Land and Soil Monitoring Programme 2013

June 2013 Technical Report 2013/019

Auckland Council
Technical report, TR2013/019
ISSN 2230-4525
ISSN 2230-4533

ISBN 978-1-927302-27-9
ISBN 978-1-927302-28-6

This report has been peer reviewed by the Peer Review Panel using the Panel's terms of reference
Submitted for review on 4 March 2013 Review completed on 24 June 2013 Reviewed by two reviewers
Approved for Auckland Council publication by:  Name: Grant Barnes Position: Manager, Research, Investigations and Monitoring Unit
Date: 24 June 2013

Recommended citation:
Curran-Cournane, F and Taylor A (2013). Land and soil monitoring programme 2013. Auckland Council technical report, TR2013/019

Land and Soil Monitoring Programme 2013

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Executive summary

Under the Resource Management Act 1991, regional councils have an obligation to monitor and report on the state of the environment in their regions. Auckland Council undertakes land and soil monitoring as part of State of Environment (SoE) reporting. The programme consists of four modules including the assessment of land pressures, land stability and disturbance, soil quality and trace elements, and sediment quantity. The land pressures module is divided into five sub-modules including land cover, land use, soil loss to urbanisation, extent of impervious surfaces and rural fragmentation. The report describes each of these modules and sub-modules and the frequency at which they are undertaken.

Multiple ecosystem services arise from soil natural capital fulfilling human needs and include cultural, regulating and provisioning services. Soil is a non-renewable resource and it is crucial that is well managed to ensure the well-being of current and future generations.

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1.0 Introduction

The Auckland region consists of a wide range of landforms, land cover and associated land uses, all of which combine to generate the soil properties at a specific location. Soil is the fine loose biologically active layer of the Earth's crust that supports plant life and billions of tiny insects, worms, bacteria and other micro-organisms. It can range in depth from a few centimetres to many meters. Soil forms into many different types, depending on the parent material and the environment that it has come from. It takes thousands of years for soil to form, and for all practical purposes, it is a non-renewable resource that must be well managed.

The land and soil in the Auckland region are important and valuable resources. They support the growing population by providing food, a place to live and work, and recreational and tourism opportunities. Some soil and landform combinations also have cultural and/ or historical significance to different groups of people.

It is important to determine and understand the dynamics of land-use change over time and its subsequent effects on the quality and quantity of land and soil resources. Use of the land and soil, and changes in land use and intensification, has a wide range of short and long-term implications for the environment. The conflict between continued agricultural production and urban expansion resulting from the increasing population in the Auckland region is putting the land and soil resource under pressure. In addition the discharges generated by land use patterns have wider implications for freshwater and marine receiving environments.

1.1 Monitoring in the context of Auckland's land resources

The underlying geology and landforms of the Auckland region are diverse. The west coast is dominated by huge dunes that form the peninsulas at Awhitu and South Kaipara Head (Carter 1980; Claridge 1961). Much of this sandy land contains Brown and Recent Soil Orders which can be, in parts, unstable and prone to erosion. In the north, the land consists of layers of sandstone, siltstone and mudstone (the Waitemata formation) (Taylor 1954). This area is dominated by highly weathered Ultic clayey soils on rolling and hilly slopes, with some steeper slopes that are unstable and prone to erosion. Ultic soils represent about 40 per cent of Auckland's soils (Figure 1) (NZLRI 2010).

Many of the Hauraki Gulf islands including Great Barrier Island and Little Barrier Island are dominated by old weathered volcanic soils with small areas of weathered clay and alluvial soil. In contrast, Rangitoto Island is a great New Zealand example of a basalt shield volcano. It is dominated by very young raw volcanic soils which have not succumb to the various degrees of weathering experienced by the latter islands (Molloy 1993).

The Waitakere Ranges in the west were formed by lava from volcanic eruptions and are covered mostly in native forest. The low undulating land of the Auckland isthmus is scattered with numerous small volcanic cones consisting of volcanic ash and lava, interspersed with patches of much older sandstone and siltstone formations. The volcanic eruptions covered a wide area and resulted in well-structured and productive Granular and Allophanic soils in the west and south (Orbell 1977). The central Franklin District is covered by airfall volcanic ash from local basaltic volcanoes and from much older rhyolitic eruptions from the central North Island volcanoes, producing well-structured and productive Granular soils. These soils represent about 20 per cent of Auckland's soil and are some of the best soils in New Zealand (MAF 1975). Alluvium (older volcanic material deposited by water) is found south of the Manukau Harbour. To the east the soils are a mixture of Brown soils from alluvium, and clayey soils from Waitemata formation. The Hunua Ranges in the south-east are characterised by steep slopes formed by greywacke and argillite.

Due to the diverse landforms, geology, soil types (natural environmental variation), and the way that these all interact with different land use types and land management practices (anthropogenic impacts), it is not feasible to monitor all of the land and soil resources and land uses at all locations. The land and soil monitoring programme measures the quantity and quality of the land and soil resources and the effects of land use. It uses a stratified approach to monitoring which enables representation across the region for most of the four modules (which will be described in greater detail in a later section) as part of the land and soil monitoring programme. Traditionally, some modules (e.g. soil quality monitoring) were specific to rural land as different rural land uses have different characteristics and different resource requirements to urban areas. However, such monitoring has now been extended into the urban area albeit sampling methodology and indicators have been catered for purposes of urban soil monitoring. Other monitoring programmes look at the effects of urban land use and the boundary between urban and rural and these are also location specific.

