics. The key and secondary qualities and characteristics were identified and catalogued in Chapter 2. Based on the FAO (1993) land classification model, a land ranking system was developed per berry. The system shows the land's degree of suitability or non-suitability based on the characteristic values.

In order to test or demonstrate the land ranking system, relevant land data was necessary, hence the need for a resource assessment. The resource assessment produced the relevant land values by 1) using existing data 2) augmenting existing data with field-testing and 3) identifying land limits. The land limits were used to eliminate areas with no berry production potential and were shown on land potential maps. Due to the scale and aim of the study, the data yielded by the resource assessment was not representative but demonstrative; therefore, the results were purely theoretical.

Finally, the resource assessment data was applied to the land ranking system through the process of matching. The matching exercise precipitated the formation of the site selection tool. The already described land ranking system was separated into a matching table per land quality. The target land received a rating by inserting the relevant characteristic values into the matching tables. The template matching tables appear in appendix B through E. It was found that the water, topography and management criteria are common to all three berry types, and are therefore grouped together in the appendix as generic tables. The soil and climatic criteria are unique to each berry, and are therefore presented separately in the appendix, per berry.

The site selection tool yields conservative results, meaning that the most limiting factors are highlighted for correction or management. This is in keeping with sustainability and good agricultural practice. In keeping with the aim of this study the site selection process is designed to identify sites with berry production potential, once on the site, the land user may initiate a farm plan with an increased sense of confidence. It is hoped that further research will refine the results of this study to the benefit of sustainable land use.

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Appendix A

CHILL UNIT RESULTS

The Chill Unit data depicted below is a continuation of that depicted in Chapter 4 section 4.6.3 Chill Units. The results are presented on three sets of tables per sample site. The first table in the set shows the measured Utah CU and Positive CU, with the respective mean CU per day. The second table in the set shows the extrapolated or theoretical extra CUs', with an explanation of the calculation method above the table. The third table of the set shows the theoretical or additional total CU per sample site.

Koppiealeen.

Table A.1. Chill Units and mean Chill Units measured 22 April to 23 August 2002, at Koppiealeen.

No	Month.	Samples	Days	Chill Units (+CU)	Mean (+CU.day^{-1})	Richardson (CU)	Mean Richardson (RCU)
1	April - May	3971	33	100	3.03	100	3.03
2	May - June	3592	29	195	6.73	203.5	7.02
3	June - July	3361	28	176	6.3	195	5.79
4	July - August	3971	33	219	6.6	162	5.9
5	**Total**	**14895**	**124**	**690**		**660.5**	

Table A.2 below shows the additional Chill Units calculated by using the mean CU for April – May, and May – August shown in table A.1.

Table A.2. Additional Chill Units extrapolated from calculated mean, Koppiealeen.

Period	Mean ($+CU.day^{-1}$)	Additional Dates	Days	Additional +CU	Additional (RCU)
April - May	3.03	15 Apr. – 21 Apr.	7	21.21	21.21
July - Aug	6.54	24 Aug. – 31 Aug.	8	52.32	47.2
Total			**15**	**73.53 say 74**	**68.41**

By adding the additional Chill Units on Table A.2 to the measured Chill Units on table A.1, table A.3 below shows the seasons theoretical total.

Table A.3. Measured CU and additional extrapolated CU for season 15 April – 31 August 2002, Koppiealeen.

No	Month	Samples	Days	Chill Units (+CU)	Mean ($+CU.day^{-1}$)
1	April - May	3971	33	100	3.03
2	May - June	3592	29	195	6.73
3	June - July	3361	28	176	6.3
4	July - August	3971	33	219	6.6
5	**Total**	**14895**	**124**	**690**	
6	**Additional extrapolated CU total**		**15**	**764** **729 (RCU)**	**5.5**

Turffontein.

Table A.4. Chill Units and mean Chill Units measured 22 April to 24 August 2002 at, Turffontein.

No	Month	Samples	Days	Chill Units (+CU)	Mean (+CU.day^{-1})	Richards on (CU)	Mean (RCU)
1	May	4747	20	88.5	4.43	88.5	4.43
2	May - June	6531	27	232	8.6	226.5	8.388
3	June - July	6948	29	207.5	7.15	207.5	7.15
4	July - August	7943	33	113	3.4	83.5	2.53
5	**Total**	**26169**	**109**	**641**		**610.5**	

Table A.5 below shows the additional Chill Units calculated by using the mean CU for May and August shown on table A.4.

Table A.5. Additional Chill Units extrapolated from calculated mean, Turffontein.

Period	Mean (+CU.day^{-1})	Additional Dates	Days	Additional +CU	Additional (RCU)
May	4.43	1 – 7 May	7	31.01	31.01
Aug	3.4	24 -31 May	8	27.2	20.24
Total			**15**	**58.21 say 58**	**51.25**

By adding the additional CU on table A.5 to the measured CU on table A.4, table A.6 below shows the seasons theoretical total.

Table A.6. Measured CU and additional extrapolated CU for season 1 May – 31 August 2002, Turffontein.

No	Month	Samples	Days	Chill Units (+CU)	Mean (+CU.day^{-1})
1	May	4747	20	88.5	4.43
2	May - June	6531	27	232	8.6
3	June - July	6948	29	207.5	7.15
4	July - August	7943	33	113	3.4
5	**Total**	**26169**	**109**	**641**	
6	**Additional extrapolated CU total**		**15**	**699** **662 (RCU)**	**5.6**

Stanford Lake.

Table A.7. Chill Units and mean Chill Units measured 22 April to 25 August 2002, Stanford Lake.

No	Month	Samples	Days	Chill Units (+CU)	Mean (+CU.day^{-1})	Richards on (CU)	Mean (RCU)
1	April - May	3972	33	100.5	3.03	83.5	2.53
2	May - June	3823	32	321	10.03	320	10.0
3	June - July	3361	28	176	6.29	162	5.79
4	July - Aug	3972	33	195.5	5.9	175	5.30
5	**Total**	**15128**	**126**	**793**		**740**	

Table A.8 below shows the additional Chill Units calculated by using the mean CU for April/May, and for July/August shown in Table A.7.

Table A.8. Additional Chill Units extrapolated from calculated mean, Stanford Lake.

Period	Mean (+CU.day^{-1})	Additional Dates	Days	Additional +CU	Additional (RCU)
April - May	3.03	15 – 21 May	7	21.21	17.71
July - Aug	5.9	26 – 31 August	6	35.4	31.80
Total			**13**	**56.61 say 57**	**49.51**

By adding the additional Chill Units on Table A.9 to the measured Chill Units on table A.7, table A.9 below shows the seasons theoretical total.

Table A.9. Measured CU and additional extrapolated CU for season 22 April – 25 May 2002, Stanford Lake.

No	Month	Samples	Days	Chill Units (+CU)	Mean (+CU.day^{-1})
1	April - May	3972	33	100.5	3.03
2	May - June	3823	32	321	10.03
3	June - July	3361	28	176	6.29
4	July - Aug	3972	33	195.5	5.9
5	**Total**	**15128**	**126**	**793**	
6	**Additional extrapolated CU total**		**13**	**850** **790 (RCU)**	**6.39**

Leliefontein.

Table A.10. Chill Units and mean Chill Units measured 22 April – 21 August 2002, Leliefontein.

No	Month	Samples	Days	Chill Units (+CU)	Mean (+CU.day^{-1})	Richardson (CU)	Mean (RCU)
1	April – May	3971	33	60.5	1.83	-46.5	-1.41
2	May - June	3368	28	317	11.32	314.5	11.23
3	June - July	3361	28	176	6.29	162	5.79
4	July - August	3971	33	166.5	5.05	83.5	2.53
5	**Total**	**14678**	**122**	**720**		**513.5**	

Table A.11 below shows the additional Chill Units calculated by using the mean CU from April/May, and from July/August shown in table A.10.

Table A.11. Additional Chill Units extrapolated from calculated mean, Leliefontein.

Period	Mean (+CU.day^{-1})	Additional Dates	Days	Additional +CU	Additional (RCU)
April - May	1.83	15 – 21 May	7	12.81	-9.87
July - Aug	5.05	22 – 31 August	10	50.5	25.3
		Total	**17**	**63.31 say 63**	**15.43**

By adding the additional Chill Units on table A.11 to the measured Chill Units on table A.10, table A.12 below shows the seasons theoretical total.

Table A.12. Measured CU and additional extrapolated CU for season 22 April – 21 May 2002, Leliefontein.

No	Month	Samples	Days	Chill Units (+CU)	Mean (+CU.day^{-1})
1	April – May	3971	33	60.5	1.83
2	May - June	3368	28	317	11.32
3	June - July	3361	28	176	6.29
4	July - August	3971	33	166.5	5.05
5	**Total**	**14678**	**122**	**720**	
6	**Additional extrapolated CU total**		**17**	**783** **529 (RCU)**	**5.6**

Summary of temperature data measured April – August 2002.

Table A.13. Average minimum, maximum and overall mean temperatures measured per farm per month over April – August 2002.

Month.	Min (ºC).	Max (ºC).	Mean (ºC).
Leliefontein (Haenertsburg)			
April - May	2.03	29.01	14.72
May - June	2.89	24.01	10.67
June - July	- 2.9	27.52	8.05
July - August	3.74	29.5	13.67
Stanford Lake (Haenertsburg)			
April - May	- 3.85	27.12	12.37
May - June	- 2.9	27.52	8.53
June - July	- 1.06	27.52	8.05
July - August	0.29	29.1	11.78
Koppiealeen (Haenertsburg)			
April - May	- 4.33	27.12	12.18
May - June	- 1.5	24.79	8.53
June - July	- 2.9	27.52	8.05
July - August	- 1.06	29.1	11.18
Turffontein (Pietersburg)			
May	- 0.16	26.73	12.28
May - June	0.29	27.12	10.71
June - July	- 3.37	25.56	9.51
July - August	- 0.16	29.9	13.54

Other Chill Unit data.

