SOILS OF THE PROPOSED WAROONA MINESITE

DESKTOP STUDY

Prepared for:

Iluka Resources Limited
ABN 34 008 675 018
PO Box 96, Capel, WA 6271

Prepared by:

Soil Water Consultants
ABN 45 096 843 659
PO Box 153, Applecross, WA 6153
Tel: 0427 105 200; Fax: (08) 9364 1625
Email: swc@soilwater.biz

26th July, 2004

PN0046-1-IR-035, Rev. 0

Document Status Record

Project Title: Desktop Study of the Soils in the Proposed Waroona Minesite

Project Number: PN0046-1-IR-035

Client: Iluka Resources Limited

Date Commenced: 01/06/04

Revision code	Date revised	Comments	Signatures		
			Originator	Checked	Approved
0	26/07/04	Submitted report to Lisa Sadler	ASP	AJH	ASP

Limitations Statement

The purpose of this report and the associated services performed by Soil Water Consultants (SWC) is to conduct a desktop study of the soils in the proposed Waroona Minesite. This work was conducted in accordance with the Scope of Work submitted to Iluka Resources ('the Client').

SWC performed the services in a manner consistent with the normal level of care and expertise exercised by members of the earth sciences profession. Subject to the Scope of Work, the desktop soil study was confined to the proposed Waroona Minesite area. In preparing this study, SWC has relied on published soil reports from various soil researchers and information provided by the Client. All information is presumed accurate and SWC has not attempted to verify the accuracy or completeness of such information. While normal assessments of data reliability have been made, SWC assumes no responsibility or liability for errors in this information. All conclusions and recommendations are the professional opinions of SWC personnel.

SWC is not engaged in reporting for the purpose of advertising, sales, promoting or endorsement of any client interests. No warranties, expressed or implied, are made with respect to the data reported or to the findings, observations and conclusions expressed in this report. All data, findings, observations and conclusions are based solely upon site conditions at the time of the investigation and information provided by the Client.

This report has been prepared on behalf of and for the exclusive use of the Client, its representatives and advisors. SWC accepts no liability or responsibility for the use of this report by any third party.

Project Summary

Iluka Resources Limited (Iluka) proposes to mine the mineralised beach deposits at the Waroona Minesite. This report represents a desktop study of the soils likely to be encountered during mining of the deposit, and provides an overview of the characteristics of these soils. This information will be used to assist mine and environmental planning and initial development of rehabilitation strategies.

The Waroona Minesite consists of three principal minepits covering a total area of 70ha. The North and South Minepits occur at a surface elevation of 60 – 90m and will access the Ridge Hill Shelf beach deposit. The Main Minepit occurs to the west of the North and South Minepits, surface elevation 38 – 70m, and will access the more recent Waroona beach deposit.

Assessment of previous soil surveys conducted in the vicinity of the Waroona Minesite, indicate that the Lotons and Gwindinup soil types dominate the area. Both soil types originally formed by colluvial processes transporting sand, sandy clay and gravel material from the adjacent Darling Scarp. Considerable pedogenesis has occurred since deposition, redistributing the sandy, silt and clay throughout the profile. Pedogenesis is facilitated by the elevated topographic position of these soils, ensuring permanent oxidising conditions in the surface soils.

The Lotons soil type consists of moderate-deep yellow-brown surface sand that gradually alters to a gravelly sandy loam at depth. The surface sands overlie a yellow-brown and yellow-red mottled sandy clay subsoil, and large lateritic boulders commonly occur at the duplex boundary. In contrast, the Gwindinup soil type has an absence of gravel and consists of deep to very deep yellow-brown sand.

Mapping of the exploration drilling data (i.e. sand and silt+clay contents) reveals that the soils in the Waroona Minesite exhibit considerable spatial (lateral and vertical) heterogeneity. Deep regions of sand, identified by this mapping, may represent areas of local and regional groundwater recharge. Investigation is required to quantify the role of these regions to the hydrogeology, so that rehabilitation strategies can be developed to restore their functioning, post-mining, if identified to be important.

Table of Contents

1.0 Introduction

Iluka Resources Limited (Iluka) engaged Soil Water Consultants (SWC) to conduct a desktop study of the soils in the proposed Waroona Minesite. The purpose of this study was to provide an overview of the soils within the minesite to assist in mine and environmental planning and initial development of rehabilitation strategies. This study provides a '*first pass*' assessment of the soils within the Waroona Minesite, which will be investigated in more detail when the Soil Management Study is conducted.

1.1 Objectives of Work

The objectives of the work were to:

- Review published soil studies that have been conducted in the vicinity of the proposed minesite;
- Describe the soils likely to be found in the proposed minesite;
- Prepared an initial soils map of the area;
- Map the vertical distribution of soils through the overburden, using exploration drilling data;
- Report on the spatial complexity of soils within the minesite;

1.2 Scope of Work

The scope of work to be completed by Soil Water Consultants included:

- Obtain and review existing soil studies covering the area of the proposed minesite;
- Summarise the information contained in these studies and prepare an initial soils map of the area;
- Obtain the exploration drilling data for the minesite, and map the distribution of the overburden soils;
- Preparation of this report.

2.0 Site Location and Description of the Waroona Minesite

2.1 Location of the Proposed Waroona Minesite

The proposed Waroona Minesite is located within the Shire of Waroona, approximately 100 km south-east of Perth and 4km north of the Waroona townsite (Figure 2.1). It is situated on the eastern side of the South Western Highway, between Peel and Wealand Roads (Figure 2.2).

