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Identification of Permeable Soils within the Waitemata Formation

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Identification of Permeable Soils within the Waitemata Formation

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1 Executive Summary

1.1 Project and Client

Landcare Research was contracted by the Auckland Regional Council to report on identifying Hydrological Class A (high to moderate permeability) soils within the dominant Class C (low permeability) soils on Waitemata Formation sedimentary rocks in the Auckland region.

1.2 Objectives

The objectives of this study were to:

- confirm the current soils on Waitemata Formation in the Auckland Region (Rodney to Franklin) that should be identified as Hydrological Group A soils with respect to US Soil Conservation Service "Rainfall-Runoff Curves" in ARC Technical Publication 108 (used to calculate stormwater runoff)
- identify the distribution of these Hydrologic Class A soils within the Waitemata Formation in the Auckland region
- identify the landscape distribution and predictability (from literature and pedological experience) of the most permeable soils (>8 mm/hr) within the Waitemata Formation
- identify and verify visual field indicators that are related to permeablities >8 mm/hr (Hydrologic A) within Waitemata Formation (e.g., bright red subsoils, absence of low-chroma mottles in upper 60 cm, size and shape of aggregates)
- identify probable density and depth of sampling/hole digging required to detect these moderate-to high-permeability soils
- test the ability of engineers to identify visual field indicators and differentiate moderate- to high-permeability soils from low-permeability soils within the Waitemata Formation geology.

1.3 Methods

Existing information of soils on Waitemata Formation in the Auckland Region was reviewed to identify the soils of different hydrological classes. Field reviews of soils on current urban development sites around the Auckland were made to identify the high to moderate permeability soils from the low permeability soils within the Waitemata Formation.

1.3.1 Identifying Moderately to Highly Permeable Soils from Low Permeability Soils on Waitemata Formation Geology

Hydrological Group A Granular and Allophanic Soils occur as small pockets within areas of hydrological Group C Ultic Soils. Granular Soils are identified by chocolate brown, clayey subsoils with finer blocky structures on red-weathered sandstone. Allophanic Soils are identified by bright strong brown, reddish yellow, or yellowish red silty subsoils with a friable, greasy feel. A positive sodium fluoride test can also be used to help identify Allophanic Soils. These soils contrast with the dominant Ultic Soils which have dull yellowish brown clayey subsoils, often with grey or red mottling, and coarse blocky or prismatic structures. Topsoils are not diagnostic for differentiating the soil hydrological groups. The distribution of Allophanic Soils is generally predicable, most being found on gently sloping or flat broad interfluves (ridges) or terraces. The locations of Granular Soils on red- weathered sandstone are sporadic and unpredictable.

Auger surveys, with closely spaced (10 m) observations to about 0.5-m depth (into the upper subsoil), along transects across landscape units are recommended to locate and differentiate these Group A soils from the dominant Group C soils. The auger surveys are required to supplement soils information from geotechnical bore holes. Natural (pre-earthworks) topsoil (Ap horizon) depths under pasture on Waitemata Formation in the Auckland Region typically are 20–30 cm, with a 10-cm mixed horizon above the subsoil (B horizons). Thus augering to 0.5-m would normally be sufficient to identify the nature of the diagnostic subsoil.

The engineers and an environmental consultant who were consulted in this project thought that the pockets of Class A soils could be identified at marginal extra cost from the dominant Class C soils on Waitemata Formation, using the descriptions and survey recommendations described in this report. The costs-benefits of separating and utilizing these more permeable soils in urban design need evaluation.

The location of permeable soils within a dominant landscape of low-permeability soils strongly favours cluster-housing development that retain these soils for their disproportionately high value for infiltrating, retaining, and releasing stormwater and supporting deep-rooted trees.

1.4 Recommendations

ARC requires surveys to be undertaken on urban development sites in areas with an underlying Waitemata Formation sedimentary rock geology likely to contain Allophanic or Granular Soils to identify minor but significant areas of hydrological Group A soils within areas dominated by Group C Ultic Soils.