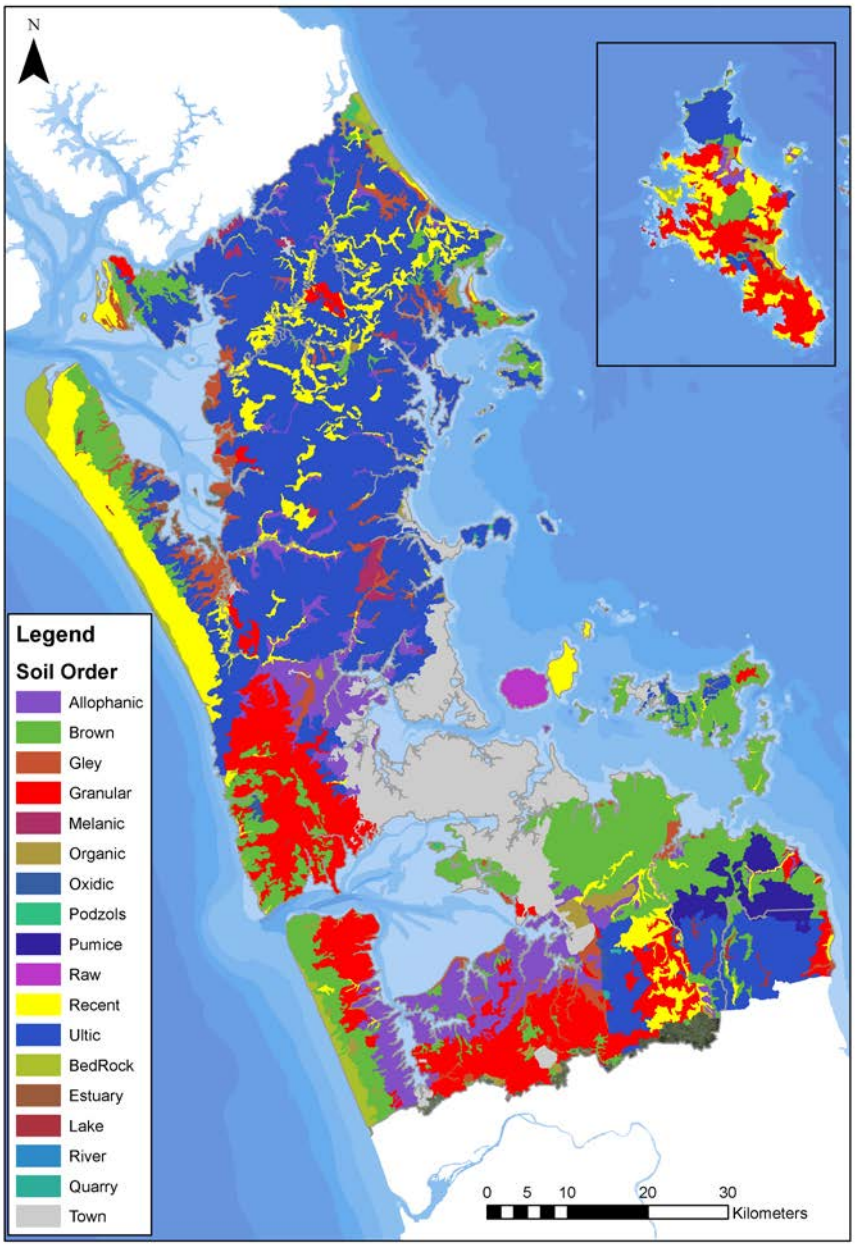

Figure 1. Distribution of Auckland's Soil Orders.

1.2 Background to design of the land and soil monitoring programme

Region-wide resource monitoring in Auckland prior to 1990 was confined principally to groundwater quality monitoring, hydrological monitoring, and surface water quality monitoring of key harbours and inland waterways. With the introduction of the RMA 1991 came the requirement for regional councils to gather information to monitor the state of New Zealand's natural environment.

In 1994 a report was commissioned by the then Auckland Regional Council (ARC) - *Monitoring Sustainability of Soil Resources: An Approach for Auckland*, in which a number of possible monitoring methods were presented. It was based on monitoring soils susceptible to degradation (Hicks 1995), and as such, was not regionally representative but issue based. However, the report also identified that a survey of land use was required for the Auckland region and should be repeated at regular intervals in order to track change.

From 1995 to 2000, the ARC was involved in a nation-wide soil-health (quality) monitoring project, commonly referred to as the '500 soils project'. Landcare Research and, the then, Crop and Food Research conducted the monitoring work on behalf of the regional councils involved, with funding assistance from the Ministry for the Environment's Sustainable Management Fund and with funding input from the councils involved.

In 2000, the ARC gathered information about the current extent of erosion and vegetation cover over parts of the region particularly at-risk from erosion (Hicks 2009b). The areas looked at included the hill-country of Rodney district and western sand country of the Awhitu and Kaipara districts (Hicks 2009d; e).

In the period 2001 – 2008 there was no monitoring of the quality and quantity of land and soils.

In 2008 the soil quality and extent of erosion monitoring components mentioned above were reinstated and have been developed into a wider land and soil monitoring programme for the Auckland region.

The land and soil monitoring programme is concerned with the land (landforms, geology, erosion, land cover) and soil resources of the region and how they are affected by land use including:

- the rate of change,
- what is causing the change,
- what impact change is having on the land/soil and how this links to receiving environments.

It is important to determine and understand the dynamics of land use change over time and its subsequent effects on the quality and quantity of land and soil resources, stability and disturbance and how this in turn affects receiving environments. A key component of the land and soil monitoring programme is the provision of information on land use, sediment disturbance and generation to other resource monitoring programmes.