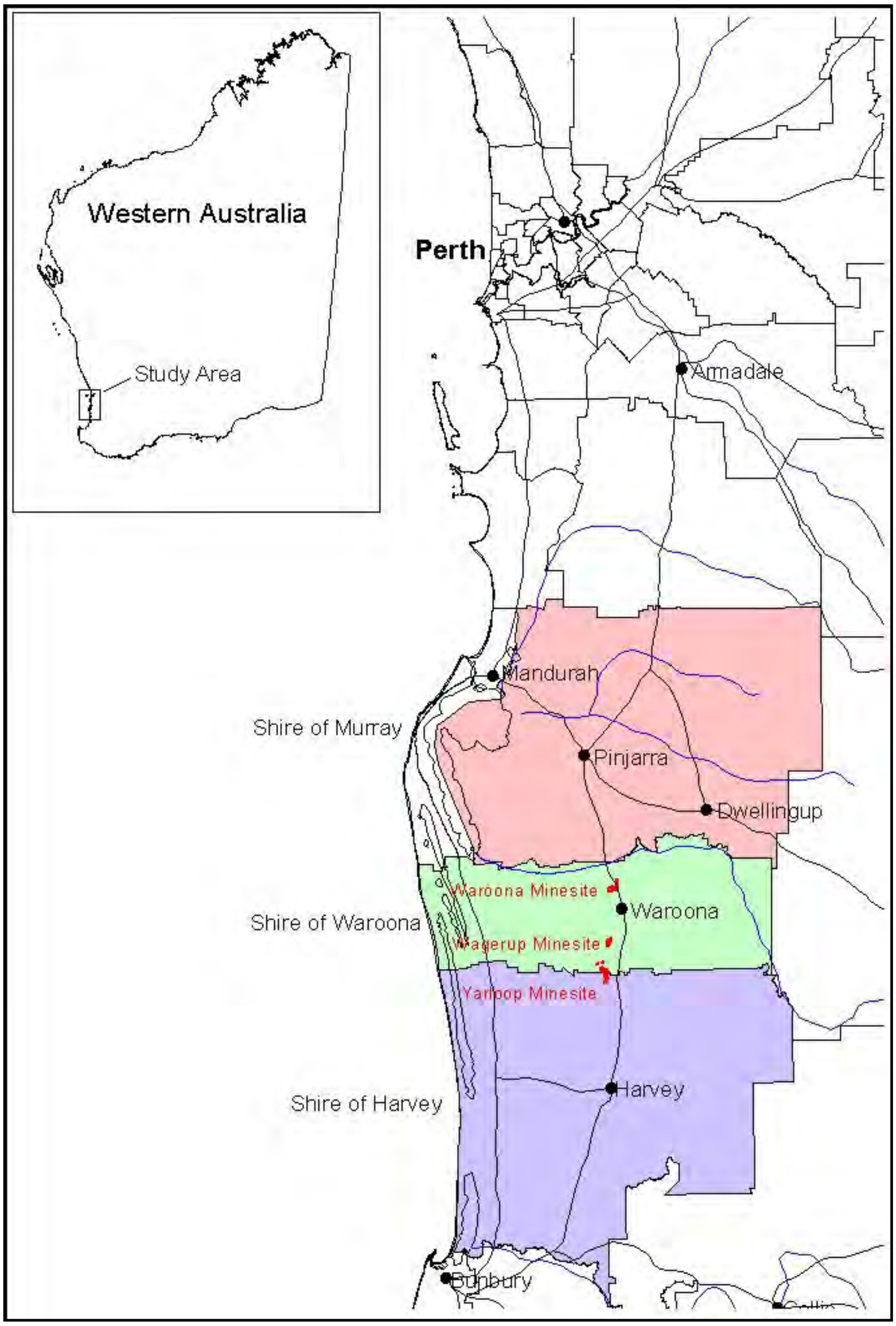

Figure 2.1: Regional location of the proposed Waroona Minesite

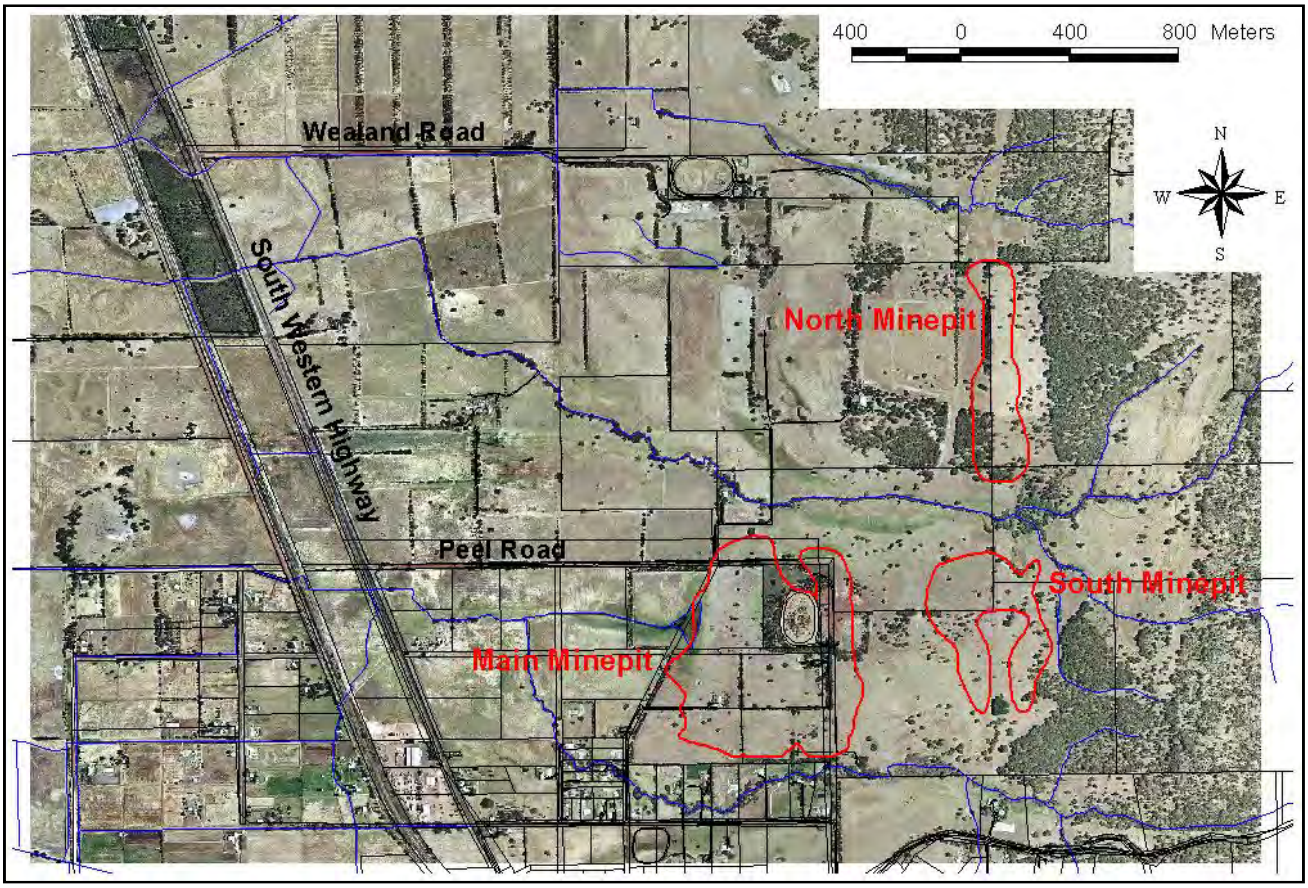

Figure 2.2: Local location of the proposed Waroona Minesite.

2.2 Description of the Waroona Minesite

The proposed Waroona Minesite consists of three principal orebodies: North Pit, South Pit and the Main Pit (Figure 2.2). The characteristics of these pits are shown in Table 2.1.

Mining within the North and South Minepits will to extract the mineralised beach deposits along the Ridge Hill Dune System (Baxter, 1977, Wilde and Low, 1980). This shoreline and associated dunal sediments were deposited during the Early to Mid Pliocene (5.3 – 2.0 Mya) when sea levels fluctuated between 60 – 90 m above present sea level (APSL) (Figure 2.3). The mineralised beach sands were deposited as a continuous unit along the developing Ridge Hill Shelf System (Wilde and Low, 1980), overlying the highly eroded, westerly sloping surfaces of the Leederville Formation and weathered Archaean granitic rocks (Baxter, 1977). Since deposition, marine regression and the establishment of highly incised drainage channels, have dissected the Ridge Hill Shelf deposits, resulting in remnant mineralised beach sand deposits occurring as isolated orebodies along lateritised spurs at the foot of the Darling Scarp (McArthur, 1991).