Table A.15 and A.16 are Utah Chill Units measured by the I.S.C.W, and a summary of the applicable Chill Unit data respectively, for Magoebaskloof.

Table A.15. Courtesy of I.S.C.W. Agro met Section showing Chill Units in blue, during target months.

Computer	18543
Station Name:	MAGOEBASKLOOF
District	PIETERSBURG
	Latitude -23.883 **Longitude** 30 **Agro Met No:** 0678/893 4 **Altitude:** 1433

Key	Statistic	Start Date	End Date	Years	Apr	May	Jun	Jul	Aug	Sep	Annual
AveN	Average	01/01/1962	01/07/1971	9.58	3.6	1.0	-1.7	-2.3	-1.2	1.0	-4.3
CU	Average	01/01/1962	01/07/1971	9.58	-107.9	**149.8**	**293.5**	**300.2**	**189.1**	-24.5	-1257.924.0
Frost	Average	01/01/1900	01/07/1971	0.00	0.0	4.8	4.8	1.4	0.4	0.0	
Rain	Average	01/10/1959	01/07/1971	11.83	108.6	31.1	28.2	16.7	18.0	31.5	1253.2
Raindays	Average	01/10/1959	01/07/1971	11.83	9.8	5.0	4.1	2.5	3.4	4.7	106.6

Table A.16. Average Chill Unit accumulation for May – August for years 1962 – 1971 measured at Magoebaskloof (I.S.C.W., 2002).

Chill Unit Data (Richardson) measured at Magoebaskloof 1962 – 1971.	
May – August	932.6 Chill Units

Appendix B

SOIL AND CLIMATE MATCHING TABLES FOR BLUEBERRIES

Table B.1. Soil ratings associated with Blueberries.

Soil.	**S1.**	**S2.**	**S3.**	**N1.**	**N2.**	**Actual value.**	**Rating.**
Drainage class (Table 8)	W0	W1		W2	W3 – W4		
Clay content	< 15%	15 – 20%	20 – 30% **S 3o**	>30% **N 1o**	>50%		
Depth	450 – 600 mm				< 450 mm		
pH	4.2 – 5.2	3.0 – 4.2 or 5.2 – 6.0 **S 2s** and **S 2ca**			0.0 – 3.0 or > 6.0 – 6.5		
						Final rating	

Other factors	**Organic matter content**	**Previous / Current land use**
Corrective action	Apply OM	Test
Yes (Y) or No (N)?		

S3o and N1o – indicates the need to add OM to soil.

S2s – indicates the addition of Sulphur to reduce soil pH.

S2ca – indicates the addition of Ca where the soil pH is too low.

Conclusions on soil:

Table B.2. Climate ratings associated Blueberries.

Climate.		Chill Units.			Actual value.	Rating.
		S1	**S3**	**N2**		
	Highbush	800 – 1100	600-800	< 600		
Variety	**Rabbiteye**	> 550	350 - 550	< 350		
	Southern High Bush	> 300	150 – 300	< 150		
Other factors	**Early Frost**	**Hail**	**Wind**	**Rain & Mist**		
Corrective action	Sprinklers	Hail net	Wind break	Pack house, land drainage, water proof structure.		
Yes (Y) or No (N)?						

Conclusions on climate:

Appendix C

SOIL AND CLIMATE MATCHING TABLES FOR CHERRIES

Table C.1. Soil ratings associated with Cherries.

Soil.	**S1.**	**S2.**	**S3.**	**N1.**	**N2.**	**Actual value.**	**Rating.**
Drainage Use table 8.	W0	W1		W2	W3 – W4		
Clay content	< 15%	≤15 – 20%	20 – 30% **S3o**	> 30% **N1o**	> 50%		
Depth	≥ 1000 mm		> 600 < 1000 mm		< 600 mm		
pH	6.0 – 6.5	> 6.5 < 7.5		> 7.5 or < 6.0			
						Final Rating	

Other factors	**Organic matter content**	**Previous / Current land use**
Corrective action	Apply OM	Test
Yes (Y) or No (N)?		

S3o and N1o – indicates the need to add OM to soil.

Conclusions on soil:

Table C.2. Climatic ratings associated Cherries

Climate.	S1.	N1.	N2.	Actual value.	Rating.
Chill Units	1000 - 1600	> 500 < 1000 **N1cu**	< 500		
				Final Rating	
Other factors	**Early Frost**	**Hail**	**Wind**	**Rain & Mist**	
Corrective action	Sprinklers	Hail net	Wind break	Pack house, land drainage, plastic cover.	
Yes (Y) or No (N)?					

N1cu – indicates Chill Unit limitations, select low Chill Unit Cherry varieties or correct aspect or shading/chilling techniques.

Conclusions on climate:

Appendix D

SOIL AND CLIMATE MATCHING TABLES FOR RASPBERRIES

Table D.1. Soil ratings associated with Raspberries.

Soil.	**S1.**	**S2.**	**S3.**	**N1.**	**N2.**	**Actual vale.**	**Rating.**
Drainage Use table 8.	W0	W1		W2	W3 – W4		
Clay content	< 15%	≤ 15 – 20%	20 – 30% **S3o**	> 30% **N1o**	> 50%		
Depth	600 – 1200 mm		450 – 600 mm		< 450 mm		
pH	5.5 – 6.5			< 5.5 or > 6.5 – 8.0 **N1ca; N1s**	< 4.0 – 4.5 > 8.0 – 8.5		
						Final rating	

Other factors	**Organic matter content**	**Previous / Current land use**
Corrective action	Apply OM	Test
Yes (Y) or No (N)?		

S3o and N1o – indicates the need to add OM to soil.

N1ca – indicates the need to add Ca to increase soil pH.

N1s – indicates the need to add Sulphur to reduce soil pH.

Conclusions on soil:

Table D.2. Climatic ratings associated with Raspberries.

Climate.	**S1.**	**N2.**	**Actual value.**	**Rating.**
Chill Units	> 250 - ~ 1600 **S1v**	< 250		
			Final rating	
Other factors	**Early Frost**	**Hail**	**Wind**	**Rain & Mist**
Corrective action	Sprinklers	Hail net	Wind break	Pack house, land drainage, plastic cover.
Yes (Y) or No (N)?				

S1v – Chill Unit requirement is variety dependent.

Conclusions on climate:

Appendix E

GENERIC MATCHING TABLES FOR WATER TOPOGRAPHY AND MANAGEMENT

Table E.1. Generic water matching table.

Water.	**S1.**	**S2.**	**N1.**	**Actual Value.**	**Rating.**
Salinity			**N 1w**		
EC; $mS.m^{-1}$*	≤ 25	> 25 ≤ 75	> 75		
$mg.l^{-1}$**	≤ 160	> 160 <800	> 800		
SAR* **	≤ 10	> 10 < 18	> 18		
Bicarbonate ($mg.l^{-1}$)	≤ 92	> 92 < 123	> 123		
Chlorides ($mg.l^{-1}$)	≤ 142	> 142 < 284	> 284		
Boron ($mg.l^{-1}$)	≤ 0.75	> 0.75 < 0.96	> 0.96		
pH	≥4 < 6-7	7 – 8	> 8		
				Final rating	

Other factors	**Water availability**	**Water table**
Corrective action	Measurement / consultation.	Ridging
Yes (Y) or No (N)?		

N1w – some form of water treatment is indicated.

* - Electrical conductivity (EC) measured in milli Siemens per meter ($mS.m^{-1}$).

** - Concentration measured in milligrams per liter ($mg.l^{-1}$); salinity represented by the sum of Na^+, Ca^{2+}, Mg^{2+}, K^+, CO_3^{2-}, HCO_3^-, SO_4^{2-} and Cl^-.

*** - Sodium adsorption ratio (SAR). $SAR = Na^+ / \sqrt{((Ca^{2+}+Mg^{2+}) / 2)}$.

Where: Na^+ = conc. $me.l^{-1}$ Na^+ = $mg.l^{-1} Na^+ / 23$.

Ca^{2+} = conc. $me.l^{-1} Ca^{2+}$ = $mg.l^{-1} Ca^{2+} / 20$.

Mg^{2+} = conc. $me.l^{-1}$ Mg^{2+} = $mg.l^{-1} Mg^{2+} / 12$.

Conclusions on water:

Table E.2. Generic topography matching table.

Topography.	**S1.**	**S2.**	**S3.**	**N1.**	**N2.**	**Actual value.**	**Rating.**
Slope	0 – 3%	3 – 6%	6 – 10%	10 – 25%	> 25 – 30%		
						Final rating	
Other factors	**Aspect**	**Accessibility**					
Corrective action	Management / Marketing	Management / Planning / Infrastructure					
Yes (Y) or No (N)?							

Conclusions on topography:

Table E.3. Generic management matching table.

Management.	S1.	S2.	S3.	N1.	N2.	Actual vale.	Rating
Ease of cultivation (% rockiness)†	No rockiness or rock outcrops	1 – 5%	5 – 10%		> 10%		
Infrastructure and transport to market.	Possible			Co-operative or additional revenue.	Not possible ††		
						Final rating	
Other factors	Available land	Labor	Energy	Socio-economic.			
Corrective action	Acquire, lease, supplement income	Availability	Availability, accessibility, affordability.	Positive or negative.			
Yes (Y) or No (N)?							