Where these more permeable soils are found, consideration is given to leaving them in situ as permeable 'green spaces' for water management, for low-impact urban design. If this is not practical, an alternative is to consider separately stripping, stockpiling if necessary, and re-using these higher permeability subsoils as fill for permeable green areas, such as constructed swales, grassed areas (playing areas of roadside verges), forested recreational or scenic reserves, or gardens.

2 Introduction

Storm water management in the Auckland Region is a key component of environmental management, particularly on urban, peri-urban, and urban development areas. The hydrological basis for stormwater management is reported in Guidelines for Stormwater Runoff Modelling in the Auckland Region (Beca Carter and Hollings & Ferner 1999).

Where moderately or highly permeable soils (Group A) are present within a sub-catchment or catchment containing mostly low-permeability soils (Group C), a key method of mitigating increased stormwater runoff is direct runoff to these permeable soils, if they are protected from compaction and degradation from earthmoving and site development operations. These more permeable soils are ideally suited for in situ green areas or may be used as replaced, fill soils, which are managed to retain their original moderate or high permeability, on urban development sites.

Waitemata Formation sedimentary geology is assumed as being covered by uniformly low permeability (<4 mm/hr) soils for hydrological modelling. However, this Formation also has pockets of soils with moderate to high permeabilities (McLeod & Jessen 2000). This report examines the practicality of identifying these moderately to highly permeable soils within the low permeability soils on Waitemata Formation geology.

3 Objectives

The objectives of this study were to:

- confirm the current soils on Waitemata Formation in the Auckland Region (Rodney to Franklin) that are identified as Hydrological Group A soils with respect to US Soil Conservation Service "Rainfall-Runoff Curves" in ARC Technical Publication 108 (used to calculate stormwater runoff)
- identify the distribution of these Hydrologic Group A soils within the Waitemata Formation in Auckland Region
- identify the landscape distribution and predictability (from literature and pedological experience) of the more permeable soils (>8 mm/hr) within the Waitemata Formation.
- identify and verify visual field indicators that are related to permeabilities >8 mm/hr (Hydrologic A) within Waitemata Formation (e.g., bright red subsoils, absence of low-chroma mottles in upper 60 cm, size and shape of aggregates).
- identify probable density of sampling/hole digging required to detect these moderate- to high-permeability soils.
- test the ability of engineers to identify visual field indicators and differentiate moderate- to high-permeability soils from low-permeability soils within the Waitemata Formation geology.

4 Methods

A field review of soils on and adjacent to urban development sites around Auckland was undertaken on 11–15 June 2007. Development sites were visited between the Flatbush and Brookby areas in Manukau City; Western Heights area, Waitakere City; and Albany and Whangaparoa-Silverdale areas on the North Shore. This included a site visit to the Manakau City area with Graham Macky, ARC, and another to the Albany area with Ted Temple, Southern Skies Environmental Ltd. Discussions were held with civil engineers (Ian Hendy, Engineering Design Consultants Ltd; Rob Fenwick, Hick Bros Civil Construction Ltd; and Trevor Matuschka, Engineering Geology Ltd) involved with urban development site engineering design.

