Methods Used to Survey Soil State in the Auckland Region 2007

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Methods Used to Survey Soil State for the Auckland Region 2007.

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Contents

1 Introduction

This document summarises methods used for a point sample survey of soil state (intactness and disturbance) from 2007 region-wide aerial photography for the Auckland region. The survey has been carried out in accordance with the National Land Monitoring Forum's (NLMF) procedure for point sampling (NLMF in prep), and is similar to surveys carried out in the Manawatu-Wanganui, Auckland, Gisborne, Waikato, Wellington, Tasman and Bay of Plenty regions between 1997 and 2005.

Auckland's survey has been carried out primarily to provide information about soil state (intactness and disturbance) for state of environment reporting. Survey data are also expected to be useful for other purposes, such as providing detail about vegetation associated with the region's land uses; assessing the extent of vegetative soil conservation measures; and as a source of facts and figures for the Council's policy documents and publications.

This document is the first of four reports:

- Methods Used to Survey Soil State in the Auckland Region 2007,
- Soil State in the Auckland Region 2007,
- Vegetation Associated with Land Uses in the Auckland Region 2007, and
- Vegetative Soil Conservation Cover in the Auckland Region 2007.

2 Background to the Survey

Key points about the survey's background are:

- The ARC has a statutory responsibility to collect information about state of the environment for its region (Section 35, Resource Management Act).
- Much of the information collected in past years relates to water. The ARC now sees a need to collect more information about soil.
- Participation in the 500 Soils Programme is already supplying useful base-line information about soil quality i.e. changes in soil fertility, structure and biology under different land uses.
- However the 500 Soils Programme does not measure soil intactness or disturbance: how well the region's soil is being kept in place as a resource for farming, forestry and conservation; and how much is being disturbed by land use or lost through erosion.
- A soil intactness/disturbance monitoring programme should be technically sound, statistically robust, provide easily understandable data, within a short space of time, and at an acceptable cost.
- Techniques should be selected that meet the ARC's particular needs, but are also consistent with methods used by other regional councils.

Point sampling from aerial photographs was trialled by several regional councils (including ARC) between 1997 and 2005, as a means of monitoring soil intactness/disturbance. The method has evolved into a standard procedure, documented by the regional councils' National Land Monitoring Forum (NLMF in prep).

One of the trials was undertaken for ARC in the year 2000, by Dr. D. Hicks of Ecological Research Associates. For that particular trial, the Council requested point sampling of rural land from aerial photographs of the Auckland mainland taken in 1999 (excluding outer Hauraki Gulf islands). Data analysis and reporting were requested for hill country and sand country on the mainland, which at that time were regarded as priority areas for soil conservation. This survey's methods, data analyses and findings were documented by Hicks (2000a, b, c, d).

In 2008 ARC commissioned Dr. D. Hicks to undertake a new point sample from region-wide orthophotos (rectified aerial photographs) taken in 2007, and stored on the Council's geographic information system (GIS). Dr. Hicks designed the survey in July 2008, in conjunction with the Council's Project Leader Land, Amy Taylor. One of the Council's GIS specialists, Myles Hicks, set up an ArcView procedure in August, for Dr. Hicks to use on the GIS. Mr. A. J. Thompson also participated in the survey, to familiarise himself with the technique and be in a position to carry out future surveys for the Council as needed. Photo-interpretation was undertaken by Dr. Hicks and Mr. Thompson in September 2008, followed by data analysis and draft report preparation in October. Following review by Council staff in October-November, Dr. Hicks and Mr Thompson carried out field checks and finalised the report in November-December 2008.

3 Brief

The ARC specified the following brief:

3.1 Objectives

The primary objective is to estimate the state of soil (intactness and disturbance) in the Auckland region and its change over time. A secondary objective is to characterise soil disturbance using factors such as land use, vegetation cover, landform, and erosion type. This will assist with addressing the issue of accelerated erosion under current land use. A third objective is to establish a regional soil intactness monitoring programme which is technically sound, statistically robust, provides easily understandable data, within a short space of time, and can be carried out at an acceptable cost.