2.0 Land and soil monitoring programmes

The overall aim of the land monitoring programmes are to describe the quantity and quality of the region's land and soil resources, and to assess the effects of pressures on them (Table 1). The SoE land and soil monitoring programme covers four key modules:

- Land pressures
- Land stability and disturbance (quantity)
- Soil quality
- Sediment (quantity)

The specific details of each programme are covered in the project summaries that follow.

Table 1. **A brief outline of each programme.**

Module	Sub-module	Baseline
Land pressures	Land cover	Regionally representative
	Land use	Regionally representative
	Soil loss to urbanisation	Regionally representative
	Extent of impervious surfaces	Location specific
	Rural fragmentation	Location specific
Land stability and disturbance (quantity)		Regionally representative
Soil quality and trace elements		Regionally representative
Sediment quantity		Regionally representative

2.1 State of the Environment Monitoring

Land pressures

An important determinant in the extent of environmental pressure on land is the way in which it is used (e.g. contrasting sediment yields from native forest vs. high production pasture on the same landform). Land uses have diverse characteristics and resource requirements and can change the quality and the quantity of natural resources. The land pressures module of the programme focuses on land use and population growth (both urban and rural).

Land cover

Land cover (vegetation or natural elements covering the ground) monitoring can identify critical causes of change or provide an early warning system for habitats being degraded. Land cover has been mapped nationally but at a scale where the data can be used at the regional level (the minimum mapping unit was 1ha). The Land Cover Database (LCDB) is a digital thematic map. LCDB1 was completed in June 2000 and used Spot II satellite imagery from 1996/1997. It used 16 land cover classes covering artificial, cultural and natural classes.

LCDB2 used Land Sat 7 satellite imagery from 2001/2 and was completed in 2004. The land cover classification was expanded to 43 classes but can be used for backward comparability of land cover information. Change analysis between the datasets is the primary use and the data is used extensively in monitoring biodiversity. The dataset is very expensive to produce and therefore is only available at 5 -7 yearly intervals.

LCDB3 became available 01 July 2012 and includes non-temporal edits to the summer 1996/97, summer 2001/02 time periods along with the new summer 2008/09 period. LCDB3 contains 26 land cover classifications.

The land cover classes mapped for the Auckland region are categorised at a high level (exotic vegetation, horticulture, native vegetation, pastoral, urban and other). These classes are used by many other programmes as a means of stratification in their programme design.

Land use change

Detection and reporting of land use change, particularly for areas undergoing rapid land use change or facing critical natural resource management issues is very important (Hicks 2009c). It is critical in evaluating and monitoring trends in natural resource condition. The Auckland Council does not maintain a formal or systematic monitoring system of land use pressures. However, it subscribes to a number of key external databases including the Land Cover Database (LCDB3), Agribase™ (2012), Statistics New Zealand census and Agricultural Production Survey. These collect data using different methods and at different temporal scales and dates and therefore, are not always comparable. Nevertheless, these databases and other data sources allow the council to investigate particular pressures when required and have sufficient spatial coverage. AgriBase™ is a spatially represented database of rural properties throughout New Zealand and provides more detailed land use information at the property level.

Soil loss to urbanisation

The type of land use, changes in land use and intensification all have a wide range of short and long-term implications for the environment. The conflict between continued agricultural production and urban expansion resulting from the increasing population in the Auckland region is putting the soil resource under pressure. The productive potential of the soil is being lost or reduced by increased development and non-economic rural residential blocks at the urban fringes. For example, it is forecasted that the population of Auckland will increase by 1 million by 2040 equating to the development of 400,000 houses. Monitoring soil loss to urbanisation uses spatial analysis to determine the amount of soil loss at defined intervals where urban boundary information has been compiled (Curran-Cournane 2013b).

The soil area is determined using the data from the New Zealand Land Resource Inventory which provides both soil information and Land Use Capability (LUC) classes. The productive capability of land is assessed using the LUC classes. The classes are a measure of the land's capacity for sustained productive use and take into account physical limitations, soil conservation needs and management requirements. There are eight classes, ranging from Class 1 (flat land with good soil and few limitations) to Class 8 (land with severe physical limitations). The rate of soil loss is monitored over each LUC class.

Extent of impervious surfaces

Auckland's urban streams have typically undergone substantial modifications to accommodate development and convey flood flows, which have significantly altered ecosystem function. Urbanisation increases the amount of surface area impervious to natural infiltration through the soil profile. Surfaces can be man-made (roads, parking lots, roofs) or natural (compacted soil or gravel). Such surfaces modify the

surface hydrology, altering the flows and can change the physical and chemical properties of surface water. The measurement of impervious surfaces is central to benchmarking and subsequently evaluating the urban stream management framework.

Impervious surfaces are monitored using medium resolution digital satellite imagery. Spot images from 2000 and 2007 have been used to map impervious cover for the rural urban boundary (RUB), urban growth areas and surrounding surface water catchments. Surfaces such roads, roofs and pavements are equivalent to 100 per cent imperviousness while surfaces like, grass trees and soil equal 0 per cent impervious. This information will contribute to other projects like Integrated Catchment Management Plans (ICMPs).

Rural fragmentation

Rural or land fragmentation is the ongoing subdivision of rural land that leads to increasingly smaller land parcels. It occurs when large land parcels used for agriculture are subdivided into small and more intensive production units, hobby farms or lifestyle blocks primarily for residential use. Rural fragmentation increases settlement density and also excludes land uses such as pastoral farming that for practical or economic reasons require large land parcels.

Rural fragmentation is monitored in rural land only (outside of the RUB; rural urban boundary) but currently Auckland Council does not maintain a formal or systematic monitoring system of rural fragmentation.