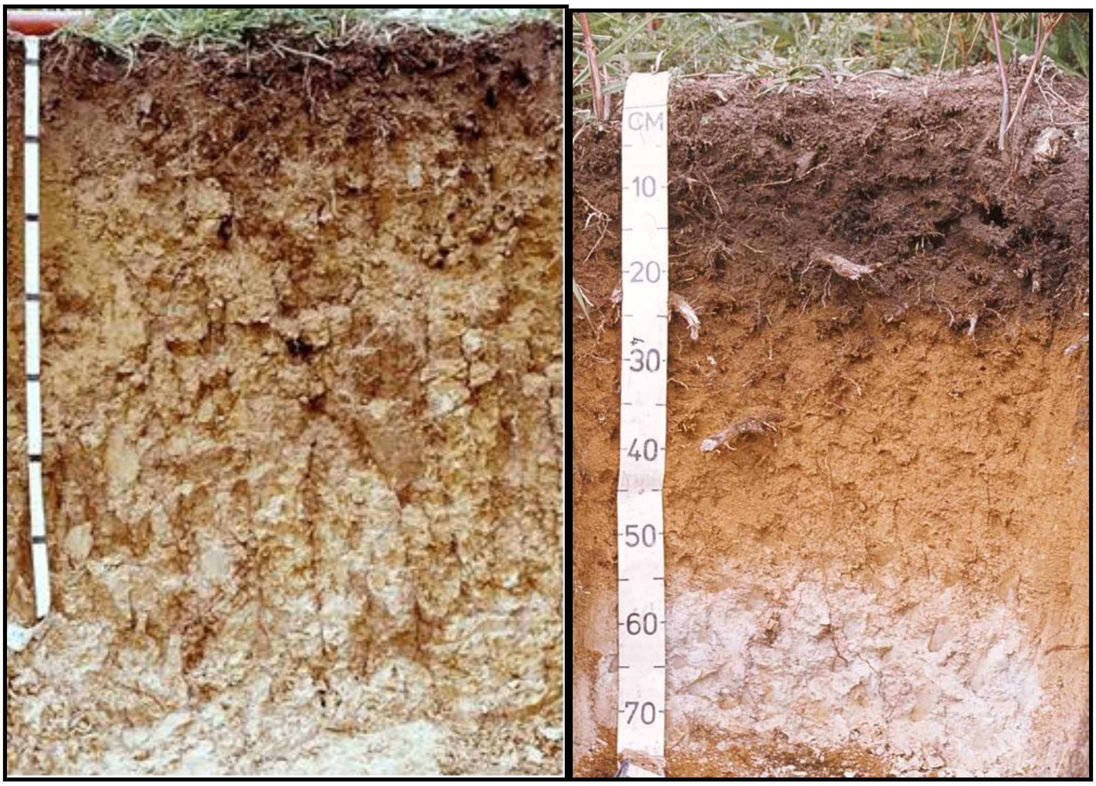
Reviews of existing soil mapping information and reports for the Auckland Region were undertaken to identify areas where high to moderately permeable soils are likely to occur as small areas included in larger areas of low permeability soils on Waitemata Formation. The "Guidelines for stormwater runoff modelling in the Auckland Region" was also reviewed.

4.1 Identifying Moderate to Highly Permeable Soils from Low Permeability Soils on Waitemata Formation Geology

4.1.1 What types of soils have moderate to high permeabilities?

Granular Soils (Figs 2, 3 & 6) on pockets of red-weathering sandstone within the Waitemata Formation and Allophanic Soils (Fig. 1) from remnant pockets of air-fall tephras (volcanic ash) and the older tephra that has been reworked by water- or wind-sorting, are within Group A hydrological soil classification (Table 1 in the Appendix). These soils are generally found as minor inclusions within soil mapping units that are predominantly Ultic Soils with low permeability Group C hydrological classification in their natural state and Group D – very low permeability – when earthworked on urban development sites (Simcock 2007). Descriptions of the general properties of Granular, Allophanic and Ultic Soils are given in Hewitt (1998) and summarised in Appendix 2.

The patches of red-weathering in the Waitemata Formation are thought to occur in pockets of sediments of volcanic origin that were hydrothermally altered and weathered to give iron mineral haematite clays, the source of the pink-red colouration. Relatively high levels of these sesquioxide clays are also associated with a more permeable soil structure than occurs on soils dominated by layer-silicate clays (kaolinite, halloysite, gibbsite, etc.). Short-range order allophanic clays provide the highly permeable structures for Allophanic Soils.



Ultic Soil (scales in 10 cm increments) Allophanic Soil

Figure 1. A low permeability, clayey Ultic Soil (left) compared with a moderate-to-high permeability, silty Allophanic Soil (right) on Waitemata Formation from the South Auckland area.