† - berries can be grown in soils high in loose shale as they have good drainage; apply drainage class on table 3.2.

†† - niche marketing or U pick (customers pick their own berries in the fields)

Conclusions on management:

Appendix F

TABLES DEMONSTRATING THE MATCHING PROCESS FOR HAENERTSBURG

This appendix is a compilation of the matching process per study area and per berry described and demonstrated in Chapter 5. The final results of this appendix are summarized in the text on tables 5.6 through 5.13 in Chapter 5.

Haenertsburg rating tables.

Cherries.

Table F.1. Soil ratings for Cherries in Haenertsburg.

Soil.	**S1.**	**S2.**	**S3.**	**N1.**	**N2.**	**Actual value.**	**Rating.**
Drainage Use table 8.	W0	W1		W2	W3 – W4	Wo	S1
Clay content	< 15%	≤ 15 – 20%	20 – 30% **S3o**	> 30% **N1o**	> 50%	35%	N1o
Depth	≥ 1000 mm		>600 <1000 mm		< 600 mm	≥ 750	S3
pH	6.0 – 6.5	> 6.5 < 7.5		> 7.5 or < 6.0		5.3	N1
						Final Rating	N1o

Other factors	**Organic matter content**	**Previous / Current land use**
Corrective action	Apply OM	Test
Yes (Y) or No (N)?	Y	Y

S3o and N1o – indicates the need to add OM to soil.

Conclusions on soil:
Final rating for soil associated with Cherry production in Haenertsburg are N1 (currently not suitable), major limitations associated with clay content, soil pH and soil depth. Depth class will not be considered here, as current land use is forestry. Forestry is associated with deep soils. Also most usable soils under Hutton and Shortlands with depths 500 – 1200 mm. Soil treatments to increase soil OM content and adjust pH should change rating to suitable.

Table F.2. Climate ratings for Cherries in Haenertsburg.

Climate.	S1.	N1.	N2.	Actual value.	Rating.
Chill Units	1000 - 1600	> 500 < 1000 **N1cu**	< 500	734	N1cu
				Final Rating	N1cu
Other factors	**Early Frost**	**Hail**	**Wind**	**Rain & Mist**	
Corrective action	Sprinklers	Hail net	Wind break	Pack house, land drainage, plastic cover.	
Yes (Y) or No (N)?	N	Y	N	Y	

N1cu – indicates Chill Unit limitations, select low Chill Unit Cherry varieties or correct aspect or shading/chilling techniques.

Conclusions on climate:
With regard to Cherry production in Haenertsburg; N1cu (currently not suitable) is the final rating, meaning that unless suitable cultivars are selected, Cherry production in Haenertsburg has a high risk factor with respect to climate. Also late frost could damage early blooms and high rainfall could cause fruit burst.

Table F.3. Generic water ratings for Cherries in Haenertsburg.

Water.	S1.	S2.	N1.	Actual Value.	Rating.
Salinity			N 1w		
EC; $mS.m^{-1}$*	≤ 25	> 25 ≤ 75	>75	6 $mS.m^{-1}$	S1
$mg.l^{-1}$**	≤ 160	> 160 < 800	>800	106.59 $mg.l^{-1}$	S1
SAR***	≤ 10	> 10 < 18	>18	0.3438	S1
Bicarbonate ($mg.l^{-1}$)	≤ 92	> 92 < 123	>123	33.55 $mg.l^{-1}$	S1
Chlorides ($mg.l^{-1}$)	≤ 142	> 142 < 284	>284	3.86 $mg.l^{-1}$	S1
Boron ($mg.l^{-1}$)	≤ 0.75	> 0.75 < 0.96	>0.96	0.02 $mg.l^{-1}$	S1
pH	≥ 4 < 6-7	7 – 8	>8	6.2	S1
				Final rating	S1
Other factors	**Water availability**	**Water table**			
Corrective action	Measurement / consultation.	Ridging			
Yes (Y) or No (N)?	Y	Y			

N1w – some form of water treatment is indicated.

* - Electrical conductivity (EC) measured in milli Siemens per meter ($mS.m^{-1}$).

** - Concentration measured in milligrams per liter ($mg.l^{-1}$); salinity represented by the sum of Na^+, Ca^{2+}, Mg^{2+}, K^+, CO_3^{2-}, HCO_3^-, SO_4^{2-} and Cl^-.

*** - Sodium adsorption ratio (SAR). $SAR = Na^+ / \sqrt{(Ca^{2+}+Mg^{2+}) / 2}$.

Where:

Na^+ = conc. $me.l^{-1}$ Na^+ = $mg.l^{-1}Na^+$ / 23.

Ca^{2+} = conc. $me.l^{-1}Ca^{2+}$ = $mg.l^{-1}Ca^{2+}$ / 20.

Mg^{2+} = conc. $me.l^{-1}$ Mg^{2+} = $mg.l^{-1}Mg^{2+}$ / 12.

Conclusions on water:
Barring limits associated with water table depth and the availability of water; this
water is highly suitable for Cherry production.

Table F.4. Generic topography ratings for Cherries in Haenertsburg.

Topography.	S1.	S2.	S3.	N1.	N2.	Actual value.	Rating.
Slope	0 – 3%	3 – 6%	6 – 10%	10 – 25%	> 25 – 30%	8%	S3
						Final rating	S3

Other factors	Aspect	Accessibility
Corrective action	Management / Marketing	Management / Planning / Infrastructure
Yes (Y) or No (N)?	Y	Y

Conclusions on topography:
The steepness of this land is cause for concern however, appropriate contouring and
slope management will reduce risk, also the fact that Cherries are a permanent crop
where mulching and inter row sodding can be used will reduce risks associated with
slope.

Table F.5. Generic management ratings for Cherries in Haenertsburg.

Management.	S1.	S2.	S3.	N1.	N2.	Actual vale.	Rating
Ease of cultivation **(% Rockiness)†**	No rockiness or rock outcrops	1 – 5%	5 – 10%		>10%	0.0%	S1
Infrastructure and transport to market.	Possible			Co-operative or additional revenue.	Not possible ††	Possible	S1
						Final rating	S1
Other factors	**Available land**	**Labor**	**Energy**	**Socio-economic.**			
Corrective action	Acquire, lease, supplement income	Availability	Availability, accessibility, affordability.	Positive or negative.			
Yes (Y) or No (N)?	Y	Y	Y	Positive			

† - Berries can be grown in soils high in loose shale as they have good drainage; apply drainage class on table 3.2.

†† - Niche marketing or U pick (customers pick their own berries in the fields)

Conclusions on management:
In terms of management this land is highly suitable.
Because land is expensive in Haenertsburg land availability is somewhat limited, in
these cases some form of and supplemental /or co-operative farming may be
considered.

Raspberries.

Table F.6. Soil ratings for Raspberries in Haenertsburg.

Soil.	S1.	S2.	S3.	N1.	N2.	Actual vale.	Rating.
Drainage Use table 8.	W0	W1		W2	W3 – W4	Wo	S1
Clay content	< 15%	≤ 15 – 20%	20 – 30% **S3o**	>30% **N1o**	> 50%	35%	N1o
Depth	600 – 1200 mm		450 – 600 mm		< 450 mm	≥ 750 mm	S1
pH	5.5 – 6.5			< 5.5 or > 6.5 – 8.0 **N1ca; N1s**	< 4.5 > 8.0	5.3	N1s
						Final rating	N1s, o

Other factors	**Organic matter content**	**Previous / Current land use**
Corrective action	Apply OM	Test
Yes (Y) or No (N)?	Y	Y

S3o and N1o – indicates the need to add OM to soil.

N1ca – indicates the need to add Ca to increase soil pH.

N1s – indicates the need to add Sulphur to reduce soil pH.

Conclusions on soil:
Final rating for soil suitability associated with Raspberry growing in Haenertsburg is N1s, o. Currently not suitable unless soil pH can be adjusted by applying sulphur and OM.

Table F.7. Climatic ratings for Raspberries in Haenertsburg.

Climate.	S1.	N2.	Actual value.	Rating.
Chill Units	> 250 - ~ 1600 **S1v**	< 250	734	S1v
			Final rating	S1v
Other factors	**Early Frost**	**Hail**	**Wind**	**Rain & Mist**
Corrective action	Sprinklers	Hail net	Wind break	Pack house, land drainage, plastic cover.
Yes (Y) or No (N)?	N	Y	N	Y

S1v – Chill Unit requirement is variety dependent.

Conclusions on climate:
Final rating for climate suitability associated with Raspberry growing in Haenertsburg is N1v, highly suitable depending on variety. Rain and mist are serious limitations to post harvest fruit quality, it is advisable to protect fruit from direct contact with precipitation, by constructing a water proof barrier above the Raspberry plants like a plastic tunnel.

Table F.8. Generic water ratings for Raspberries in Haenertsburg.

Water.	S1.	S2.	N1.	Actual Value.	Rating.
Salinity			**N 1w**		
EC; $mS.m^{-1}$*	≤ 25	> 25 ≤ 75	> 75	6 $mS.m^{-1}$	S1
$mg.l^{-1}$**	≤ 160	> 160 < 800	> 800	106.59 $mg.l^{-1}$	S1
SAR* **	≤ 10	> 10 < 18	> 18	0.3438	S1
Bicarbonate ($mg.l^{-1}$)	≤ 92	> 92 < 123	> 123	33.55 $mg.l^{-1}$	S1
Chlorides ($mg.l^{-1}$)	≤ 142	> 142 < 284	> 284	3.86 $mg.l^{-1}$	S1
Boron ($mg.l^{-1}$)	≤ 0.75	> 0.75 < 0.96	> 0.96	0.02 $mg.l^{-1}$	S1
pH	≥ 4 < 6-7	7 – 8	> 8	6.2	S1
				Final rating	S1
Other factors	**Water availability**	**Water table**			
Corrective action	Measurement / consultation.	Ridging			
Yes (Y) or No (N)?	Y	Y			

N1w – some form of water treatment is indicated.