Mining within the Main Pit at the Waroona Minesite will extract the mineralised beach deposits along the Waroona Shoreline (Baxter, 1977). This shoreline represents a westerly extension of the Ridge Hill Shelf deposit, having been formed as sea levels regressed to the west. Deposition of the mineralised sands occurred between 50 – 70 m APSL, and overlies the westerly sloping surface of the Leederville Formation.

Since deposition of the Ridge Hill and Waroona mineralised deposits an average of 6m of overburden material has been deposited over the mineralised orebodies. This overburden material consists primarily of colluvial sand to clay that has been eroded from the adjacent Darling Scarp at an average annual rate of 0.005 mm/year. This very low Pleistocene sedimentary rate is equivalent to the regional depositional rate for the Swan Coastal Plain (SCP) as suggested by Playford *et al*. (1976).

Table 2.1: General characteristics of the three orebodies at the proposed Waroona Minesite.

Orebody	Corresponding shoreline of Baxter (1977)	Surface elevation (RL, mAHD)	Area (m^2) {ha}	Depth of overburden (m) (*Average depth*)
North Pit	Ridge Hill Shelf	60 – 90	119,581 {11.96}	0 – 16 (*7*)
South Pit	Ridge Hill Shelf	60 – 95	149,491 {14.95}	0 – 16 (*5*)
Main Pit	Waroona	38 – 70	432,311 {43.32}	0 – 14 (*5*)

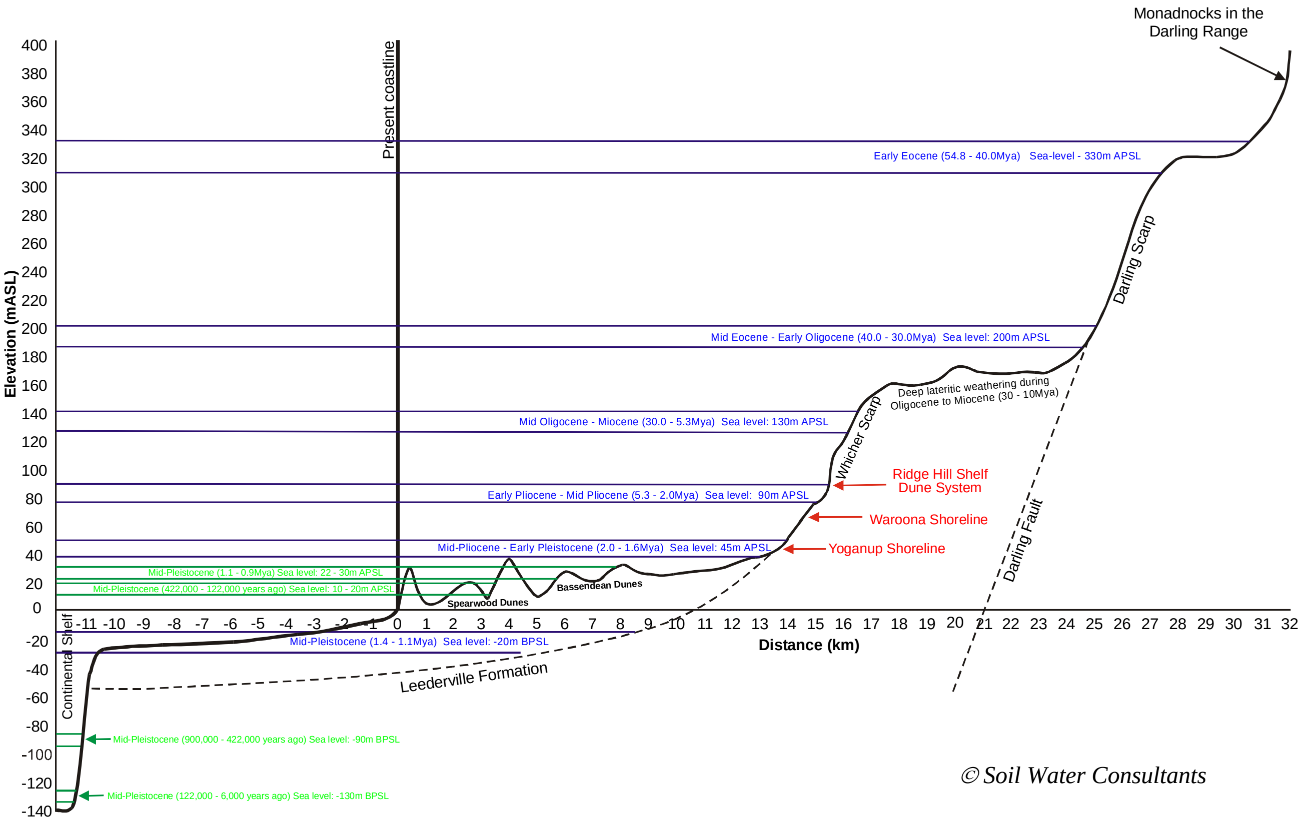

Figure 2.3: Marine regression and transgression events that have occurred in the Perth Basin, and the associated deposition of the Ridge Hill Shelf and Waroona mineral sands deposits.

3.0 Previous Soil Surveys of the Waroona Minesite

Soils of the Waroona area, covering the proposed Minesite, have been mapped by CSIRO (Smith, 1952; McArthur *et al*., 1959) and the Western Australia Department of Agriculture (van Gool and Kipling, 1992). Smith (1952) first mapped the area into broad *Soil Associations* corresponding to the dominant geomorphic elements of the Swan Coastal Plain (SCP): Bassendean Dune System (Bassendean Soil Association), Pinjarra Plain (Guildford Soil Association, Serpentine River Soil Association), Ridge Hill Shelf (Forrestfield Soil Association), and the Darling Scarp (Darling Scarp Soil Association) (Figure 3.1; Table 3.1). The proposed Waroona Minesite occurs solely within the Ridge Hill Shelf geomorphic element and subsequently, consists of soils belonging to the Forrestfield Soil Association.

The Ridge Hill Shelf straddles the Darling Fault, forming a transition zone between the Darling Scarp and Plateau, and the Pinjarra Plain (Figure 3.1). The Darling Fault represents the boundary between the Archaean Yilgarn Craton and the Proterozoic Perth Basin. Subsequently, the Ridge Hill Shelf is underlain by Archaean rocks, on its eastern side, and Phanerozoic sediments, on its western margin. The Ridge Hill Shelf was formed in response to isostastic adjustment between the Perth Basin and the Yilgarn Craton, where soil material was eroded from the uplifting Yilgarn Craton and deposited in the downfaulting Perth Basin to maintain crustal equilibrium. The result of this erosion/deposition process is a gently westward sloping landsurface, from the Darling Plateau to the Pinjarra Plain.

Formation of the Ridge Hill Shelf from material that originated from the weathering of Archaean granitic and gneissic rocks in the adjacent Darling Plateau, has resulted in the soils of the Forrestfield Soil Association being composed primarily of sands and sandy gravels (Bettenay *et al*., 1960). These sandy soils have experienced a protracted leaching and oxidising soil environment, in response to their elevated topographic position, and consequently they have typically developed a well-defined massive to gravelly lateritic horizon close to the soil surface (i.e. *lateritic podzolic*; McArthur, 1991). Residual ferruginous sandstone and conglomerate has developed in areas of preferential leaching (Wells, 1989), and undifferentiated alluvial and valley soils occurs along defined drainage channels dissecting the Ridge Hill Shelf.