Figure 2. A moderately permeable Granular Soil on red weathering in Waitemata Formation sandstone in the South Auckland area. (scale in 10 cm increments)

Figure 3. A moderately permeable, clayey Granular Soil, showing fine blocky structure and no mottling, from the South Auckland area. (scale in 10 cm increments)

Figure 4. Low permeability Ultic Soils, showing coarse blocky structures and grey mottling in the subsoil, on Waitemata Formation sandstone in the West Auckland area. (Scale in 10 cm increments. Note: the surface white material is hydroseeding mulch.)

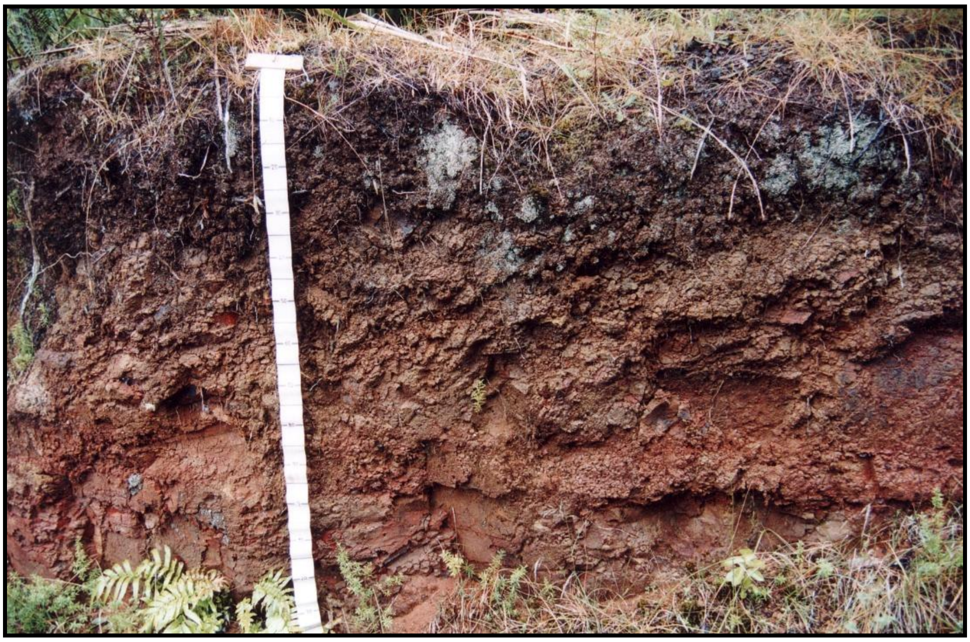


Figure 5. A high permeability Granular Soil from the Waitakere area. (scale in 10 cm increments)