* - Electrical conductivity (EC) measured in milli Siemens per meter ($mS.m^{-1}$).

** - Concentration measured in milligrams per liter ($mg.l^{-1}$); salinity represented by the sum of Na^+, Ca^{2+}, Mg^{2+}, K^+, CO_3^{2-}, HCO_3^-, SO_4^{2-} and Cl^-.

*** - Sodium adsorption ratio (SAR). $SAR = Na^+ / \sqrt{(Ca^{2+}+Mg^{2+}) / 2}$.

Where:

Na^+ = conc. $me.l^{-1}$ Na^+ = $mg.l^{-1}Na^+$ / 23.

Ca^{2+} = conc. $me.l^{-1}Ca^{2+}$ = $mg.l^{-1}Ca^{2+}$ / 20.

Mg^{2+} = conc. $me.l^{-1}$ Mg^{2+} = $mg.l^{-1}Mg^{2+}$ / 12.

Conclusions on water:
Barring limits associated with water table depth and the availability of water; this
water is highly suitable for Raspberry production.

Table F.9. Generic topography ratings for Raspberries in Haenertsburg.

Topography.	**S1.**	**S2.**	**S3.**	**N1.**	**N2.**	**Actual value.**	**Rating.**
Slope	0 – 3%	3 – 6%	6 – 10%	10 – 25%	> 25 – 30%	8%	S3
						Final rating	S3
Other factors	**Aspect**	**Accessibility**					
Corrective action	Management / Marketing	Management / Planning / Infrastructure					
Yes (Y) or No (N)?	Y	Y					

Conclusions on topography:
With reards to topography, growing Raspberries in Haenertsburg is rated as S3 –
marginally suitable. Besides appropriate slope management, further limitations apply
to slope in that plastic structures have limits w.r.t. maximum slope class upon which
they can be constructed. Structure complexity and design will need to be matched to
existing slopes.

Table F.10. Generic management ratings for Raspberries in Haenertsburg.

Management.	S1.	S2.	S3.	N1.	N2.	Actual vale.	Rating
Ease of cultivation (% Rockiness)†	No rockiness or rock outcrops	1 – 5%	5 – 10%		> 10%	0.0%	S1
Infrastructure and transport to market.	Possible			Co-operative or additional revenue.	Not possible ††	Possible	S1
						Final rating	S1
Other factors	**Available land**	**Labor**	**Energy**	**Socio-economic.**			
Corrective action	Acquire, lease, supplement income	Availability	Availability, accessibility, affordability.	Positive or negative.			
Yes (Y) or No (N)?	Y	Y	Y	Positive			

† - Berries can be grown in soils high in loose shale as they have good drainage; apply drainage class on table 3.2.

†† - Niche marketing or U pick (customers pick their own berries in the fields)

Conclusions on management:
In terms of management this land is highly suitable for berry production.
Because land is expensive in Haenertsburg land availability is somewhat limited, in
these cases some form of supplemental and / or co-operative farming may be
considered. Raspberries are highly perishable and a very efficient cold chain and
marketing system need be in place.

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Appendix G

TABLES DEMONSTRATING THE MATCHING PROCESS FOR PIETERSBURG

Blueberries.

Table G.1. Soil ratings for Blueberries in Pietersburg.

Soil.	S1.	S2.	S3.	N1.	N2.	Actual value	Rating.
Drainage class (Table 8)	W0	W1		W2	W3 – W4	Wo	S1
Clay content	< 15%	15 – 20%	20 – 30%	> 30%	> 50%	25%	S3o
			S3o	**N1o**			
Depth	450 – 600 mm				< 450 mm	> 400 < 1200	S1
pH	4.2 – 5.2	3.0 – 4.2 or			0.0 – 3.0 or	4.85	S1
		5.2 – 6.0			> 6.0 – 6.5		
		S 2s and **S 2ca**					
						Final rating	S3o
Other factors	**Organic matter content**	**Previous / Current land use**					
Corrective action	Apply OM	Test					
Yes (Y) or No (N)?	Y	Y					

S3o and N1o – indicates the need to add OM to soil.

S2s – indicates the addition of Sulphur to reduce soil pH.

S2ca – indicates the addition of Ca where the soil pH is too low.

Conclusions on soil:
Soils associated with growing Blueberries in Pietersburg are generally highly suitable.
Clay content as the limiting factor resulting in a final rating of S3o – indicating the
need to introduce OM.

Table G.2. Climatic ratings for Blueberries in Pietersburg.

Climate.		Chill Units.			Actual value.	Rating.
		S1	S3	N2		
	Highbush	800 – 1100	600-800	< 600	641	S3
Variety	Rabbiteye	> 550	350 - 550	< 350	641	S1
	Southern High Bush	> 300	150 – 300	< 150	641	S1
Other factors	Early Frost	Hail	Wind	Rain & Mist		
Corrective action	Sprinklers / variety selection.	Hail net	Wind break	Pack house, land drainage, waterproof structure.		
Yes (Y) or No (N)?	Y	Y	N	Y		

Conclusions on climate:
Climate associated with growing Blueberries in Pietersburg is Marginally suitable for
Highbush and Highly suitable for Rabbiteye and Southern Highbush.
Relatively low rainfall is desirable during harvest and hail protection is strongly
advised. Variety selection imperative.

Table G.3. Generic water ratings for Blueberries in Pietersburg.

Water.	S1.	S2.	N1.	Actual Value.	Rating.
Salinity			N 1w		
EC; $mS.m^{-1}$*	≤ 25	> 25 ≤ 75	> 75	54 $mS.m^{-1}$	S2
$mg.l^{-1}$**	≤ 160	> 160 < 800	> 800		
SAR* **	≤ 10	> 10 < 18	> 18	?	
Bicarbonate ($mg.l^{-1}$)	≤ 92	> 92 < 123	> 123	142 $mg.l^{-1}$	N1
Chlorides ($mg.l^{-1}$)	≤ 142	> 142 < 284	> 284	15.9 $mg.l^{-1}$	S1
Boron ($mg.l^{-1}$)	≤ 0.75	> 0.75 < 0.96	> 0.96	?	
pH	≥ 4 <6-7	7 – 8	> 8	6.8	S1
				Final rating	N1w
Other factors	**Water availability**	**Water table**			
Corrective action	Measurement / consultation.	Ridging			
Yes (Y) or No (N)?	Y	Y			

N1w – some form of water treatment is indicated.

* - Electrical conductivity (EC) measured in milli Siemens per meter ($mS.m^{-1}$).

** - Concentration measured in milligrams per liter ($mg.l^{-1}$); salinity represented by the sum of Na^+, Ca^{2+}, Mg^{2+}, K^+, CO_3^{2-}, HCO_3^-, SO_4^{2-} and Cl^-.

*** - Sodium adsorption ratio (SAR). SAR = $Na^+ / \sqrt{((Ca^{2+}+Mg^{2+}) / 2)}$.

Where: Na^+ = conc. $me.l^{-1}$ Na^+ = $mg.l^{-1} Na^+ / 23$.

Ca^{2+} = conc. $me.l^{-1} Ca^{2+}$ = $mg.l^{-1} Ca^{2+} / 20$.

Mg^{2+} = conc. $me.l^{-1}$ Mg^{2+} = $mg.l^{-1} Mg^{2+} / 12$.

Conclusions on water:
Water quality associated with berry production in the Pietersburg area are considered
N1w (currently not suitable) but to improve water quality some form of water
treatment is indicated. Further testing indicated.

Table G.4. Generic topography ratings for Blueberries in Pietersburg.

Topography.	S1.	S2.	S3.	N1.	N2.	Actual value.	Rating.
Slope	0 – 3%	3 – 6%	6 – 10%	10 – 25%	> 25 – 30%	5%	S2
						Final rating	S2

Other factors	Aspect	Accessibility
Corrective action	Management / Marketing	Management / Planning / Infrastructure
Yes (Y) or No (N)?	Y	Y

Conclusions on topography:
Topography ratings associated with berry production in Pietersburg are S2 – moderately suitable. The permanent nature of a berry planting will reduce the risk associated with slope, however some form of slope management is indicated.

Table G.5. Generic management ratings for Blueberries in Pietersburg.

Management.	S1.	S2.	S3.	N1.	N2.	Actual vale.	Rating
Ease of cultivation (% Rockiness)†	No rockiness or rock outcrops	1 – 5%	5 – 10%		> 10%	0.0%	S1
Infrastructure and transport to market.	Possible			Co-operative or additional revenue.	Not possible ††	Possible	S1
						Final rating	S1
Other factors	**Available land**	**Labor**	**Energy**	**Socio-economic.**			
Corrective action	Acquire, lease, supplement income	Availability	Availability, accessibility, affordability.	Positive or negative.			
Yes (Y) or No (N)?	Y	Y	Y	Positive			

† - Berries can be grown in soils high in loose shale as they have good drainage; apply drainage class on table 3.2.

†† - Niche marketing or U pick (customers pick their own berries in the fields)

Conclusions on management:
Final rating associated with berry production in Pietersburg with regards to management are S1 – highly suitable. Berry production needs high levels of management.

Cherries

Table G.6. Soil ratings for Cherries in Pietersburg.