McArthur *et al*. (1959) conducted a detailed soil survey within the Waroona area (Figure 3.2). They identified several distinct *Soil Types* within the Forrestfield Soil Association (Table 3.1), with the Lotons series being the dominant soil type (Figure 3.2). The *Lotons Series* is well developed on the undissected parts of the Ridge Hill Shelf, and consists of a surface grey-brown gritty sand which quickly passes into a dull yellow-brown gravelly sand at approximately 50 cm of depth (Plate 3.1). Ferruginous gravel may be present in all or part of the upper soil horizons, and the upper sandy surface horizons overlie a yellow-brown and red-brown mottled sandy clay subsurface (Bettenay *et al*., 1960). A morphological description of a typical Lotons soil in the Waroona area is provided in Table 3.2, whilst the general physical and chemical properties of this soil are shown in Table 3.3.

The *Gwindinup Series* is the next most extensive soil type in the Forrestfield Soil Association, forming a western fringe to the lateritic Lotons soil (McArthur *et al*., 1959) (Figure 3.2). It consists of deep to very deep yellow to yellow-brown sand with ferruginous gravel generally absent from the surface sands – the absence of gravel in the surface horizons of the Gwindinup soil distinguishes it from the Lotons soil (Plate 3.2). A morphological description of a typical Gwindinup soil is provided in Table 3.4, whilst the general physical and chemical properties of this soil are shown in Table 3.5. Debate has existed as to the formation of the deep sands of the Gwindinup soil, with McArthur and Bettenay (1960) suggesting derivation from laterite weathering, whilst Biggs (1977) and Woods (1979) proposed that the deep sands were deposited along a fossil shoreline and associated dune system.

Dissection of the Ridge Hill Shelf along major drainage channels has resulted in the truncation of the higher-level lateritic Lotons soil. These truncated soils, which are referred to as the *Isandra Series* (McArthur *et al*., 1959; Bettenay *et al*., 1960), consist of a shallow sand to sandy loam surface overlying a compacted yellow-brown sandy clay subsoil containing abundant quartz grit and water-worn pebbles (Plate 3.3). Along the main drainage channels undifferentiated *Valley Slope Soils* have been deposited, consisting of brown to yellow brown sandy alluvium and colluvium overlying a brown sandy clay subsoil (Plate 3.4) (McArthur *et al*., 1959).

Table 3.1: Soil Types within the Waroona area (McArthur *et al.*, 1959).

Geomorphic element	Soil Association	Soil Types
Bassendean Dune System	Bassendean	Gavin
Pinjarra Plain	Guildford	Coolup
		Boyanup
		Mayfields
		Fairbridge
	Serpentine River	Wellesley
Ridge Hill Shelf	Forrestfield	Lotons
		Gwindinup
		Isandra
		Valley slope
Darling Scarp	Darling Scarp	–

Table 3.2: Morphological description of a typical Lotons Soil from the Waroona Area (Hingston, 1957).

Depth (cm)	Morphological description
0 – 10	Greyish-brown sandy loam with slight iron gravel (~ 14%)
10 – 30	Brown sandy clay with moderate amounts of iron gravel (~ 28%)
30 – 65	Yellowish-brown sandy clay with large amounts of iron gravel (~ 55%)
65 – 90	Yellowish-brown sandy clay with very large amounts of iron gravel (~ 76%)
90 – 180	Yellowish-brown sandy clay with very large amounts of iron gravel (~ 77%)
180 – 210	Brownish-yellow and brown mottled sandy clay with slight iron gravel (~ 21%)

Table 3.3: Physical and chemical properties of a typical Lotons Soil from the Waroona Area (Hingston 1957).

Depth (cm)	Physical properties				Chemical properties										
	% CS	% FS	% Si	% C	pH	TSS (%)	C %	N %	K %	P %	Exchangeable cations (meq/100g soil)				
0 – 10	38	37	8	12	6.2	0.044	3.9	0.12	0.02	<0.01	Ca	Mg	K	Na	CEC
10 – 30					6.3	0.015					1.6	1.6	0.36	0.22	3.8
30 – 65					6.1	0.013									
65 – 90	28	25	3	45	6.2	0.014		0.03	0.02	<0.01	1.4	1.8	0.34	0.24	3.8
90 – 180					6.2	0.022			0.02	<0.01					
180 – 210					7.0	0.011			0.01	<0.01					

TSS % = Total soluble salts determined from a 1:5 soil/water suspension.
% CS = % Coarse sand, % FS = % Fine sand, % Si = % Silt; % C = % Clay

Table 3.4: Morphological description of a typical Gwindinup Soil from the Waroona Area (Hingston, 1957).

Depth (cm)	Morphological description
0 – 10	Grey-brown sand
10 – 30	Greyish-yellow sand
30 – 84	Yellow sand
84 – 110	Yellow sand

Table 3.5: Physical and chemical properties of a typical Gwindinup Soil (Hingston 1957).

Depth (cm)	Physical and Chemical properties				
	pH	TSS (%)	NaCl %	I.L %	M.L %
0 – 10	6.7	0.014	0.006	0.8	0.2
10 – 30	6.4	0.004	0.002	0.7	0.1
30 – 84	6.3	0.004	0.001	0.8	0.1
84 – 110	6.4	0.004	0.002	0.93	0.2

I.L – Loss in weight on ignition of oven-dry sample to 900°C for 30 minutes.
M.L – Gravimetric moisture content of field sample.

A further detailed soil survey of the Waroona area was completed by van Gool and Kipling (1992), during development of a Soil – Landscape Map for the Peel – Harvey Region. This survey identified similar soils as reported by McArthur *et al*. (1959), however the distribution of soils was refined for several soil types originally mapped by McArthur *et al*. (1959). The revised soils map for the Waroona area is shown in Figure 3.3. It can be seen in the revised soils map, that the proposed Waroona Minesite occurs predominately within the Lotons Soil Type, with minor areas of the Gwindinup Soil occurring along the margins of the mine boundary.