3.2 Monitoring area

The monitoring will be defined by the boundaries of the area that the ARC has statutory responsibility for. Within this area, soil state will be assessed at 5277 sample points, distributed at 1 kilometre intervals on the NZTM map grid. Although spatially regular, this sample design will be random with respect to land use and other factors which are unrelated to the map grid.

3.3 Sampling method

The method is to involve the use and interpretation of digital orthophotos (rectified aerial photographs) by on-screen viewing through GIS software, with direct entry of data to a GIS-linked database. Viewing is to be carried out at a scale of 1:5000, zooming to larger scales to inspect detail at points when necessary, and to smaller scales to view points in the context of surrounding terrain.

3.4 Sample point size

The data is to relate to the area delineated by a 1 hectare square superimposed on the image and centred on the sample point.

3.5 Data items

Data to be recorded are land use, secondary vegetation, soil state, soil disturbance type, and landform.

3.6 Cluster analysis of bare soil

A cluster analysis is to be carried out for each combination of land use and soil conservation cover, by applying a 100 dot measuring grid to an area of 1 hectare at each point where bare soil is detected. Measurement is to be carried out at a viewing scale of 1:5000. The measuring grid is to be applied to each point by means of a GIS layer.

3.7 Photo-interpretation error

This is to be ascertained by randomly selecting 100 points and viewing them in the field.

3.8 Analysis procedure

The analysis procedure is to be sorts either by database query or transfer to spreadsheets, followed by point counts and conversion of totals to percentages of regional area, area in each land use, or area with each soil conservation cover (as appropriate). Significance tests are to be applied, to calculate confidence limits for results.

3.9 Reporting

A draft report is to be supplied to ARC prior to presentation of a final report. The final report is to include results and interpretation, in a format similar to recent reports for Environment Waikato, Greater Wellington Regional Council, and Environment Bay of Plenty.

An additional feature is to be comparison of 2007 point sample data with data from a previous survey of the same points, carried out for ARC in 2000. This comparison is to detect, and comment on, any changes or trends in soil state (disturbance/intactness) between the two dates.

4 Survey Concepts

Before discussing survey methods, it may be helpful to state some concepts that underpin the measurement of soil erosion for environmental reporting.

4.1 Soil intactness and disturbance

The concept of soil intactness expresses whether soils are staying in place. A decrease in soil intactness occurs when soil is disturbed. The disturbance may occur under indigenous vegetation, or where land cover has been modified by uses such as farming and forestry, or where the soil itself is modified, for instance by machinery in the course of track construction, roading or urban subdivision. Soil disturbance manifests itself as:

- Changes in thickness,
- Change in exposed area,
- Movement of soil on-site,
- Removal of soil off-site.

The disturbance may reduce land's productive capacity on-site. Off-site, it may create environmental pressures, notably if soil enters waterways.

4.2 Soil erosion and accumulation

Soil erosion is one way soil intactness changes for the worse. The term encompasses removal of soil particles by wind, overland flow of runoff, rills and gullies, stream bank scour and collapse, and mass movement (landslides, earthflows, slumps and debris avalanches). Part of the eroded soil is deposited on-site, but some - often most - is removed.

There are other ways for soil intactness to decline, notably:

- Break-down of structure by machine compaction or animal treading,
- Loss of nutrients by removal of produce, leaching to groundwater, or volatilisation to the atmosphere,
- Decrease in topsoil depth by oxidation of organic matter, combustion, or shrinkage after draining.

The other forms are commonly thought of as declines in soil's condition, quality or "health".

Soil intactness can also change for the better, through soil accumulation. There are several ways:

- Long-term build-up in soil depth, by addition of decaying vegetable matter and weathering of regolith,
- Deposition of soil that has been eroded from upslope,
- Deposition of sediment transported from up-river,
- Deposition of wind-blown dust around growing plants,
- Airfall volcanic ash.