Soil.	S1.	S2.	S3.	N1.	N2.	Actual value.	Rating.
Drainage Use table 8.	W0	W1		W2	W3 – W4	W0	S1
Clay content	< 15%	≤ 15 – 20%	20 – 30% **S3o**	> 30% **N1o**	> 50%	25%	S3o
Depth	≥ 1000 mm		> 600 < 1000 mm		< 600 mm	400 – 1200 mm	S1
pH	6.0 – 6.5	> 6.5 < 7.5		> 7.5 or < 6.0		4.85	N1
						Final Rating	N1

Other factors	**Organic matter content**	**Previous / Current land use**
Corrective action	Apply OM	Test
Yes (Y) or No (N)?	Y	Y

S3o and N1o – indicates the need to add OM to soil.

Conclusions on soil:
Soil rating for Cherry production in Pietersburg is rated at N1 – Currently not
be suitable. Soil pH needs to adjusted and applying OM will be beneficial.
As the area has varied soil depths, it is advisable to assess intended lands for soil
depth.

Table G.7. Climatic ratings for Cherries in Pietersburg.

Climate.	S1.	N1.	N2.	Actual value.	Rating
Chill Units	1000 - 1600	> 500 < 1000 **N1cu**	< 500	641	N1cu
				Final Rating	N1cu
Other factors	**Early Frost**	**Hail**	**Wind**	**Rain & Mist**	
Corrective action	Sprinklers	Hail net	Wind break	Pack house, land drainage, plastic cover.	
Yes (Y) or No (N)?	N	Y	N	Y	

N1cu – indicates Chill Unit limitations, select low Chill Unit Cherry varieties or correct aspect or shading/chilling techniques.

Conclusions on climate:
With respect to growing Cherries in the Haenertsburg area – climate rates as N1cu –
Currently not suitable, barring a cultivar or variety that may be tolerant of the realised
Chill Units. Low rainfall is a benefit w.r.t. post harvest fruit quality and fruit burst,
hail netting is highly recommended.

Table G.8. Generic water ratings for Cherries in Pietersburg.

Water.	S1.	S2.	N1.	Actual Value.	Rating.
Salinity			N 1w		
EC; $mS.m^{-1}$*	≤ 25	> 25 ≤ 75	> 75	54 $mS.m^{-1}$	S2
$mg.l^{-1}$**	≤ 160	> 160 < 800	> 800		
SAR***	≤ 10	> 10 < 18	> 18	?	
Bicarbonate ($mg.l^{-1}$)	≤ 92	> 92 < 123	> 123	142 $mg.l^{-1}$	N1
Chlorides ($mg.l^{-1}$)	≤ 142	> 142 < 284	> 284	15.9 $mg.l^{-1}$	S1
Boron ($mg.l^{-1}$)	≤ 0.75	> 0.75 < 0.96	> 0.96	?	
pH	≥ 4 < 6-7	7 – 8	> 8	6.8	S1
				Final rating	N1w
Other factors	**Water availability**	**Water table**			
Corrective action	Measurement / consultation.	Ridging			
Yes (Y) or No (N)?	Y	Y			

N1w – some form of water treatment is indicated.

* - Electrical conductivity (EC) measured in milli Siemens per meter ($mS.m^{-1}$).

** - Concentration measured in milligrams per liter ($mg.l^{-1}$); salinity represented by the sum of Na^+, Ca^{2+}, Mg^{2+}, K^+, CO_3^{2-}, HCO_3^-, SO_4^{2-} and Cl^-.

*** - Sodium adsorption ratio (SAR). $SAR = Na^+ / \sqrt{((Ca^{2+}+Mg^{2+}) / 2)}$.

Where: Na^+ = conc. $me.l^{-1}$ Na^+ = $mg.l^{-1} Na^+ / 23$.

Ca^{2+} = conc. $me.l^{-1} Ca^{2+}$ = $mg.l^{-1} Ca^{2+} / 20$.

Mg^{2+} = conc. $me.l^{-1}$ Mg^{2+} = $mg.l^{-1} Mg^{2+} / 12$.

Conclusions on water:
Water quality ratings in the Pietersburg area are N1w (currently not suitable).
Treat water where possible or further testing indicated.

Table G.9. Generic topography ratings for Cherries in Pietersburg.

Topography.	**S1.**	**S2.**	**S3.**	**N1.**	**N2.**	**Actual value.**	**Rating.**
Slope	0 – 3%	3 – 6%	6 – 10%	10 – 25%	> 25 – 30%	5%	S2
						Final rating	S2
Other factors	**Aspect**	**Accessibility**					
Corrective action	Management / Marketing	Management / Planning / Infrastructure					
Yes (Y) or No (N)?	Y	Y					

Conclusions on topography:
Topography ratings associated with berry production in Pietersburg are S2 –
moderately suitable. The permanent nature of a berry planting will reduce the risk
associated with slope, however some form of slope management is indicated.

Table G.10. Generic management ratings for Cherries in Pietersburg.

Management.	S1.	S2.	S3.	N1.	N2.	Actual vale.	Rating
Ease of cultivation (% Rockiness)†	No rockiness or rock outcrops	1 – 5%	5 – 10%		> 10%	0.0%	S1
Infrastructure and transport to market.	Possible			Co-operative or additional revenue.	Not possible ††	Possible	S1
						Final rating	S1
Other factors	Available land	Labor	Energy	Socio-economic.			
Corrective action	Acquire, lease, supplement income	Availability	Availability, accessibility, affordability.	Positive or negative.			
Yes (Y) or No (N)?	Y	Y	Y	Positive			

† - Berries can be grown in soils high in loose shale as they have good drainage; apply drainage class on table 3.2.

†† - Niche marketing or U pick (customers pick their own berries in the fields)

Conclusions on management:
Final rating associated with berry production in Pietersburg concerning management
is S1 – highly suitable. Berry production needs high levels of management.

Raspberries.

Table G.11. Soil ratings for Raspberries in Pietersburg.

Soil.	**S1.**	**S2.**	**S3.**	**N1.**	**N2.**	**Actual vale.**	**Rating.**
Drainage Use table 8.	W0	W1		W2	W3 – W4	Wo	S1
Clay content	< 15%	≤ 15 – 20%	20 – 30% **S3o**	> 30% **N1o**	> 50%	25%	S3
Depth	600 – 1200 mm		450 – 600 mm		< 450 mm	400-1200 mm	S1
pH	5.5 – 6.5			< 5.5 or > 6.5 – 8.0 **N1ca; N1s**	< 4.5 > 8.0	4.85	N1
						Final rating	N1ca

Other factors	**Organic matter content**	**Previous / Current land use**
Corrective action	Apply OM	Test
Yes (Y) or No (N)?	Y	Y

S3o and N1o – indicates the need to add OM to soil.

N1ca – indicates the need to add Ca to increase soil pH.

N1s – indicates the need to add Sulphur to reduce soil pH.

Conclusions on soil:
With respect to land rating in Pietersburg the soil has an N1ca rating, - currently not
suitable unless Ca is applied to adjust pH.
Adjust soil pH and apply OM.

Table G.12. Climate ratings for Raspberries in Pietersburg.

Climate.	S1.	N2.	Actual value.	Rating.
Chill Units	> 250 - ~ 1600 S1v	< 250	641	S1v
			Final rating	S1v
Other factors	**Early Frost**	**Hail**	**Wind**	**Rain & Mist**
Corrective action	Sprinklers	Hail net	Wind break	Pack house, land drainage, plastic cover.
Yes (Y) or No (N)?	Y	Y	Y	Y

S1v – Chill Unit requirement is variety dependent.

Conclusions on climate:
With regards to land classification in Pietersburg; climate is S1v, - highly suitable for
growing Raspberries depending on the variety. The variety must be compatible with
641 CU. Hail netting highly recommended

Table G.13. Generic water ratings for Raspberries in Pietersburg.

Water.	S1.	S2.	N1.	Actual Value.	Rating.
Salinity			N 1w		
EC; $mS.m^{-1}$*	≤ 25	> 25 ≤ 75	> 75	54 $mS.m^{-1}$	S2
$mg.l^{-1}$**	≤ 160	> 160 < 800	> 800		
SAR* **	≤ 10	> 10 < 18	> 18	?	
Bicarbonate ($mg.l^{-1}$)	≤ 92	> 92 < 123	> 123	142 $mg.l^{-1}$	N1
Chlorides ($mg.l^{-1}$)	≤ 142	> 142 < 284	> 284	15.9 $mg.l^{-1}$	S1
Boron ($mg.l^{-1}$)	≤ 0.75	> 0.75 < 0.96	> 0.96	?	
pH	≥ 4 < 6-7	7 – 8	> 8	6.8	S1
				Final rating	N1w
Other factors	**Water availability**	**Water table**			
Corrective action	Measurement / consultation.	Ridging			
Yes (Y) or No (N)?	Y	Y			

N1w – some form of water treatment is indicated.

* - Electrical conductivity (EC) measured in milli Siemens per meter ($mS.m^{-1}$).

** - Concentration measured in milligrams per liter ($mg.l^{-1}$); salinity represented by the sum of Na^+, Ca^{2+}, Mg^{2+}, K^+, CO_3^{2-}, HCO_3^-, SO_4^{2-} and Cl^-.

*** - Sodium adsorption ratio (SAR). $SAR = Na^+ / \sqrt{(Ca^{2+}+Mg^{2+}) / 2}$.

Where:

Na^+ = conc. $me.l^{-1}$ Na^+ = $mg.l^{-1}Na^+$ / 23.

Ca^{2+} = conc. $me.l^{-1}Ca^{2+}$ = $mg.l^{-1}Ca^{2+}$ / 20.

Mg^{2+} = conc. $me.l^{-1}$ Mg^{2+} = $mg.l^{-1}Mg^{2+}$ / 12.