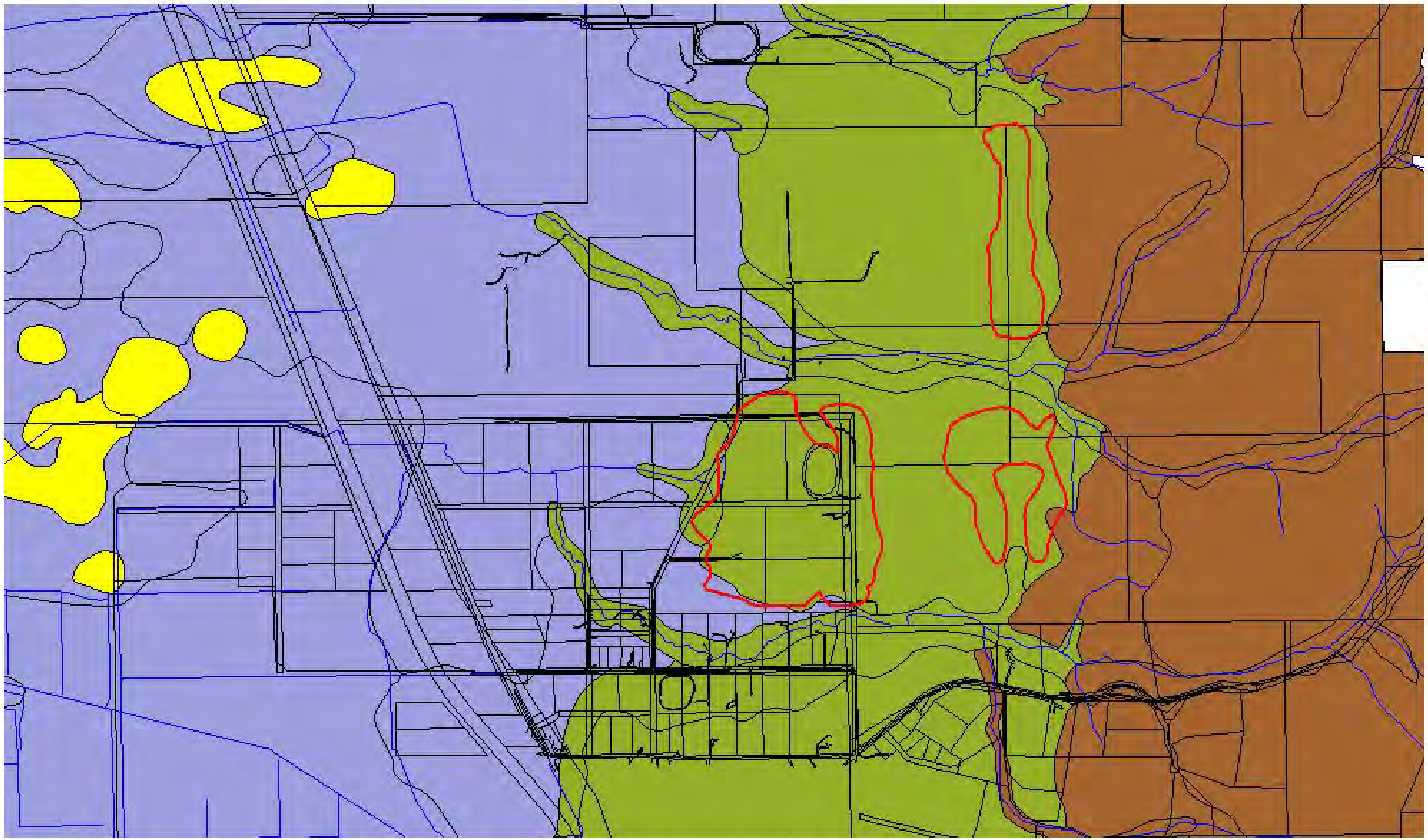

Figure 3.1

SWC

Soil Associations of the Waroona Area (Smith, 1952)

Waroona Minesite
DOLA Cadastral Map
Roads
Streams

Soil Associations
Darling Range Soil Association
Forrestfield Soil Association
Guildford Soil Association
Bassendean Soil Association

Prepared by: ASP
Checked by: AJH
Scale: 1:20,000

N
W E
S

Figure 3.2 Soils in the Waroona area identified by McArthur et al (1959)

SWC

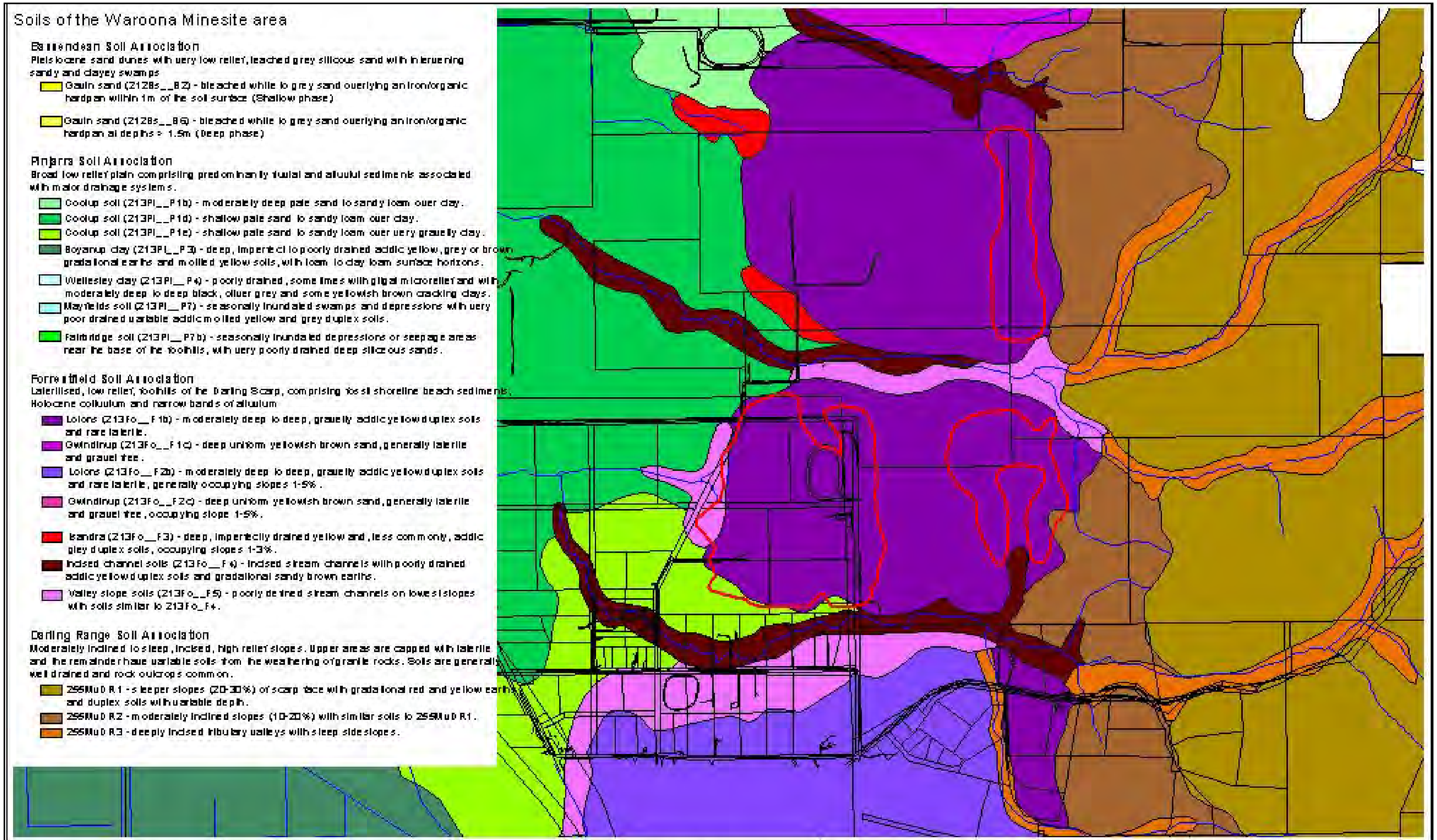

Figure 3.3	Soils of the Waroona Minesite	Waroona Minesite	Prepared by: ASP
SWC		DOLA Cadastral Map	Checked by: AJH
		Roads	**Scale: 1:20,000**
		Streams	N / W / E / S

Plate 3.1: Example of a Lotons Soil

Plate 3.2: Example of a Gwindinup Soil

Plate 3.3: Example of an Isandra Soil.