However, various options of rural fragmentation monitoring are being considered which include:

1. using LINZ (Land Information New Zealand) cadastral information at various years and determining the change in number of land parcels, for example between 1998 and 2008. Cadastral information is available regionally and at yearly intervals which can be classified into parcel size categories to gain more detail about rural fragmentation.
2. using LINZ database of titles. This option will allow the assessment of average title size in an area or local board of interest. However, up until 2013 this information would only provide data of when a title was last subdivided and not illustrate re-subdivision. The latter can be now be calculated and will be undertaken at annual intervals by the Land Use Built Environment Team in the Research Investigations and Monitoring Unit (RIMU) at Auckland Council.

Both options of rural fragmentation monitoring can be used in conjunction with the LUC database to provide information on the potential type of land (e.g. high class land- LUC 1-3) that may be lost to rural fragmentation.

It is worth noting that Landcare Research and the Regional Council Land Monitoring Forum are partners on a 2-year Envirolink tools project (Jan 2013 – Dec 2014) to help develop consistent national guidelines for monitoring rural fragmentation.

Land stability and disturbance

Soil erosion is a natural process by which soil is gradually eroded by water or wind from the Earth's surface, and then replaced in the soil forming process. It is important to understand the stability of the land resource, so that it continues to be available for urban use, farming, forestry and conservation across the Auckland region. Measuring the stability of the land gives us an understanding of its natural stability, and the amount of unstable land and land that has been affected by natural erosion processes.

Land disturbance activities or inappropriate land management activities can expose bare earth surfaces, accelerating soil erosion. It can also significantly increase the potential for the generation and discharge of

elevated levels of sediment. High sediment loads have an adverse effect on the quality of water bodies and coastal water.

Monitoring for land stability and disturbance uses a point sample methodology that uses aerial photography to identify and measures 5277 one hectare sample areas in a grid across the region. That is, a regionally representative sample. Within each sample area, the land stability and any soil disturbance as a result of land use or natural processes are recorded (Hicks 2009a).

Soil disturbance is measured by interpreting the one hectare sample area and recording any sign of disturbance. Wherever soil disturbance is recorded within a sample area, a cluster analysis is used to record the percentage of bare ground within each of those sample areas. This determines the percentage of bare soil in the one hectare sample area and provides information on the proportion of soil within the Auckland region that is bare at the time of the survey. The survey also records land use and vegetation data that can provide information for land use monitoring and other monitoring programmes.

Sufficient sample points to ensure statistical robustness and repeatability for future comparative monitoring were selected. The monitoring is repeated when aerial photography is available for the entire region, approximately every 5 years. Each of the selected points are analysed using standard photo-interpretation techniques in accordance with the Land Monitoring Forum's (LMF) procedure for point sampling (Burton *et al.* 2009).

Soil Quality

Soil quality is often referred to as the capacity of a soil to sustain biological production, maintain environmental quality, and promote plant and animal health. Soil quality is monitored to provide data about the effects of primary land uses on long-term soil quality. It tracks trends over time by collecting and analysing samples from sites that represent the dominant land-use types and Soil Orders, to characterise their chemical, physical and biological attributes. Soil Orders in the Auckland region include (with percentage in parentheses) Ultic (38->40%), Granular (19%), Recent (14%), Brown (10%), Allophanic (7%), Gley (5%), Raw (4%), Organic (2%), Melanic (1%), Podzol (0.3%) and Oxidic (0.2%) (NZLRI 2010). Land use types include dairy farming, drystock farming (sheep, cattle and deer), exotic (pine) forestry, outdoor vegetable cropping and horticulture (e.g. vine crops). Long-term indigenous bush sites were also selected for the determination of background soil quality.

Soil quality is assessed by sampling the topsoil (0–10 cm depth) along a 50m transect for seven key soil parameters (Table 2) (Hill and Sparling 2009). For chemical and biological soil analysis composite soil samples are collected at 2m (0-10 cm depth 2.5cm diameter) intervals across the 50m transect and comprise of 25 individual samples. For soil physical analyses, three stainless steel rings (7.5cm depth by 10cm diameter) are inserted into the soil at 15m, 30m and 45m intervals across the 50m transect for determination of macroporosity (-5 and -10kPa) and bulk density (Table 2). It is requested that the appropriate laboratory return the air-dried and sieved composite samples for each site after analysis for archiving purposes. Deeper soil layers can also greatly influence soil suitability for use. Therefore detailed soil profile information has also been collected at each site. A basic soil profile description including horizons, depths, colour and texture, combined with potential rooting depth and character of any limiting layer are also completed. This enables the soil type and classification to be determined.

Table 2. Seven soil parameters assessed.

Soil property (indicator)	Soil management issue
Total C	Carbon depletion
Total N	Nutrient depletion/saturation
Mineralisable N	Biological activity change
pH	pH changes (acidity)
Olsen P	Nutrient depletion/saturation (fertility)
Bulk density	Structural decline (compaction)
Macroporosity	Structural decline (compaction)

Each soil parameter result is compared against a target range for that land use or soil type, which was defined by collated field data, modelling and a panel of soil experts during a two day workshop in the early 2000s (Sparling *et al.* 2003). It is worth noting that these target ranges were refined by a panel of soil experts at a one day workshop in 2011 (Taylor 2011).

Rural Auckland has about 110 soil quality sampling sites (the majority established during the period 1995-00) covering the following land use types (Figure 2): pastoral grazing n=38; (dairy, drystock, dairy-drystock, forestry-pasture and lifestyle block sites); cropping and horticulture (n=18); forestry (n=16); indigenous forest (n=35). Eight new plantation forestry sites were selected in 2011 to build up the dataset for this land use. Fifteen new indigenous sites were selected in 2012 extending the sampling area to the Great Barrier Island and the Waitakere and Hunua Ranges.