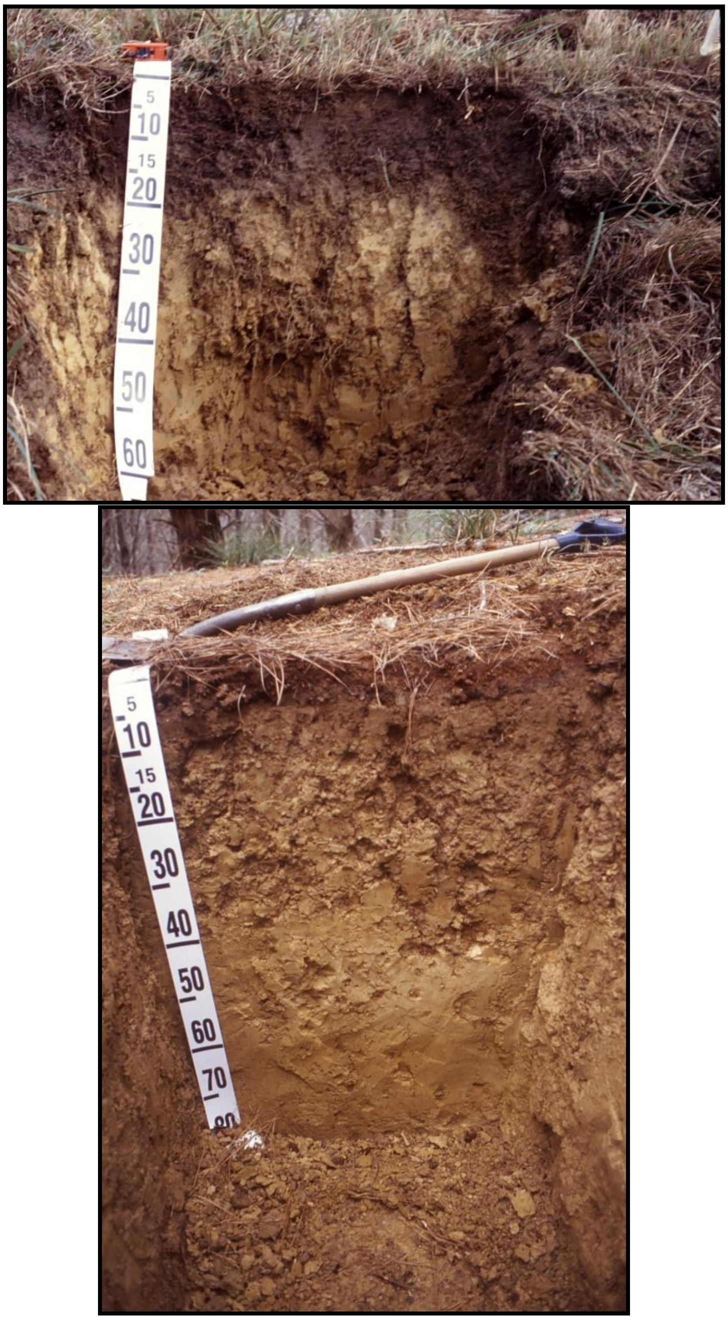


Figure 6. Low permeability Ultic Soils from the North Auckland area. (scales in 10 cm increments)

Examples (from: Wilson et al. 1975; Orbell 1977; Purdie 1981; Cox et al. 1983; Sutherland et al.1985a & b; Hicks 1996; McLeod & Jessen 2000) of the high permeability Allophanic soils in the Auckland Region are: Otao series, Waitemata series, Karaka complex, Torehape complex, Manukau series, and Hapludands[1].

Examples of moderate permeability Granular soils are: Cornwallis series, Waitakere series, Nihitapu series, Patuhahoe series, Pukekohe series, Hamilton series, Haplohumults, and Hapludalfs.

[1] The USDA *Soil Taxonomy* classifications for soils were used for mapping units in the Manukau City soil survey.

Examples of low permeability Ultic Soils are: Mahurangi series, Albany series, Swanson series, Coatesville series, Whangaripo series, Warkworth series, Huia series, Te Hihi series, Hapludults, Paleaquults, and Ochraquults.

Table 1. Soil series names for soils with high, moderate and low permeability. Soils series names are commonly used on the New Zealand Land Resource Inventory and soil maps, e.g., Wilson et al. (1975), Orbell (1977), Cox et al. (1983), Sutherland et al. (1985a & b), Hicks (1996), McLeod & Jessen (2000). USDA Soil Taxonomy terms were only used for the soil survey of Manukau City (Purdie 1981).