All these can be said to improve soil intactness. However, they can also temporarily reduce land's productive capacity e.g. siltation of a flooded river terrace; or create different environmental pressures e.g. burial of vegetation by the silt.

4.3 Soil state

Soil intactness, disturbance, erosion and accumulation are related concepts. Some geomorphologists and soil scientists prefer to analyse the landscape in terms of its stability or state. They differentiate very old surfaces where soil has remained stable for centuries if not thousands of years, from others where it is rapidly eroding or accumulating, or where it is alternating between erosion and accumulation on a time-scale of decades.

If soil intactness and disturbance, or soil erosion and accumulation, are to be measured for state-of-environment reporting, it will be more enlightening to interpret them in terms of soil state. Is the site of the soil naturally stable? Is it naturally unstable? If so, is it a site of erosion or accumulation? Does it alternate between the two? Is the erosion, accumulation or alternation rapid or slow? Only if data are collected in a format that enables these questions to be answered, can conclusions be drawn about whether a change indicates environmental deterioration - or improvement.

Accordingly, the NLMF's standard report format interprets soil intactness etc. using the broader framework of soil state. Reports identify whether points are on stable or unstable landforms. They then show whether current vegetation cover (or its absence) indicates points as being intact, at risk of soil disturbance, or recently disturbed, or freshly disturbed. They also differentiate whether disturbance entails the shifting around of soil by land use, or its erosion and accumulation by natural processes.

5 Description of Survey Methods

5.1 Design

Key features of survey design are:

Measurement from aerial photographs

The reasons for selecting this technique are:

- New digital aerial photographic coverage is available.
- Current land use can be recorded from the aerial photos, simultaneous with soil surface stability.
- They enable a region-wide sample to be collected faster than by approximate field measurement at sample points.
- A region-wide sample enables firm identification of where soil disturbance occurs.

A point sample (dispersed grid) at 1 km by 1 km NZTM map grid intersections

Reasons for selecting this strategy are:

- Orthophoto coverage is amenable to direct overlay of the NZTM map grid.
- The map grid, although spatially non-random, provides a random sample of the underlying terrain, because soils and land uses are irregularly distributed in geographic space
- 1 km by 1 km spacing will provide 5277 points; sufficient to represent the region-wide figures to within ± 1%.
- The sampling grid, stored in the Council's GIS, can be easily re-located for re-survey.

5.2 What has been recorded

This section outlines what data has been recorded in the ARC's geographic information system. For guidance about definitions of data items and interpretation methods, refer to the National Land Monitoring Forum's technical guide (NLMF in prep). It is a standard reference, equally applicable to other Councils' surveys.

At each of the sample points, information was recorded about the following attributes. The data relate to the area delineated by a one hectare square superimposed on the orthophoto and centred on the sample point.

5.2.1 Point number

A unique reference number for each sample point, from 1 to 5277. It is needed for sample data checks, and useful when querying the database for points with specific features.

5.2.2 Grid reference

NZTM Map Grid reference, stored as 8 figures e.g. 17400510. This is essential if the same points are to be located for a future re-survey. They also enable point data to be analysed relative to spatial data stored in the GIS; for instance Land Cover Database or Land Resource Inventory.

5.2.3 Soil state

These codes are essential for analysing soil intactness/disturbance:

s	stable surfaces (vegetated)
u	erosion-prone unstable surfaces (inactive, vegetated)
r	eroded unstable surfaces (recently disturbed, revegetating)
e	eroding unstable surfaces (freshly disturbed, bare)

Stable surfaces: show no sign of past erosion, have a smooth appearance and are completely vegetated (unless topsoil is disturbed by land use).

Erosion-prone unstable surfaces: show signs of past erosion but are currently not eroding, erosion scars have healed and are well vegetated. Erosion has usually occurred at least a decade prior to photography.