At least four of the original sites selected in 1995-00 were lost due to changing land use e.g. the development of a glass house or development of recreational activity on rural land. There have also been significant land use changes within rural Auckland, particularly for pastoral land. For example, many of the original dairy and drystock sites have converted to lifestyle blocks (Curran-Cournane *et al.* 2013). Hence these land uses have been pooled together and categorised at 'pastoral'.

When dairy sites are scheduled to be resampled in 2014 several new sites will have to be identified and sampled. Although this creates difficulty in developing soil quality trends for dairy and drystock sites over time as a result of the extent of land use change that is being experienced within rural Auckland, it is important to capture the impact pastoral land use categories, such as intensive dairying and extensive drystock operations, have on soil quality.

A service level agreement (SLA) and field work protocol exists between the environmental science and monitoring teams to ensure that the soil quality monitoring programme is consistently delivered to a high standard.

Urban soil quality monitoring

There is a gap in knowledge regarding the health of soil in the urban environment with a large proportion of green areas across the RUB being parks and reserves. These green areas provide many ecosystem services such as recreational, aesthetic and biodiversity values as well as regulating greenhouse gas emissions and assisting in storm and flood protection (Dominati *et al.* 2010). In order for the soil to assist in

the functioning of these ecosystem services it is important to begin monitoring soil health in the urban environment and to start filling these gaps in knowledge.

A research study was undertaken in 2012 to fill this knowledge gap and data is yet to be reported. Sixty sites across the urban area were selected for these monitoring purposes (Figure 2).

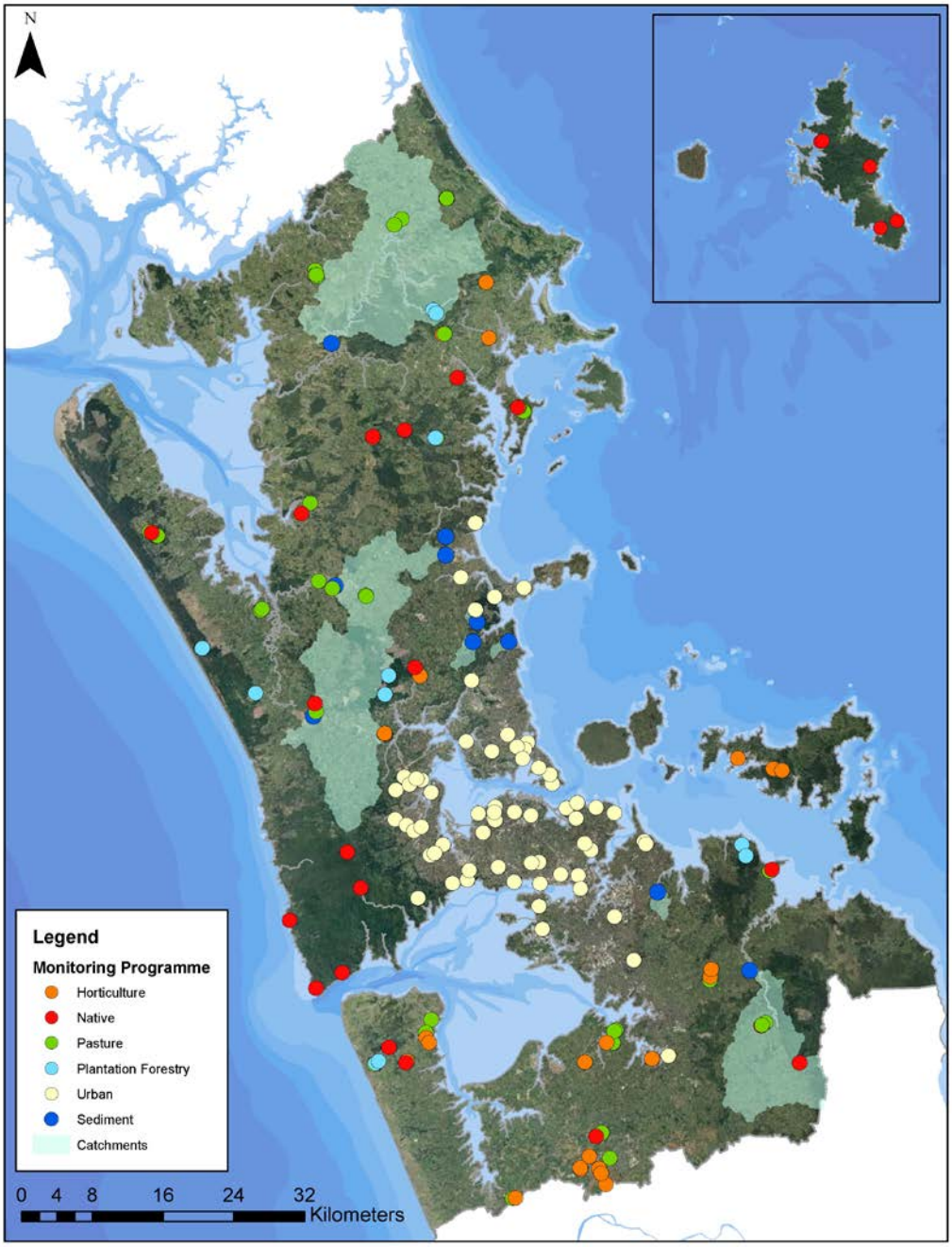

Figure 2. Location of the soil quality sites for various land uses and sediment monitoring sites across Auckland.

A programme for repeat sampling of sites re-commenced in 2008 and is based around a new framework that samples the sites based on a land use category. This will provide information specific to that land use and allow for reporting of soil quality information each year rather than waiting for five years when the review of all sites is completed. Land use categories are re-sampled at set timeframes (Table 3) and Table

4 gives an indication of the sampling regime from recent years and provides an indication of timeframes for future sampling events.