Permeability	NZ Soil Classification & United USDA Taxonomy	Soil series and complexes
High – Hydrologic Class A	Allophanic Soils Hapludands	Otao series, Waitemata series, Karaka complex, Torehape complex, Manukau series
Moderate – Hydrologic Class B	Granular Soils Haplohumults, Hapludalfs	Cornwallis series, Waitakere series, Nihitapu series, Patuhahoe series, Pukekohe series, Hamilton series
Low – Hydrologic Class C	Ultic Soils Hapludults, Paleaquults, Ochraquults	Mahurangi series, Albany series, Swanson series, Coatesville series , Whangaripo series,Warkworth series, series, Huia series, Te Hihi series

Figure 7. Earthworking Ultic Soils in West Auckland (left) and Albany (right) has caused significantly reduced permeability to very low (Hydrological Class D); created massive soil structure; mixed topsoil with subsoil and regolith materials; and grey and red mottling has developed throughout the profile. (scale in 10 cm increments)

4.2 Finding the moderate to high permeability soils

Moderately to highly permeable soils tend to occur generally as relatively small pockets within much larger areas of low-permeability Ultic Soils on Waitemata Formation sedimentary rocks. The Allophanic Soils generally are located on more stable parts of the landscape, such as on broad, gently-sloping interfluvial ridges and terraces. These soils are developed from either wind- or water-reworked Hamilton or Kauroa Ashes or more recent air-fall tephra. The Granular Soils are more sporadic and unpredictable in occurrence, being found as small pockets when the red-weathered materials in the Waitemata sandstone form the soil-forming parent material (i.e. are close to the surface).

Given the unpredictable nature of these soils within mapped soil units, the most reliable method of identifying their occurrence and aerial extent is by auger-survey. Hand augering to 0.5 m would identify the different subsoils. Natural (pre-earthworks) topsoil (Ap horizon) depths under pasture on Waitemata Formation in the Auckland Region typically are 20–30 cm, with a 10-cm mixed horizon above the subsoil (B horizons). Thus augering to 0.5-m would normally be sufficient to identify the nature of the diagnostic subsoil.

A general guide to the intensity of surveying is transects (from crest to bottom) spaced at 20–30 m across landscape units (generally perpendicular to the slope), with 10 m-spaced observations along each transect. Geotechnical bore holes (e.g., about 15 per hectare) would provide some of the soils information, supplemented by hand auger surveys to complete the required observations. A maximum of 40–60 observations/ha are required to determine whether there are significant inclusions of the more permeable Granular or Allophanic Soils in amongst the low permeability Ultic Soils. The landscape units warranting subsoil surveys are areas proposed for soil stripping (cutting) and relatively low angle slopes, such as broad interfluves and terraces on both rolling and hilly land. Alluvial flats, steep land, and landscapes not underlain by Waitemata sedimentary geology are excluded from consideration in this report. Parts of the landscape where the occurrence of more permeable soils is of little or no practical value to water engineering design and soil stripping for urban development, such as steep-sided gullies and narrow ridges, should also be excluded from the subsoil surveying.

Figure 8. Moderately permeable subsoil from a Granular Soil on red weathered Waitemata Formation stripped for retail/industrial development at Albany.

4.3 How to identify the more permeable soils from low permeability soils

Subsoils are the key factor for identifying high- to moderate-permeability soils from the low-permeability soils, rather than topsoils. The low-permeability Ultic Soils have sticky, clayey, dull yellowish coloured subsoils, often mottled with grey zones with red flecks (described in more detail below). Allophanic Soils have silty, brighter yellowish coloured subsoils that feel greasy under moist to wet field conditions that prevail in the Auckland Region. Earthworked subsoils that may dry out should have water added to make them moist before the soil consistency is tested for a greasy or sticky feel. Granular soils also have clayey subsoils but are chocolate-brown coloured and feel sticky when moist to wet, rather than greasy.

Topsoils are less diagnostic because they do not vary markedly between the different soils. Topsoils are not nearly as thick as subsoils, and thus much smaller volumes of topsoil materials are affected by earthworks compared with subsoils. Also, topsoils are relatively easily manipulated during urban development works in comparison with subsoils.