Eroded unstable surfaces: erosion scars are partially vegetated, surface is still rough. Erosion has usually occurred in the decade prior to photography.

Eroding unstable surfaces: erosion scars have no vegetation as yet. Erosion has usually occurred in the year prior to photography.

5.2.4 Nature of disturbance

Soil intactness/disturbance can be ascertained from the soil state codes above. However, recording the nature of disturbance enables additional analyses.

Topsoil:

c	exposed by cultivation
x	exposed by harvest
y	exposed by spraying
z	exposed by grazing pressure
t	exposed by farm or forest track (not sealed)
r	exposed by road (not sealed)
d	exposed by drain excavation, cleaning or tile drainage
e	exposed by earthworks

Topsoil disturbance is generally due to land use. It is recorded where visible on soil state categories 's' and 'u'. Topsoil disturbance is not recorded where visible on soil state categories 'r' and 'e', on the grounds that it is associated with, and over-ridden by, subsoil or other disturbance.

Subsoil:

l	landslide or slip
u	slump or earthflow
a	debris avalanche
p	tunnel (under-runner) gully
g	open gully

Subsoil disturbance is generally due to natural processes, but may be exacerbated by land use. It is recorded where visible on soil state categories 'r' and 'e'. Subsoil disturbance is not recorded where visible on soil state category 'u', on the grounds that it is vegetated and inactive.

Other:

bs	streambank scour
bd	streambank deposition
w	wind erosion or deposition of sand
s	sheetwash
br	rockfall or rock outcrops

Other disturbance is generally due to natural processes. It may have been initiated by land use, but the natural process has taken over. It is always associated with soil state categories 'r' and 'e'.

5.2.5 Percentage bare ground

This is recorded for fresh disturbance by natural processes (where soil state is 'e';) also for fresh disturbance due to land use (where soil state is 's' and 'u'). It is not recorded for recent disturbance where soil state is 'r'; because here bare ground is diffuse amongst revegetation, and is generally less than 1% by area. Percentages are determined by using a 10 x 10 grid of dots superimposed as a GIS layer on a one hectare area around the orthophoto sample point.

5.2.6 Land use

This set of land use codes is a pre-requisite for analysing soil intactness/disturbance. The land use code recorded is used as the primary (dominant) vegetative cover when discussing the vegetation cover observed at a sample point. The land use code also provides additional information to supplement other sources on the GIS (Land Cover Database, Agribase).

v	grape vineyards
k	kiwifruit vineyards
h	vegetable crops (horticulture, market gardens, outdoor vegetable production)
o	orchards
g	grain crops
gf	greenfeed crops
d	dairy pasture
i	improved drystock pasture
u	unimproved drystock pasture

c	exotic softwood/conifer forest
b	exotic hardwood/broadleaf forest
f	natural (native) forest
x	exotic woody scrub
s	natural (native) woody scrub
m	coastal scrub and grass (sand-binding or salt-tolerant plants)
w	freshwater wetland vegetation (rushes, sedge, raupo, flax)
mg	saline wetland vegetation (mangrove, saltmarsh)

For intensive uses (k, v, h, o, g, gf), g' etc. indicates cultivated fields, including recent plantings that do not provide complete ground cover; g# etc. indicates harvested fields.

In grasslands (d, i, u), d' etc. indicates sparse pasture that does not provide complete ground cover; d# etc indicates pasture that has been freshly harvested for hay or silage.

In forest (c, b, f), c' etc. indicates young trees (not yet closed canopy); c# etc. indicates trees harvested and not yet replanted.

In scrubland (x, s), x# etc. indicates recently cleared scrub.

A second set of land use codes has to be used when points fall on soil that is extensively disturbed by recontouring, or partly covered by buildings. For these points it is no longer possible to ascertain soil state, but type and extent of fresh disturbance is recorded (if present).