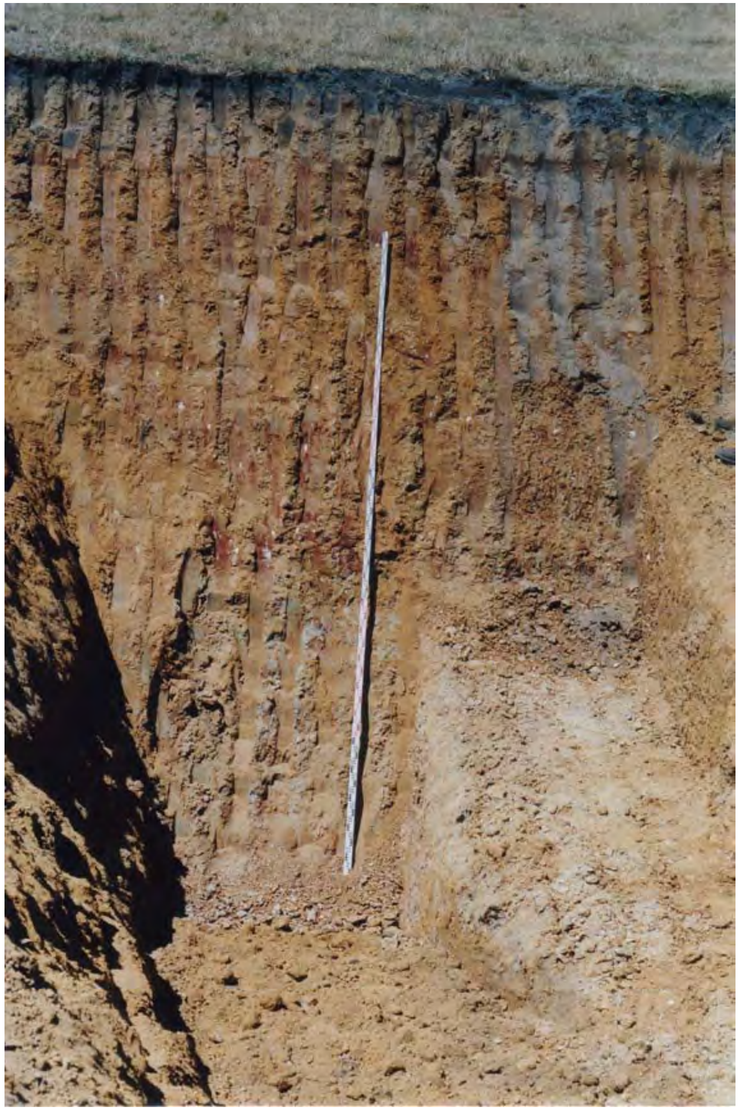

Plate 3.4: Example of a Valley Slope Soil

4.0 Distribution of Soils in the Waroona Minesite

Soil Water Consultants (SWC) have established the reliability of using the exploration drilling data to map the distribution of soils in a mining area (SWC, 2002; 2003). Traditional soil survey techniques, as used by McArthur *et al*. (1959) and van Gool and Kipling (1992), require a sampling density of one sample point per hectare (Gunn, 1988). Exploration drilling involves collecting and analysing overburden and ore materials, at one meter vertical intervals, at a sampling/drilling density often exceeding ten sampling points per hectare. Subsequently, the drilling data can be used to accurately map the distribution of soils in a mining area.

At the Waroona Minesite, exploration drilling occurred at a density of 18, 15, and 16 drillholes per hectare for the North, South and Main Minepits, respectively. This drilling intensity, and the sampling of overburden and orebody soils every vertical meter, resulted in the collection and analysis, of 22,037 samples, for which the sand and silt + clay content was determined. This information therefore provides an accurate assessment of the distribution of soils in the Waroona Minesite.

Figures 4.1 – 4.3 shows the distribution of the silt+clay soil fraction (i.e. slimes content), in the surface 12 m of the soil profile in the North, South and Main Minepits at Waroona. In these maps, the areas occupied by deep sands (i.e. areas that contain low silt+clay contents – green areas in Figures 4.1 – 4.3) correspond to the Gwindinup Soils of McArthur *et al*. (1959), whilst the areas that contain a dominant sandy clay subsoil (i.e. considerable silt+clay – orange areas) correspond to the Lotons, Isandra and Valley Slope soils of McArthur *et al*. (1959). These soils associations were confirmed during a soil survey at the Wagerup Minesite (SWC, 2003).

Figure 4.1 – 4.3 clearly show the spatial complexity (lateral and vertical heterogeneity) of the soils within the Waroona Minesite. Although the characteristics of the different soils resemble the Lotons and Gwindinup Soils, identified by McArthur *et al*. (1959) and van Gool and Kipling (1992), the actual variability of these soils is observed to be much greater than identified by these previous soil surveys – this variability will be investigated during the Soil Management Plan that will be completed at a later date.

The occurrence of deep sands, which are surrounded by more clayey material and commonly extend to depths of up to 12 m (i.e. through the entire overburden material; Figures 4.1 – 4.3), has important implications for the local and regional hydrogeology. These deep sandy areas are likely to act as preferential groundwater recharge zones, resulting in rapid groundwater recharge following rainfall events. The clayey lateritic soils, surrounding these areas, have high soil water storage capacities (field capacity = 40% v/v; SWC, 2003) and low hydraulic conductivities (< 30 mm/day, SWC, 2003). Water movement and groundwater recharge through these clayey soils is therefore low, and consequently, groundwater recharge and movement is likely to be strongly controlled by the presence and abundance of the deep sands. Detailed investigation is therefore recommended to identify the role that the deep sand regions play in local and regional groundwater recharge and movement. If these regions are important to the local and regional hydrogeology of the area, and reconstruction of the soil profile does not restore these zones, then significant changes to the hydrogeology of the area is likely to occur.