Table 3. Recommended re-sampling frequencies for different land uses.

Land use	Purpose of monitoring	Frequency	Examples
Intensive pastures and horticulture (dairy and horticulture)	Show accumulative effects of land use over several years. Show immediate effect of changed land use on soil characteristics.	Every 2–3 years	Monitor organic matter status. Demonstrate soil recovery after compaction or depletion
Extensive pastures (drystock)	Monitor slowly changing soil properties.	Every 3–5 years	Monitor nutrient status to look for depletion. Demonstrate soil recovery after compaction or depletion.
Forestry	Soil changes during forest development	Every 5–10 years plus after harvest and after re-planting.	Forest cycles take 20–30 years, with most change occurring around harvest and re-planting
Indigenous vegetation	Get information on what soils were like before development for agriculture and forestry.	Every 10–20 years	Sample forest reserves to establish baseline data. Mature forests would be expected to have reached equilibrium status

Table 4. Corresponding previous and future soil sampling event regime.

Sampling Years	Budget Year	Land use Class SOE	Land use Actual	Sample
2008	2008/2009	Horticulture	Horticulture[a]	2nd
2009	2009/2010	Pastoral Farming	Dairying[b]	2nd
2010	2010/2011	Pastoral Farming	Drystock[c]	2nd
2011	2011/2012	Plantation Forestry	Plantation forestry[d]	2nd
2012	2012/2013	Indigenous Vegetation	Indigenous vegetation[e]	2nd
2013	2013/2014	Horticulture	Horticulture	3rd
2014	2014/2015	Pastoral Farming	Dairying and pastoral[1]	3rd
2015	2015/2016	Pastoral Farming	Drystock and pastoral[1]	3rd
2016	2016/2017	Plantation Forestry	Plantation forestry	3rd

[1] This will include both former and new dairy sites as well as formerly known dairy sites to account for sites that have experienced land use change. This will also be the case for drystock sites.

a,b,c,d,e

Refer to Sparling (2009), Stevenson (2010), Fraser and Stevenson (2011), Curran-Cournane (2013a), Curran-Cournane (2013)

Sediment Quantity

Sediment loss to receiving water bodies is of concern and the council needs to understand and monitor the movement of sediment through the waterways, quantify the amount of sediment coming off the land, and identify where sediment is from, and where it is going. In the past ARC have conducted a number of sediment investigations. These investigations have generally been at catchment or sub-catchment level and have usually been in response to concerns regarding surface water quality, actual or proposed land-use change or increased sedimentation of estuarine environments and habitats.

A key requirement with state of the environment reporting is to provide a region wide picture. Since it is not practical to monitor sediment loads continuously in all streams around the region, a sampling programme has been designed that is regionally representative and stratified by geology and land cover. Ten sediment monitoring sites have been selected that are representative of the region's dominant geology and land use, the latter known to be major sediment generating determinants. The duration that the site is monitored depends on the number of events sampled and the site type (Curran Cournane *et al.* 2013; Hicks *et al.* 2009a). Typically this could take between 2-10 years depending on the site. Reference sites will be established for the long term. There are four types of sites:

- Calibration/baseline - relatively uniform catchment land use, smaller catchments, short term duration, and event sediment yields
- Validation - larger catchments, medium term duration, annual and mean annual data
- Reference - catchments that are relatively pristine and are expected to remain so, with no significant development or land use change planned; have uniform lithology and land cover, ongoing monitoring, mean annual yield
- Compliance - catchments, typically small, subject to development or activity requiring resource consent, often with mitigation measures in place (such as sediment retention ponds); duration dependent of the nature of the resource consent.

The basis for developing the regional picture would be a spatially-distributed sediment yield model that would be responsive to rainfall, land use and erosion treatment measures. A catchments surrounding land use, hydrological and physical characteristics are major determinants on the amount of sediment lost to the aquatic environment. The locations of the ten sediment monitoring sites are selected based on these sediment generating determinants that vary at each site (Figure 2).

Monitoring would be undertaken to service a sediment yield model and its predictions and it is proposed that monitoring would be split between tactical (short term monitoring at small uniform catchments focusing on filling gaps in current land use-lithology knowledge) and strategic objectives (long-term monitoring at key receiving environments and measuring sediment yields from larger mixed use catchments).

The sediment monitoring programme will in time report (Curran Cournane *et al.* 2013; Hicks 2011; Hicks *et al.* 2009b):

- Point-data on mean annual and/or annual sediment loads (t/yr) to estuaries/harbours/the open coast on a sub-region/harbour/catchment basis, e.g., figures at sites stream/river mouths, tables of all site data.
- Spatially-distributed data on mean annual or annual sediment specific yield ($t/km^2/yr$), e.g. maps locating high sediment generation areas, tables listing yields by land cover by catchment or harbour.
- Changes in the above since the last reporting period.
- Trends in the above over multiple reporting periods.

For trend monitoring, council needs to distinguish climate-driven change in sediment yield from that associated with land use activities. This requires information from reference catchments that retain a stable land use.

Current monitoring will determine the spatial pattern of sediment generation. In the future, monitoring will show how riparian zones and changes in land use and land management practices (policy effectiveness) influence the generation and delivery of sediment which will be assessed with time.

A service level agreement (SLA) exists between the environmental science and monitoring teams to ensure that the sediment monitoring programme is consistently delivered to a high standard.

3.0 Issue specific monitoring

As well as providing regionally representative coverage of temporal change, monitoring carried out at a number of locations is designed to answer additional questions related to specific issues. These issue specific programmes may be spatially specific or temporally intensive in specific locations or may measure a selected suite of parameters additional to those monitored in the core monitoring programme.