Conclusions on water:
Water quality associated with berry production in the Pietersburg area are considered
N1w (currently not suitable) but to improve water quality some form of water
treatment is indicated. Further testing indicated.

Table G.14. Generic topography ratings for Raspberries in Pietersburg.

Topography.	**S1.**	**S2.**	**S3.**	**N1.**	**N2.**	**Actual value.**	**Rating.**
Slope	0 – 3%	3 – 6%	6 – 10%	10 – 25%	> 25 – 30%	5%	S2
						Final rating	S2
Other factors	**Aspect**	**Accessibility**					
Corrective action	Management / Marketing	Management / Planning / Infrastructure					
Yes (Y) or No (N)?	Y	Y					

Conclusions on topography:
Topography ratings associated with berry production in Pietersburg are S2 –
moderately suitable. The permanent nature of a berry planting will reduce the risk
associated with slope, however some form of slope management is indicated.

Table G.15. Generic management ratings for Raspberries in Pietersburg.

Management	S1.	S2.	S3.	N1.	N2.	Actual vale.	Rating
Ease of cultivation (% Rockiness)†	No rockiness or rock outcrops	1 – 5%	5 – 10%		> 10%	0.0%	S1
Infrastructure and transport to market.	Possible			Co-operative or additional revenue.	Not possible ††	Possible	S1
						Final rating	S1
Other factors	Available land	Labor	Energy	Socio-economic.			
Corrective action	Acquire, lease, supplement income	Availability	Availability, accessibility, affordability.	Positive or negative.			
Yes (Y) or No (N)?	Y	Y	Y	Positive			

† - Berries can be grown in soils high in loose shale as they have good drainage; apply drainage class on table 3.2.

†† - Niche marketing or U pick (customers pick their own berries in the fields)

Conclusions on management:
Final rating associated with berry production in Pietersburg with regards to
management are S1 – highly suitable. Raspberry production needs high levels of
management and marketing.

Appendix H

BOTANICAL DESCRIPTION OF BLUEBERRIES, CHERRIES AND RASPBERRIES.

The following descriptions are adapted from publications issued by the University of Georgia (Rieger, 2002).

Blueberries.

Figure H.1. Rabbiteye Blueberries at various stages of ripening.

Taxonomy.

Three commercially important Blueberry species are recognized; along with two inter-specific hybrids:

1. *Vaccinium corymbosum* L. - **Highbush Blueberry** (figure H.1 above). Native range is sunny, acidic, swampy areas of eastern North America, from Nova Scotia west to Wisconsin, south to northern Georgia.

2. *V. ashei* Raede - **Rabbiteye Blueberry**. Native to river bottoms and swampy, acid soils of southern Georgia and Alabama to northern Florida. Similar to highbush in habit, but lower chilling requirement (earlier bloom) and longer period from flowering to maturity (90 days v. 45 - 75 days). Rabbiteye fruit has somewhat thicker skin and more (larger) seeds.

3. **Lowbush Blueberry** - *V. angustifolium, V. myrtilloides, V. brittonii, V. lamarckii. V. myrtilloides* is the predominant species in recently established fields, but *V. angustifolium* is most abundant in older plantings, and is the lowbush Blueberry of commerce.

4. **Southern highbush** - *V. corymbosum x V. darrowi or V. ashei.* Recently introduced from the University of Florida breeding program. Similar in most ways to northern highbush, but very low-chilling (250 - 500 CU); Fruit ripen earliest of all Blueberries.

5. **Half-high highbush** - *V. corymbosum x V. angustifolium*. These are the recent products of the Minnesota and Michigan breeding programs. The bushes are short-statured (0.6 m - 1.2 m), cold hardy, and similar to highbush in fruit characteristics. They are designed to be adapted to the extreme winters and snow loads of the northern continental US.

Botanical description.

Plant:

1. Highbush - Erect, deciduous shrubs, to 4 meters, 1.0 m -3.0 m in cultivation. Leaves small (25 mm – 50 mm length), ovate or elliptic, entire margins.

2. Rabbiteye - Erect shrub to 10 m, 1.0 – 3.0 m in cultivation. Leaves small (25 mm – 50 mm length), ovate or elliptic, entire margins.

3. Lowbush - Low-growing (less than 900 mm, usually 800 mm), trailing, rhizomatous shrubs. Main portion of plant is rhizome 25 – 75 mm under surface, which produces upright shoots along its length, concentrated at tip. Leaves are smaller than highbush or rabbiteye (10-12 mm) and have mildly serrate margins.

Flowers: For all species - White or cream flowers (1 - 16, usually 7 - 10) are borne on short racemes (25 – 50 mm), on upper portion of 1-yr-old wood (see figure H.2). Flowers are urn-shaped, and inverted, on very short pedicels (nearly sessile). Flower (inflorescence) buds are noticeably larger and more conical shaped than vegetative buds.

Figure H.2. Blueberry flowers.

Pollination:

1. Highbush is self-fruitful, but higher set and larger fruit occur with pollinizer. Bees are necessary for pollination even in self-fruitful types since flowers are inverted, and pollen falls out of the flower without impacting the stigma.

2. Rabbiteye and Southern Highbush cultivars, in contrast to highbush, are partially or completely self-incompatible, and require pollinizers usually in alternate rows.

3. Lowbush are highly self-incompatible, must have pollinizer to set fruit. Fruit ripens 70 - 90 days after fertilization.

Bumble bees (*Bumbus sp*.) and the southeastern Blueberry bee (*Harbropoda laboriosa*) pollinate flowers naturally, whereas honey bees are much less effective. This stems from the differential ability of bumble and honey bees to "sonicate" flowers and stimulate pollen release. The frequency of wing flapping of bumble bees is such that anthers dehisce and release pollen; honey bees flap their wings at a different frequency.

Fruit: in all cases, an epigenous berry (figure H.3).

Figure H.3. Blueberry fruits.

1. Highbush - blue-black color; good fruit quality, but most processed. Shortest period from flowering to maturity of all Blueberries (45 - 75 days).

2. Rabbiteye - blue-black color; good fruit quality, most processed. Fruit mature in about 90 days from corolla drop.

3. Lowbush -black to bright blue color, inferior fruit quality to other cultivated types, 99% processed. Intermediate fruit maturation period of 70 - 90 days.

All species - high degree of set required for full crop (60-80%) - no thinning.

Cherries.

There are two types of Cherries, sweet Cherries or fresh fruit Cherries and Sour or Tart Cherries used in cooking and processing.

Taxonomy.

Cherries occupy the *Cerasus* subgenus within *Prunus*, being fairly distinct from plums, apricots, peaches, and almonds. They are members of the Rosaceae family, subfamily *Prunoideae*. *Prunus avium* L. is the Sweet Cherry, and *Prunus cerasus* L. the Sour Cherry.

As a group, Cherries are relatively diverse and broadly distributed around the world, being found in Asia, Europe, and North America. In addition to the main species above, *P. fruticosa* (ground Cherry) and *P. pseudocerasus* (Chinese Cherry) are minor fruit species in the former USSR and China. While sweet Cherries are virtually all *P. avium*, the term sour Cherry may include hybrids between *P. avium* and *P. cerasus* (referred to as "Duke Cherries"), ground Cherry, and hybrids of ground Cherry with *P. cerasus.* (Rieger 2002)

Botanical description.

A. Sweet Cherry.

Plant: Vigorous tree with strong apical control with an erect-pyramidal canopy shape; grows to 18 m. In cultivation, sweet Cherries are maintained less than 4 m in height. Leaves are relatively large, elliptic with acute tips, petiolate, and strongly veined.

Figure H.4. Cherry flower buds and flowers.

Flowers: White, with long pedicels, borne in racemose clusters of 2-5 flowers on short spurs with multiple buds at tips; the distal bud is vegetative and continues spur growth (figure H.4 and H.5). Spurs are long-lived, producing for 10-12 years. Bloom occurs relatively late in spring, so frost is less of a hazard than for other stone fruits, except sour Cherries, which bloom slightly later.

Figure H.5. Section of Cherry male and female fruiting bodies.

Pollination: Pollination is absolutely essential for production, since sweet Cherries are self-incompatible. 25-50% of flowers must set fruit for a commercial crop. Bees are the main pollinator. Pollinizers are usually set every third tree in every third row, or in alternate rows.

Fruit: A drupe; small 12 – 25 mm diameter, glabrous, with long pedicel attached. Fruit color ranges from pale yellow to dark purple (black).

Thinning is unnecessary for fruit size development, and since a high proportion of flowers must set for a crop, this is not practiced.

Maximum yields are obtained beginning in the 5-6th year after budding, and trees are productive for 25-30 years, despite living much longer.

B. Sour or tart Cherry.

Plant: Medium sized tree with a rounder, more spreading habit than the erect sweet Cherry. Kept less than 4 m in cultivation. Leaves, elliptic with acute tips, smaller than sweet Cherry; petiolate.

Flower: Similar to sweet Cherry. Sour Cherry inflorescence buds usually produce 2-4 flowers, with long pedicels, as in sweet Cherry. However, 35-45% of the flowers are borne laterally on 1 year wood, not exclusively on spurs as in sweet Cherries. Spurs are shorter-lived on sour than sweet, gradually declining in productivity over 3-5 years.

Sour Cherries are the latest blooming of the stone fruits, therefore would be less frost prone than sweets.

Pollination: Sour Cherries are self-fertile, and require no pollinizers.

Fruit: Fruits are the same as for sweet Cherry, but sour Cherries generally have lower sugars and higher organic acid contents, and are generally red in color (figure H.6). Fruiting begins earlier for sour Cherry trees, after 3-4 yr. Productive life is shorter, however, only 20-25 years. Thinning is unnecessary for sours since a high proportion must set for a full crop.