The Allophanic subsoils have silty textures, are friable with a greasy feel and have bright, strong brown (7.5YR 5/6, 5/8 – Munsell colour system), reddish yellow (7.5 YR6/6, 6/8), or yellowish red (5YR 5/6, 5/8) colours devoid of mottling. An additional field test is the Fieldes and Perrott (1966) sodium fluoride test (also described in Milne et al. 1995) for reactive aluminium, such as allophane or ferrihydrite. A drop of sodium fluoride solution is added to a soil aggregate or a smear of soil on a filter paper impregnated with phenolphthalein indicator. The intensity of red colour development indicates the level of allophane in the soil. A high allophane content indicates tephric soil.

The Granular subsoils are clayey like the Ultic subsoils but have finer blocky structures and strong brown colours (7.5YR 5/6, 5/8) with little or no mottling (Figs 2&3). The red weathered sandstone below the subsoil has bright red colours (5 or 7.5R 4/6, 4/8) that are very different from the yellowish brown subsoils (Figs 2&6) and the non-red weathered rock underlying the Ultic Soils. Ultic subsoils have coarser blocky or prismatic structures and paler yellowish brown (10YR 5/4, 5/6, 5/8) matrices with grey (5/7 5/1, 7/1) and reddish (2.5YR 4/6, 4/8; 5YR 4/6, 5/6, 5/8) mottling (Figs 1&4). However, both soils lose the blocky structures to give a more massive appearance with stronger mottling when earthworked (Fig. 5).

5 Conclusions and Recommendations

Granular and Allophanic Soils, which have Group A soil permeability, occur as minor inclusions in landscapes dominated by Group C permeability Ultic Soils on Waitemata Formation sedimentary rocks in the Auckland region.

Granular Soils occur in relatively small pockets where red weathered sandstone forms the soil forming material (i.e. is near to the surface). They can be recognized by the red weathered sandstone beneath strong brown-coloured, blocky clayey subsoils. Their location is sporadic and unpredictable in the landscape.

Allophanic Soils, developed from air-fall or reworked tephras (volcanic ash), are relatively predictable, being found usually in small areas on stable parts of the landscape, such as low angle broad ridges or terraces. Their diagnostic features are strong brown or reddish yellow or yellowish red silty subsoils with a greasy feel.

Granular and Allophanic Soils both have poor compaction and soil strength characteristics compared with Ultic Soils. Subsoils from Granular and Allophanic Soils are currently often excavated and are either removed and dumped during site earthworks or incorporated as minor fractions with higher strength Ultic subsoils and regolith for foundation fill.

Hand auger surveys, to supplement geotechnical bore holes with 10-m-spaced observations to 0.5-m depth along transects spaced at about 20–30 m are recommended across landscape units to identify significant areas of these soils.

On urban developmental sites, these Group A permeability soils should be retained in situ where possible, such as on low impact development sites. Where these soils must be excavated, they should be separately stripped and preferentially placed as a layer of up to 1.5 m thick subsoil into sites used for green spaces where their free drainage, permeability, and water storage/supply are valuable, for
example, stormwater reserves, grassed playing fields, constructed grassed swales, or roadside verges, amenity plantings, and parks.

If these more permeable soils need to be excavated, removed, stockpiled, and/or used as fill for re-contouring, consideration should be given to handling them separately from the Ultic subsoils. Earthworking operations, especially wheel trafficking and handling, on these more permeable subsoils should be minimized to retain their permeable structures. With careful earthworking operations, these subsoils also have the potential to be preferentially used for constructing permeable 'green areas' on urban development sites, thus improving water management. However, this should only be for stable sites where earth movement is not at risk' i.e. flat or terraced and gently sloping areas (<10°). They would also be useful for developing permeable swales. While the Ultic subsoils have high strength for foundation materials, the volcanic ashes of the Allophanic Soils and red weathered sandstones of the Granular Soils are relatively low strength and need to be mixed with a dominant quantity of Ultic Soil clays for geotechnical foundation material. These low-strength materials are thus of more practical use as subsoil material for constructed, permeable green spaces than as foundation fill.