Trace elements

Trace elements occur naturally in soils, mainly as a result of the natural weathering of rocks and minerals. These natural levels are often referred to as 'background concentrations' and can vary depending on the soil type, geology and climate.

Trace elements can also be added to the soil as the result of agricultural and horticultural land use activities. Soils on land used for production can have different trace element concentrations than natural background conditions. Trace elements can reach levels that exceed guidelines for human and animal health and may restrict the future use of the soil resource and have the potential to contaminant receiving environments.

Monitoring for trace elements in the Auckland region is issue specific monitoring carried out as part of the soil quality monitoring module which is regionally representative, monitoring the main Soil Orders and land uses in Auckland (Curran-Cournane and Taylor 2012). Trace elements of interest include arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc.

3.1 Spatial coverage

The spatial coverage of the land monitoring programmes is displayed in Figure 2.

Although not shown on this map, the coverage for monitoring land stability and disturbance is spatially regular. Point samples are at 1km spacings on a grid format covering the entire region. Although spatially regular, this sample design will be random with respect to land use and other factors which are unrelated to the map grid. Therefore representative regional data is collected.

Whilst the network of soil quality monitoring sites is widely distributed around the region, the design of the soil quality programme is not driven strictly by spatial coverage because the region's soil resources, and the land use types acting upon them, are not distributed in a spatially uniform manner. Soil quality is stratified by Soil Order and land use type.

Likewise the sediment monitoring sites are driven by geology and land use but are also integrated with freshwater and marine sampling sites. However, the data from sample sites will be used in a spatial model that will enable the entire region to be represented. The choice of catchments monitored for sediment loads/yields are based on land cover types, geology and location to major coastal receiving environments.

3.2 Data collection and management

Data for each programme is collected at regular time periods. Data collection is carried out by both internal staff and external providers (Table 5). Some data sets are sourced externally as they are part of a national data set i.e. LCDB and Agribase™ datasets, cadastral information. These datasets are often used in GIS for further analysis pertinent to the region (e.g. determining the proportion of the region's land cover) and all analysis mapping is stored within the GIS.

For programmes where regional data is collected by internal or external parties there are protocol documents which set out the methods for collecting the data, checking data and storage of data in electronic databases. Where data is collected by external providers it is generally provided at the end of each contract or financial year in agreed formats using a template supplied to them by the Auckland Council.

Table 4. Sampling intervals for land and soil monitoring.

Module	Sub-module	Sampling Interval	Sampled by	Data entry	Database
Land pressures	Land cover	5-7 years	External (MfE)	Data received from provider	GIS
	Land use	2-5 years	External (Agribase™)	Data received from provider	GIS
	Soil loss to urbanisation	1-5 years	External/Internal	Data received from provider	GIS
	Extent of impervious surfaces	2-5 years	External	Data received from provider	GIS
	Rural fragmentation	1-5 years	External/Internal	Data received from provider	GIS
Land stability and disturbance (quantity)		5-7 years	External	Data received from provider	GIS
Soil quality		By land use 3-10 years	Auckland Council, samples sent to Landcare Research and Watercare Services	Data received from provider	Excel/ Hydstra
Sediment (quantity)			Auckland Council, samples sent to Watercare Services	Data received from provider	Hydstra

4.0 Reporting

Information is disseminated in a variety of formal and informal means to ensure that it is available for a wide range of end users and stakeholders. The various modules have a standard reporting and review framework.

4.1 Data reporting

Raw data from monitoring is held in databases (Hydstra) and attribute tables and databases associated with GIS. The land stability and disturbance data is stored in attribute tables in GIS. All this data can be accessed and specific data requests can be accommodated.

4.2 Technical reports

The purpose of technical reports is to make detailed monitoring results publicly available and provide a technical interpretation of the findings. Technical reports are produced for each of the quantity and quality monitoring programmes on a regular basis (Table 6). The information collected on land pressures is compiled every four-five years and reported in the State of Environment report.

Soil quality results are reported annually and a compilation of the entire dataset every five years. The soil quality monitoring programme is independently reviewed for design and performance after the compilation of results is reported.

Land stability and disturbance monitoring is reported approximately once every five years as aerial photography for the region becomes available.

The data from the sediment monitoring will be reported every three-five years and data will be used to inform the spatial model. The model will be updated annually once there is sufficient information to use from the monitoring sites. A comprehensive analysis of the data and reporting is planned for every five years where state and any trends will be reported.

As with the other Auckland Council monitoring programmes, the results from the land and soil monitoring programmes are updated as the information becomes available and reported via the web.

Table 5. Reporting of land and soil monitoring programme timeframes.

Programme	Sub Programme	Current Data Reporting	Technical Reporting Frequency
Land Pressures	Land cover	5-7 yearly	SOE cycle
	Land use	2-5 yearly	SOE cycle
	Soil loss to urbanisation	2-5 yearly [1]	SOE cycle
	Extent of impervious surfaces	2-5 yearly	SOE cycle
	Rural fragmentation	2-5 yearly [1]	SOE cycle
Land stability and disturbance (quantity)		Appendices in technical report	5 yearly
Soil quality		Appendices in technical report	By land use each year and all sites 5 yearly
Sediment (quantity)		3-5 yearly	5 yearly

[1] Subject to the availability of updated aerial photography

4.3 Spatial and web based reporting

The detailed results of monitoring programmes are published as technical reports. However, these reports tend to be highly specific and quite complex. As a result, the information is not accessible to all audiences. To help address this issue, a range of spatial and web based reporting mechanisms are being implemented which utilize reporting indicators. Report cards have also been drawn up to disseminate such information to the public and the various local boards (e.g. Rodney, Franklin, Great Barrier Island, Waitakere, current rural urban boundary) that make up the Auckland region. The first suite of land and soil monitoring report cards were completed and made available in September 2013.