Figure H.6. Sour or tart Cherry fruits.

Raspberries.

Taxonomy.

Blackberries and Raspberries, often termed "Brambles", are a diverse group of species in the genus *Rubus*. They are members of the *Rosaceae* family, subfamily *Rosoideae*. *Rubus* is one of the most diverse genus of angiosperms in the world, consisting of 12 subgenera, some with hundreds of species. The geographic distribution ranges from the Arctic Circle (Arctic berry) to the tropics (Mysore Raspberry), on every continent except Antarctica.

1. Subgenus *Eubatus* - Blackberries and dewberries. Dewberries are basically smaller, prostrate, low-chill blackberries native mostly to the southeastern US.

2. Subgenus *Idaeobatus* - Raspberries (200 species)

Red Raspberry - *R. idaeus* L. (figure H.7).

The European subspecies of this group is designated *R. idaeus* subsp. *vulgatus* Arrhen, whereas the North American red Raspberry is termed *R. idaeus* subsp. *strigosus* Michx, or more simply *R. idaeus* (European) and *R. strigosus* (North American).

Black Raspberry - *R. occidentalis* L.

The distinction between Blackberries (figure H.8) and Raspberries revolves around fruit characteristics. All *Rubus* fruits are aggregates of druplets, but Raspberry druplets come free from the receptacle, whereas blackberry receptacles come off with druplets. Also, Raspberry druplets are hairy and adhere to one-another, whereas blackberry druplets are glabrous.

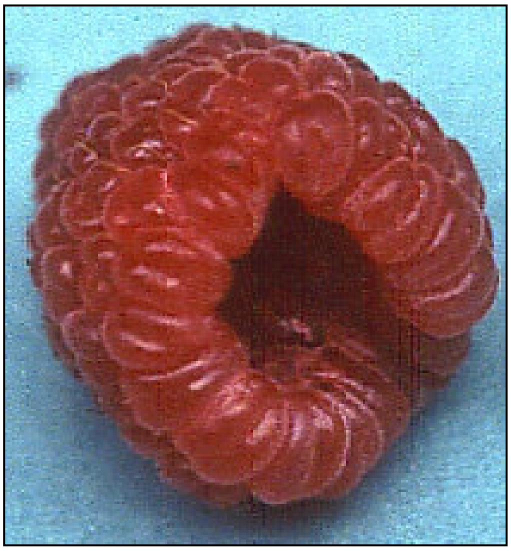

Figure H.7. Red Raspberry fruit showing fruit druplets and the hole where the receptacle comes away from the fruit at picking.

Botanical description.

Figure H.8. Blackberry fruits.

Plant: *Rubus* species are prostrate to erect, generally thorny shrubs producing renewal shoots from the ground (called canes). They are perennials only because each bush consists of biennial canes which overlap in age. Individual canes grow vegetatively for one year, initiate flower buds in late summer, and fruit the following spring-summer, and then die. Leaves are compound with 3-5 leaflets, the middle one being the largest; margins serrate to irregularly toothed.

Figure H.9. Raspberry buds and flowers.

Flower: Small (1-1.5 cm), white to pink flowers are borne terminally on several-flowered racemes (10-20 flowers/cluster for blackberry, 10 for dewberry) of current season's growth (figure 38). For dewberry and some blackberries, inflorescences are cymose (determinate, central flower opens first). Flowers are initiated in late summer in biennial types, mid-summer in primocane fruiting types. The gynoecium's consists of 60-80 ovaries, each of which develops into a druplet. There are 60-90 stamens. Black- and Raspberries produce copious amounts of nectar, and attract bees.

Pollination: Most commercial cultivars of blackberries and Raspberries are self-fruitful and do not require pollinizers. However, dewberries are self-sterile, and must be interplanted for good fruit set. Honey bees are naturally attracted to brambles, and wind also aids pollination. Bees should be supplied if natural populations are low.

Fruit: In all cases, fruit are classified as an aggregate of drupelets. In black - and dewberries, since the receptacle detaches with the fruit, it also may be considered an accessory fruit. Pyrenes (stones) are larger in blackberry druplets.

Fruiting begins in the second year of the planting, and continues for greater than 10 years if properly managed. Primocane or autumn-fruiting types produce 2 crops per year if not mowed.

Yields in well-managed plantings in Georgia average 5000 - 10,000 $kg.ha^{-1}$

Fruit development occurs rapidly, taking only 30-36 days for most Raspberries, but 40-70 days for blackberries.

Appendix I

FURTHER INFORMATION ON BLUEBERRY SPECIES AND VARIETIES

City Gardening (2005) describes Blueberries as; **Lowbush Blueberries (V. augustifolium Ait)** grows wild in northeastern states and Canada. The plants grow between 150 to 200 mm high. Common lowbush has shiny smooth tooth leaves. Black Lowbush (V.augustifolium forma nigrum) has blue-green leaves with shiny blackberries. Various types of bees pollinate them. The berries have excellent flavor but are of a smaller size.

Highbush Blueberries (V. corymbosum L) grow wild from Florida to Maine and from Ontario to southern Michigan. The plants grow to between 2.5 m to 3 m high. The berries are sweet with a mild flavor. They have been grown up into zone 3 but their southern range is limited by a fairly high chilling requirement of 700 hours or greater.

Dry-land Blueberries (V. pallidum Ait) grow from northern Alabama and Georgia to Maryland and West Virginia. The plants grow between 1.0 m to 1.5 m high and spread by underground shoots. They are drought resistant and survive in fairly poor soils. The Blueberries are tasty and ripen later than lowbush and highbush cultivars.

Evergreen Blueberries (V. ovatium Par.) are grown in California, Oregon, and Washington. The plants grow up to 6m high. The berries are shiny black with a very strong flavour that makes them more suitable for pies than eating fresh.

Mountain Blueberries (V. membranaceaum Doug) grow in the northwest part of the United States. They grow from 1.0 m to 1.5 m tall. The berries are black or maroon with a tart flavour.

Rabbiteye Blueberries (V. ashei Read) grow in the southeastern part of the United States. They can grow from 3.0 m to 7.0 m high. They thrive in hot humid environments. They are not as cold hardy as other cultivars and so they are generally limited to growing in zones 6 or above. The berries are small and somewhat gritty. They generally required more than one cultivar to get good fruit set.

Southern highbush is a cross between northern highbush varieties and Blueberry species native to Florida.

Appendix J

ANOMALIES

1. According to Prinsloo (2002), the best Blueberry production observed to date in South Africa, was under 20% white hail net, attributed to reduced Ultra Violet radiation. Generally in the USA and in South Africa, Blueberries are grown in full sun. The differences in production are yet to be quantified but must be taken into consideration.

2. According to Prinsloo (2002), Blueberries were produced in Lydenburg on soils with a clay content of 70%. At point SL on Fig 2, Blueberries are currently and successfully produced on soils with a clay content of 35 - 55%. Note: at point SL, when Blueberries were established, the land received heavy applications of compost. Both sites have high clay contents, however, soil drainage is adequate at point SL.

3. Soil pH for Blueberry production should be 4.2 – 5.2 however, Kinsey and Walters (1999) state that the soil pH can reach 6.0 – 6.5 as long as the nutrient balance is correct. Further investigation reveals that low Ph soils are required for Blueberry production so as to reduce Iron deficiencies (Prinsloo 2002; Strik *et.al.* 2002).