The Engineers and Environmental Consultant who participated in this project agreed that the Class A permeability soils could be identified from the less permeable Class C soils using the descriptions and survey recommendations given in this report. Some expressed reservations on the extra costs to geotechnical site investigations but acknowledged that these were likely to be marginal costs rather than substantive. There was general agreement that there would be benefits to separating and utilizing these more permeable Class A soils from Class C soils for water infiltration ‘green areas’ on development sites. However, the costs-benefits need to be evaluated.

5.1 Recommendations to ARC

ARC requires urban developers to identify areas of Hydrological Class A soils in landscapes on Waitemata Formation dominating by Class C soils. This identification should exclude alluvial flats and steep land which has little practical relevance to soil stripping and water engineering design.

Where these pockets of soils Class A occur it is recommended that,

a) the runoff calculations are re-done, based on the areas of Hydrological Class A soils to take into account the presence of these soils, i.e. lower runoff in the pre-development baseline condition compared with a complete cover of Hydrological Class C soils;

b) consideration is given to separating these higher permeability soils from low permeability soils in situ (e.g., low impact or water sensitive design) or to reconstructing permeable green areas (e.g., small parks, lawns, playing fields, grassed swales, forested recreational areas, amenity plantings) for storm water infiltration in urban designs.

6 Acknowledgements

Thanks to Graham Mackay, formerly of ARC for facilitating this project and his help with locating urban development sites to examine. Dr Robyn Simcock helped with information and advice, and reviewed the report. Earl Shaver, Mike Martindale and Judy-Ann Ansen, ARC are thanked for their advice on a draft of the report. Ted Temple, Southern Skies Environmental Ltd; Ian Hendy, EDC Engineering Design Consultants Ltd; Rob Fenwick, Hick Bros Civil Engineering Ltd; and Trevor Matuschka, Engineering Geology Ltd; civil engineers and consultants advised on the practicalities of identifying, separating, and reusing Class A soils in landscapes dominated by Class C soils. Anne Austin edited and Mandy Cains formatted this report.

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8 Appendices

8.1 Appendix 1.

Table 1. Hydrological Soil Classifications for prevalent Auckland soils (from ARC Technical Publication No. 108, 1999)

Auckland Soil	SCS Hydrological Soil Group
Weathered mudstone and sandstone (Waitemata and Onerahi Series)	Group C
Alluvial sediments	Group B
Granular volcanic loam (ash, tuff, scoria)	Group A
Granular volcanic loam underlain by free-draining basalt	Use CN = 17 for all pervious areas

8.2 Appendix 2. General descriptions of Allophanic, Granular and Ultic Soils, cited from Hewitt (1998).

"Allophanic Soils have properties that are strongly influenced by minerals with short-range order, especially allophane, imogolite and ferrihydrite. They are characteristically weak in strength and sensitive, with very low bulk density. They occur mostly in volcanic parent materials, especially ash and basaltic scoria, but can occur also in quartzo-feldspathic and tuffaceous (greywacke) sandstone.

Granular Soils are clayey soils in which kaolin-group minerals are dominant, and are usually associated with vermiculite and hydrous-interlayered vermiculite. The soil fabric comprises polyhedral peds with strength characteristics which change rapidly with water content. The presence of vermiculite gives these soils a moderate buffer capacity. The soils lack the weak strength, friable failure, low plasticity, and low-activity-clay properties which either define or are accessory to Oxidic soils. Clay coatings where they occur are thin.

Ultic Soils are acid soils with clayey and/or organic illuvial features in subsoil horizons. They are developed in clayey weathering products of siliceous sediments or acid igneous rocks and usually contain mixtures of clay minerals, including kaolinite, halloysite, aluminium-interlayered vermiculite, and smectite. A few are developed in the weathering products of limestones and greensands. They have low potassium, magnesium and phosphorus reserves and small concentrations of weatherable minerals. E horizons or other features such as skeletans in the upper parts of the Bt horizon are indicative of clay destruction/removal processes. Argillic horizons are usually present."