Indicator Implementation

All of the land and soil monitoring modules and sub modules have measures that can be reported as indicators of status. The land pressure indicators are compiled from analysis of data sets within a regional context. They contain detailed data that is categorised at a high level and reported as status.

Soil quality is a measure of whether a soil is in good condition for its current land use. The soil quality indicator is based on seven key soil chemical, physical and biological parameters. These parameters are assessed against guideline values, which differ depending on the land use and Soil Order. The target ranges for each soil quality parameter were assigned for various land use types and soil classes at a series of workshops in 1999. Such key soil quality indicator guidelines were recently reviewed at a workshop in Wellington in 2011 by a panel of soil experts (Taylor 2011). These target ranges represent critical levels where deterioration of soil function occurs. Scores for individual soil quality parameters are grouped together for each land use to give the percentage of the region's land area that meet all indicator thresholds or fail to meet one, two, three etc. indicator thresholds.

It is important to understand how well the land resource is remaining in place so that it continues to be available for urban use, farming, forestry and conservation across the Auckland region. Measuring the stability of the land gives us an understanding of its natural stability, and how much of it is unstable and has been affected by natural erosion processes. The land stability indicator uses a direct measure, there are no established guidelines for determining whether the situation is deteriorating or improving.

Further indicators for the sediment monitoring programme will be developed with time. The key indicator will utilise a regional sediment model that will be continually updated with sediment data and with time will become web based.

4.4 Programme reviews

The modules are reviewed individually each monitoring cycle to refine methods, make use of the most up to date technology, or enable more advanced data collection, storage and handling. Each technical report programme will be reviewed with respect to parameters, stratification or site locations e.g. to account for the extent of land use change being experienced within the Auckland region.

The entire land and soil monitoring programme will be reviewed on a five yearly basis. The last review was in 2007 before the monitoring programme re-commenced.

5.0 Linkages to other monitoring and research programmes

5.1 Internal linkages

Contaminants originating from a range of land uses (e.g. forestry or industrial land use) enter freshwater rivers and streams and eventually discharge into the marine environment.

The Auckland Council maintains rainfall and stream-flow monitoring sites throughout the region. Information collected from a number of these sites has been particularly useful for generating direct estimates of sediment runoff into the coastal environment, and for providing data for the development of sediment runoff models. This type of information is becoming increasingly valuable for the interpretation of marine monitoring results. Currently sediment loads are available from only a limited number of flow monitoring sites. A programme for increasing the coverage of these data is currently being implemented.

The marine monitoring programmes are also complimented by the Regional Stream Monitoring Programme which provides information on the quality of freshwater receiving environments. Eight water quality parameters are common across both water quality monitoring programmes and have been used to compare trends in water quality. Results of this regional scale assessment of marine water quality were found to closely mirror results observed for the freshwater quality monitoring programme.

With both the sediment and stream monitoring programmes, efforts are being made to integrate the establishment of new sites with existing monitoring sites in the marine receiving environment. For example, the Weiti sediment monitoring site was selected because it is situated in a forest block scheduled to be harvested in the imminent future that could potentially deliver elevated loads of fine sediment into the receiving estuary and consequently into the coastal Long Bay marine reserve. This could ultimately have a detrimental ecological impact on local benthic plant and animal communities.

Between all the monitoring programmes, land use is a key driver and the effects of land use on the land, freshwater and marine are key components of each programme. There is an integral link between what happens on land, what flows down streams and what ends up in the sea.

Land use is also a key link between the freshwater monitoring programmes and the marine monitoring programmes. The sediment monitoring component of the land and soil programme has been integrated with the other programmes. Flow sites and sites where freshwater and or ecological sampling is conducted have been used where possible and key marine receiving environments have been used as the basis of site selection where all the other criteria were met. Land cover is a core dataset for terrestrial biodiversity monitoring and vegetation data is also available from the land stability and disturbance monitoring programme.

5.2 External linkages

Auckland's soil quality information is used in national reporting by MfE and is available to other interested parties for research purposes i.e. LUCAS programme and FRST funded top soil carbon mapping project. The land stability and disturbance monitoring is conducted by a number of regional councils according to the Land Monitoring Forum (LMF) protocols established. The LMF is hoping to investigate ways to report this data at a national level.

6.0 Moving land and soil monitoring forward

On completion of the second complete round of soil quality sampling a comprehensive review of data is required and sites will be added to the programme to account for the sites that have under gone land use change but are still in the monitoring programme as the new land use.

Data analysis needs to concentrate on trace element concentrations as part of the soil quality monitoring. This data can be added to the data collected earlier through the contaminated sites programme and be used to build up a regional picture of trace element levels in rural land in the Auckland region.

Soil quality and trace element monitoring has begun to concentrate sampling within the urban environment to determine soil health across various parks and reserves that provide many ecosystem services. In order for the soil to assist in the functioning of these ecosystem services it will be important to focus on monitoring soil health in the urban environment and to start filling these gaps in knowledge.

The pressure indicators require review to determine if they are the most suitable indicators and to asses them against other potential indicators that other councils are using. There has been a gap identified around nutrients and some form of indicator needs to be determined.

Finally, considering the Auckland Plan's projections of a population increase of 1 million by 2040, equating to the development of 400,000 dwellings, it has never been more critical to continue land and soil monitoring to determine how these land pressures will affect Auckland's non-renewable land and soil resources.

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