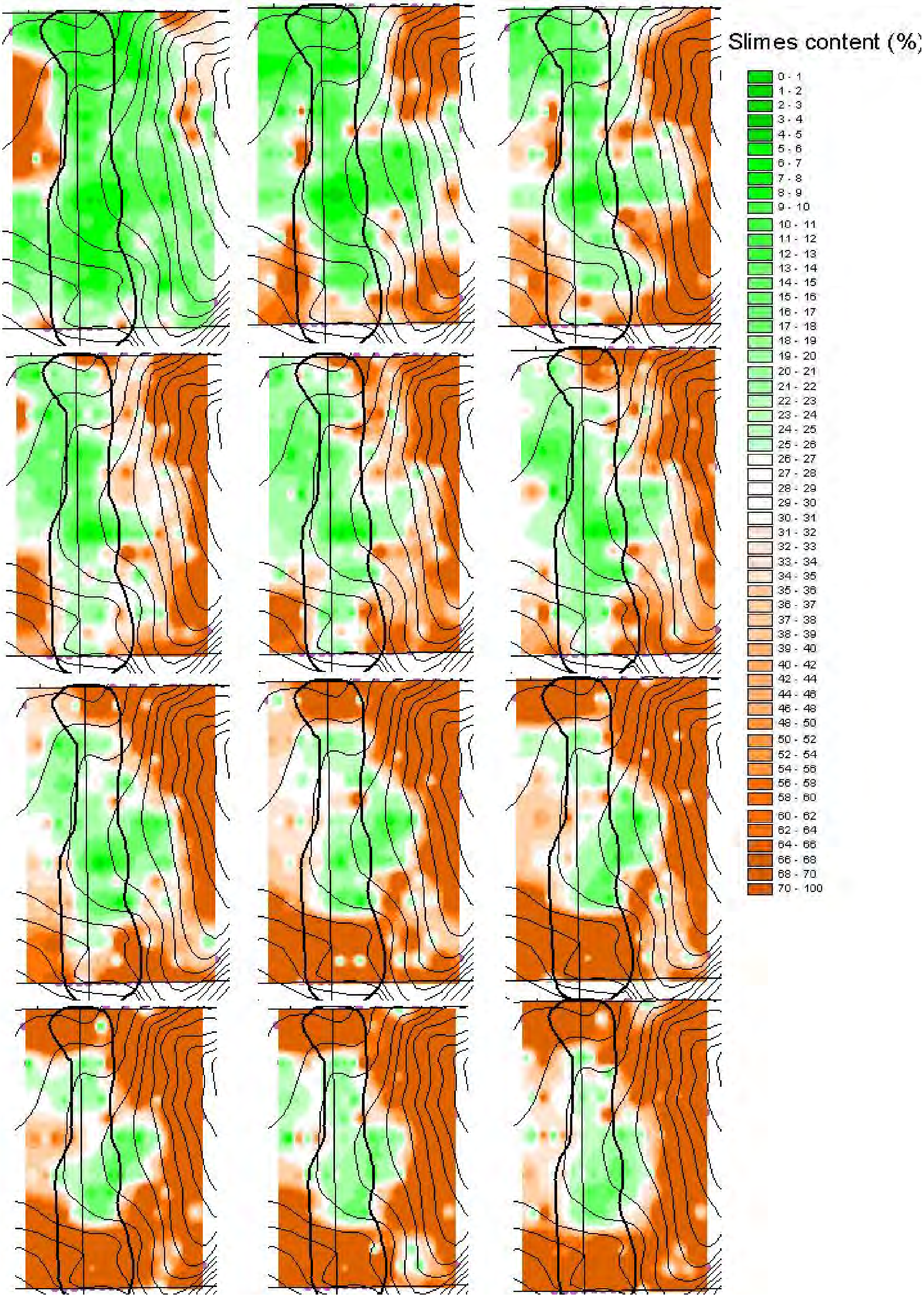

Figure 4.1: Distribution of the sand and silt+clay fraction in the soils in the northern mine pit. Each map represents a one meter slice through the profile commencing at the soil surface (i.e. the first map = 0-1m, second map = 1-2m and so on moving left to right)

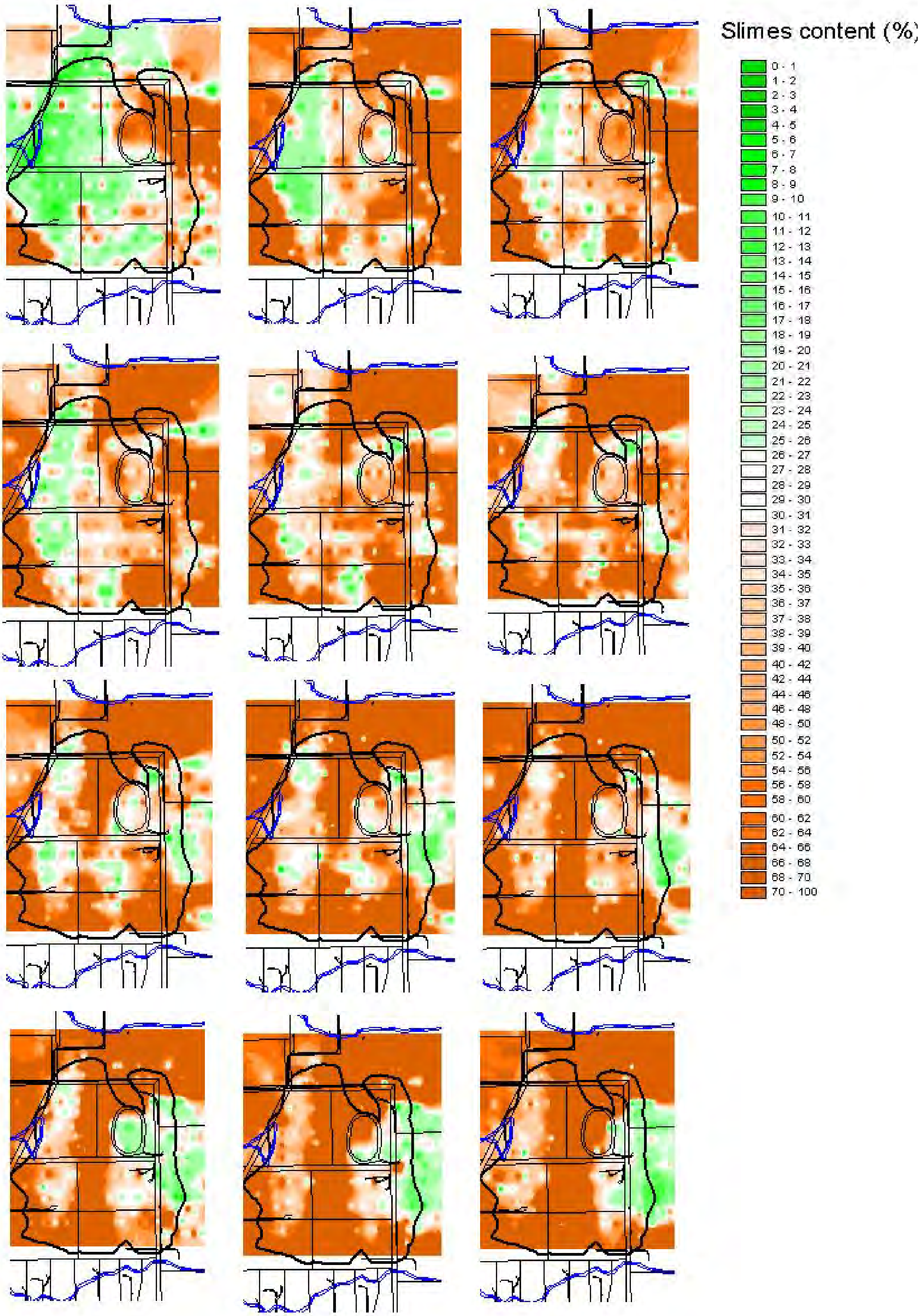

Figure 4.2: Distribution of the sand and silt+clay fraction in the soils in the main mine pit. Each map represents a one meter slice through the profile commencing at the soil surface (i.e. the first map = 0-1m, second map = 1-2m and so on).