Appendix K

GENERAL MAPS

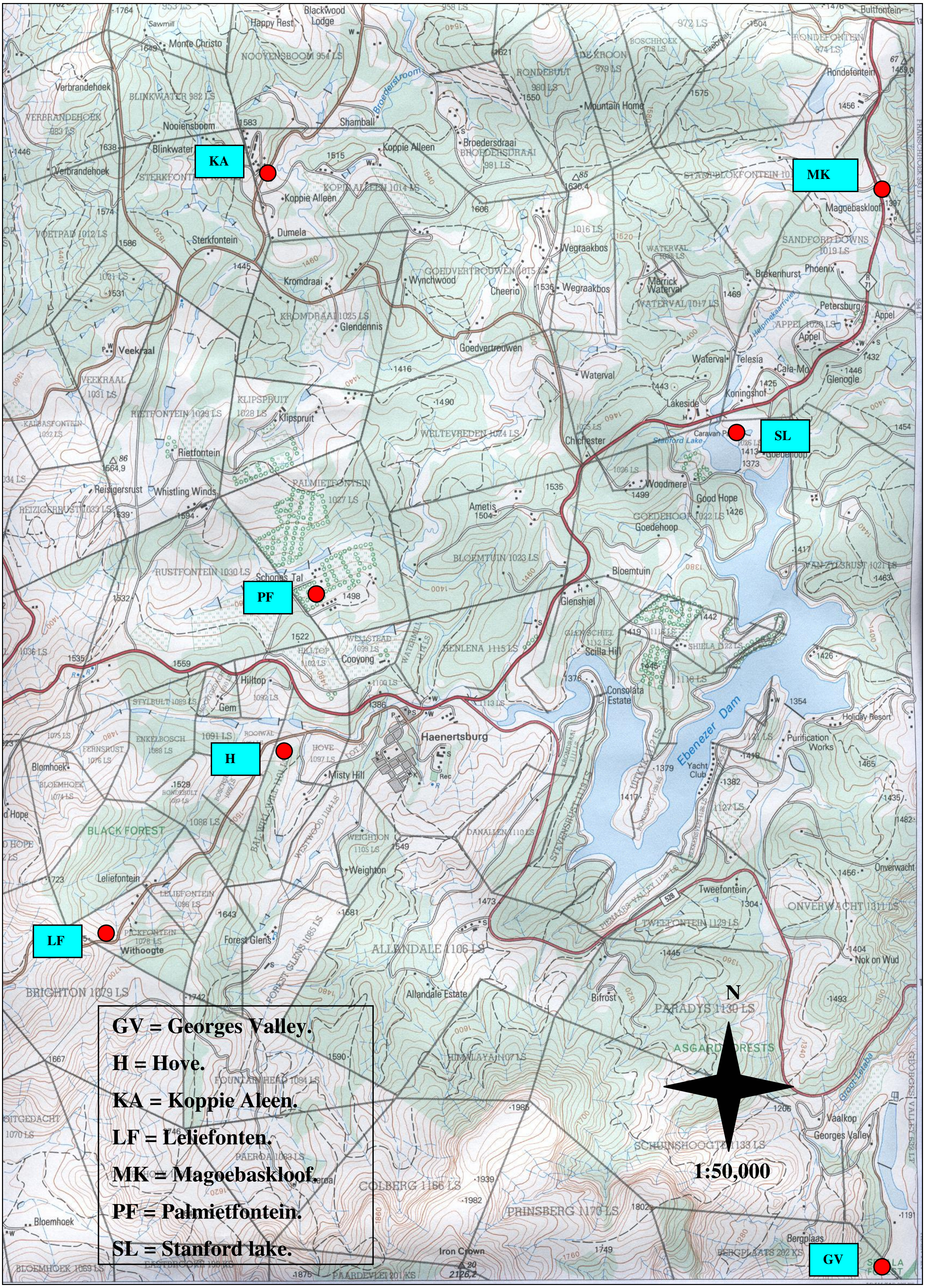

Figure K.1. Showing the Haenertsburg study area with sample sites.

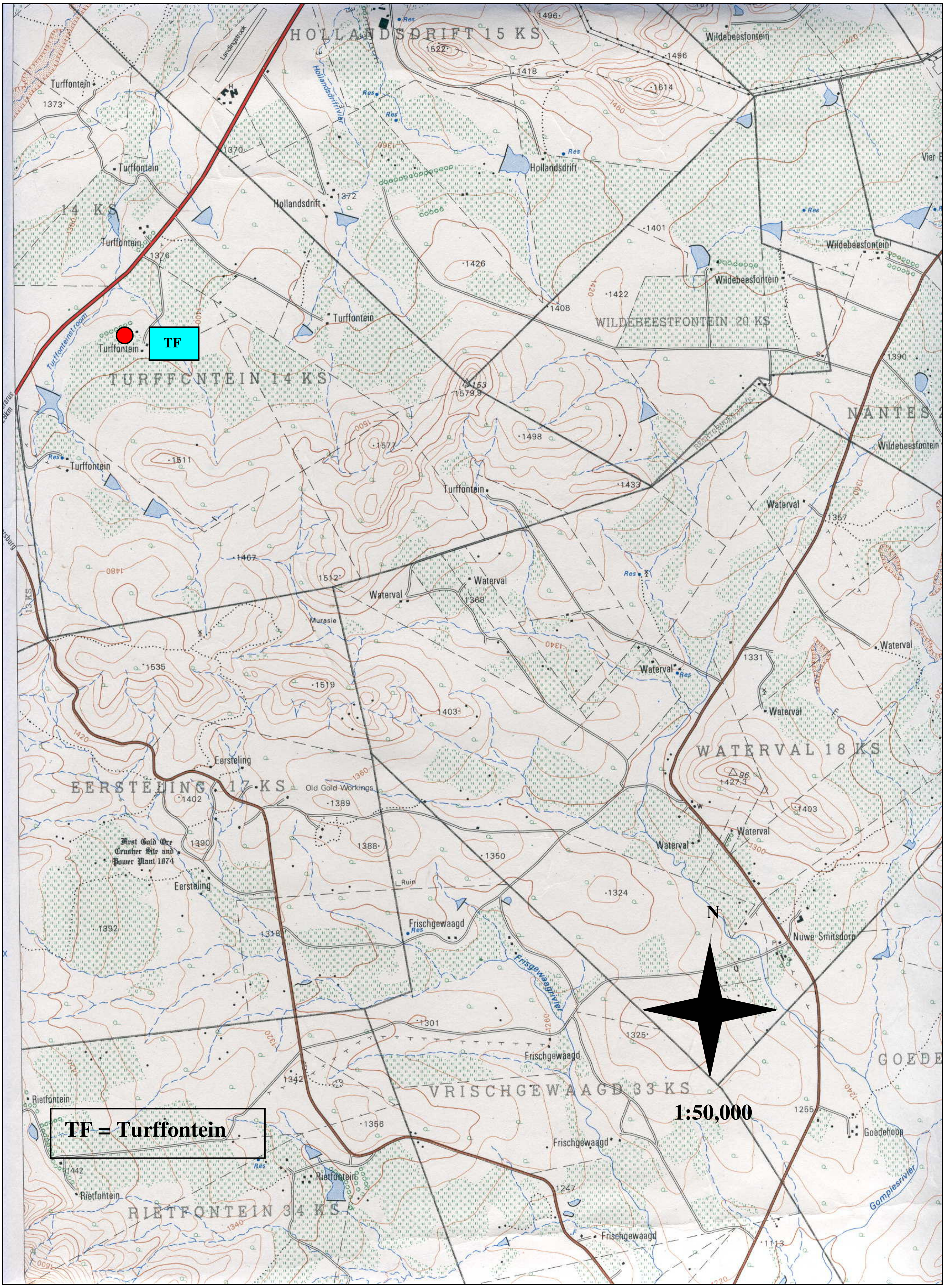

Figure K.2. Pietersburg area showing sample site on Turffontein.

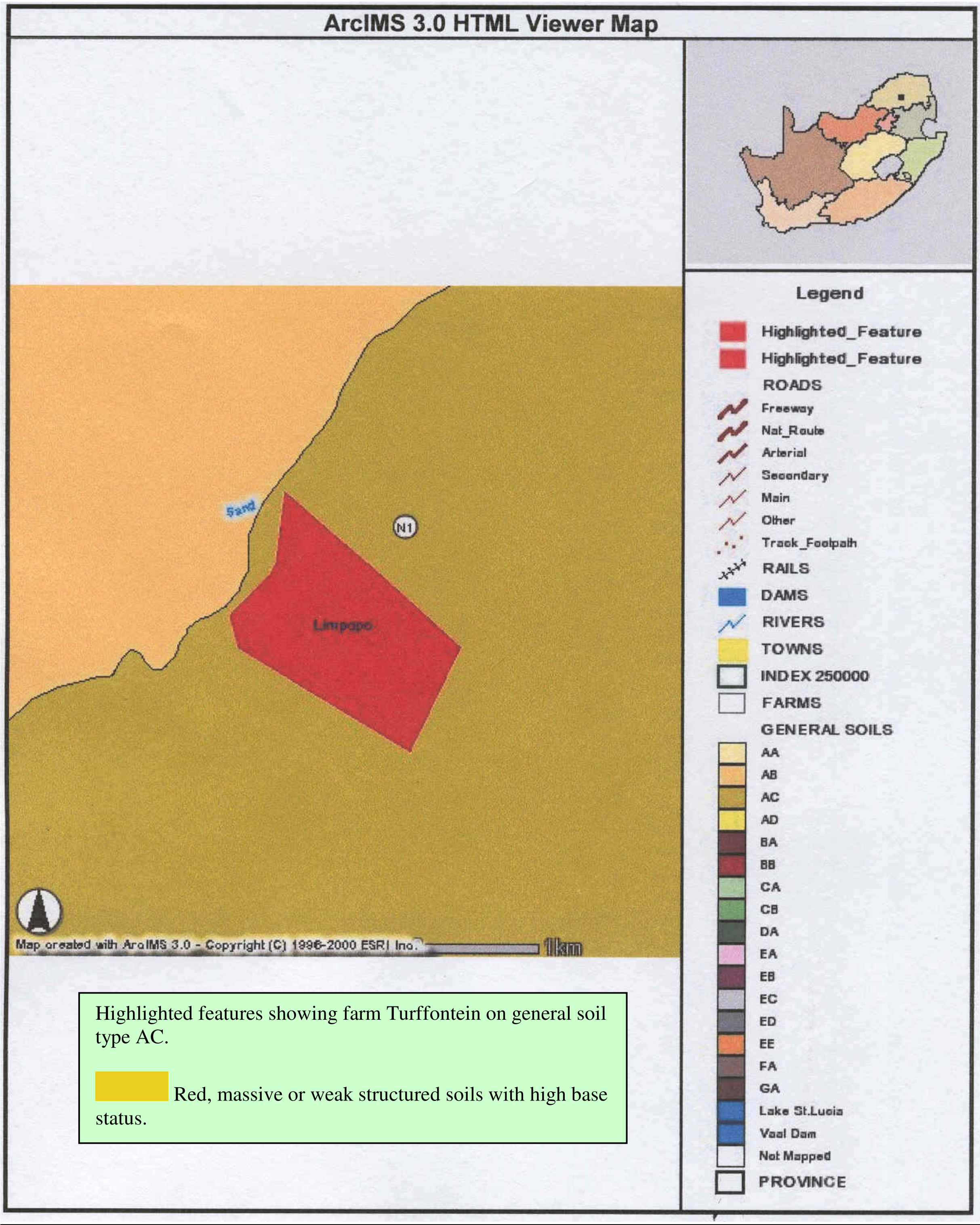

Figure K.3. Showing a general soil map of Turffontein taken from AGIS.