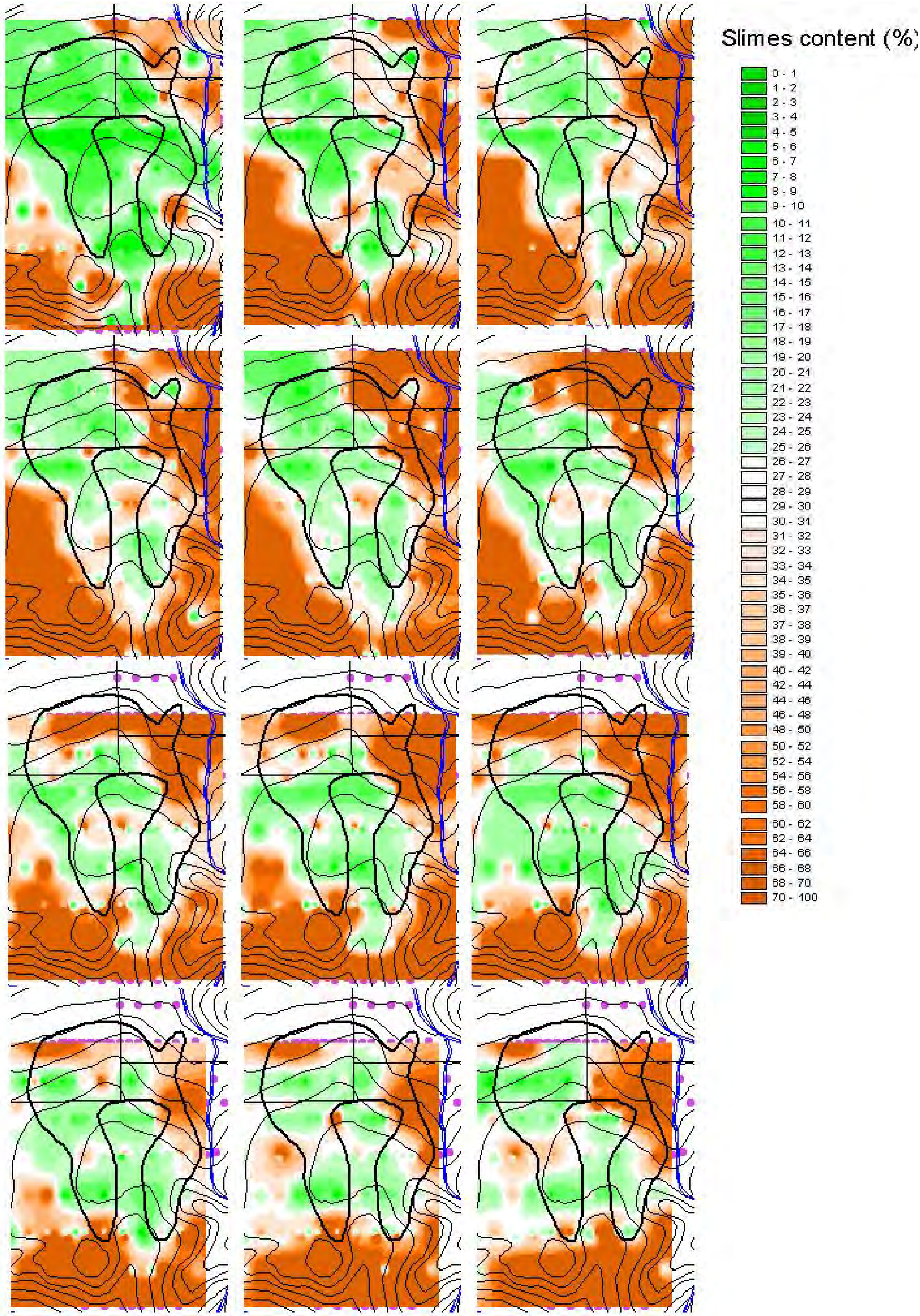

Figure 4.3: Distribution of the sand and silt+clay fraction in the soils in the southern mine pit. Each map represents a one meter slice through the profile commencing at the soil surface (i.e. the first map = 0-1m, second map = 1-2m and so on).

References

Baxter, J.L. (1977). H*eavy Mineral Sand Deposits of Western Australia*, Mineral Resources Bulletin 10, Geological Survey of Western Australia, Perth, Western Australia.

Bettenay, E., McArthur, W.M. and Hingston, F.J. (1960). *The Soil Associations of Part of the Swan Coastal Plain, Western Australia*, Soils and Land Use Series No. 35, Division of Soils, CSIRO, Melbourne, Australia.

Gunn, R.H. (1988). 'Developing land survey specifications', In: Gunn, R.H., Beattie, J.A., Reid, R.E. and van de Graaff, R.H.M. (Eds.). *Australian Soil and Land Survey Handbook. Guidelines for Conducting Surveys*, Inkata Press, Melbourne, pp. 73-89.

Hingston, F.J. (1957). *Laboratory Examination of Soils from the Pinjarra – Waroona Area, Western Australia*, Divisional Report 6/57, Division of Soils, CSIRO, Melbourne, Australia.

McArthur, W.M., Bettenay, E. and Hingston, F.J. (1959). *The Soils and Irrigation Potential of the Pinjarra – Waroona Area, Western Australia*, Soils and Land Use Series No. 31, Division of Soils, CSIRO, Melbourne, Australia.

McArthur, W.M. (1991). *Reference Soils of South-Western Australia*, Western Australia Department of Agriculture, Perth, Western Australia.

Playford, P.E., Cockbain, A.E., and Low, G.H. (1976). *Geology of the Perth Basin*, Western Australian Geological Survey Bulletin 124.

Smith, R. (1952). *Soil Associations of Part of the Swan Coastal Plain*, Division of Soils, Report 1/52, CSIRO, Melbourne, Australia.

Soil Water Consultants (2002) (Previously ORACLE Soil and Land Pty Ltd), *Wagerup Minesite Soil Management Plan*, Unpublished Report submitted to Iluka Resources Limited.

Soil Water Consultants (2003) (Previously ORACLE Soil and Land Pty Ltd), *Yoganup Extended Soil Management Plan*, Unpublished Report submitted to Iluka Resources Limited.

Van Gool, D. and Kipling, B. (1992). *Land Resources in the Southern Section of the Peel-Harvey Catchment, Swan Coastal Plain, Western Australia*. Division of Resource Management, Western Australia Department of Agriculture, Perth, Western Australia.

Wells, M.R. (1989). *Land Capability Study of the Shires of Mandurah and Murray*, Land Resource Series No. 2, Western Australian Department of Agriculture, Perth, Western Australia.

Wilde, S.A. and Low, G.H. (1980). *Pinjarra, Western Australia, 1:250 000 Geological Series – Explanatory Notes*, Geological Survey of Western Australia, Perth Western Australia.

Wilde, S.A. and Walker, I.W. (1982). *Collie, Western Australia, 1:250 000 Geological Series – Explanatory Notes*, Geological Survey of Western Australia, Perth Western Australia.