Rural buildings

by	farm buildings and yards (including lifestyle homes)
bg	indoor agricultural buildings (glasshouses, poultry barns, pig sheds)
bi	industrial buildings on rural sites
rr	rural roads, railways and airfields

Urban areas

qm	quarries and mines
uo	urban open space (parks, playing fields, waste ground)
ui	urban industrial and commercial buildings
uh	urban housing
ur	urban roads, railways and airfields

Where soil is extensively disturbed by natural processes but there is no land use, the following codes are recorded. For these points, the type and extent of any fresh disturbance is also measured:

Beach

Coast

Estuary

Lake

Pond

Sand

5.2.7 Secondary vegetation

The same codes as used for land use (primary vegetation) are recorded in a second column to indicate that another vegetation is intermingled with the main land use. Amongst intensive uses and grassland:

- a second code indicates extensive secondary vegetation e.g. u followed by s denotes unimproved drystock pasture with clumps of scrub,
- a dashed second code e.g. s' denotes scattered secondary vegetation,
- shelterbelts are denoted by an asterisk e.g. b*; hedgerows by an ampersand e.g. b@,

In scrub and forest:

- a second code indicates canopy gaps with dense secondary vegetation e.g. s followed by x denotes natural scrub containing pockets of exotic scrub.
- a dashed second code e.g. x' denotes sparse secondary vegetation in the canopy gaps.

5.2.8 Landform

The following landforms are recorded. They are not essential for ascertaining soil intactness/disturbance, but may be useful for other analyses.

s	steepland - ranges
h	hill country - hillsides, ridges, spurs
d	downlands, plateaux
t	raised terraces and plains
f	floodplains

w	wetlands
u	active sand dunes
ur	old dune ridges
uf	old dune flats
tc	raised coastal terraces
fc	sea-level coastal flats

Additional landform codes are recorded at points which lack soil. For these points no other attributes can be recorded.

l	lake
p	pond
d	drain
sa	small river or stream (alluvial)
sr	small river or stream (rock channel)
e	estuary
b	beach
c	cliff, rock outcrop or rock platform
flow	recent lava flows

5.3 Data storage, analysis and presentation

5.3.1 Data storage

Sample point locations are stored as ArcView attributes. These are cross-referenced to an ArcView database table which contains raw data for all points. It is duplicated in an Excel spreadsheet which enables data sorting.

5.3.2 Sorts and point counts

An initial data sort is carried out in the Excel spreadsheet, to check for consistency in use of codes, and correct where necessary. Subsidiary spreadsheets are created for each land use e.g. dairy pasture. These are repeatedly sorted to count points in each category of interest i.e. soil state and disturbance (second report); primary and secondary vegetation (third report); soil conservation cover and bare soil (fourth report).

5.3.3 Statistical analysis

Formulae are inserted into a modified version of each spreadsheet, enabling calculation of percentages for each category of interest.

Point counts are expressed as percentages of the regional sample, for:

- land use,
- soil intactness/disturbance,
- type of disturbance,

They are expressed as percentages of each land use, for:

- primary vegetation,
- associated secondary vegetation

They are expressed as percentages of stable and unstable land under each use, for:

- vegetative soil conservation cover

Finally, they are expressed as percentages of land under each soil conservation cover for:

- bare soil.

For percentages based on point counts, sample error has been calculated at 95% confidence level, using the formula:

$\pm$ 2 s.e. = 1.96 * sqrt (p(100-p)/n)

where:

s.e.	=	standard error
sqrt	=	square root
p	=	percentage from point count
n	=	number of points

It has been calculated for percentages based on cluster samples around points (bare soil), using the formula:

$\pm$2 s.e. = 1.96 * s/sqrt(n)

where:

s.e.	=	standard error
s	=	standard deviation of mean percentage for clusters
sqrt	=	square root
n	=	number of clusters

5.3.4 Data presentation

Large spreadsheets are fairly complex and hard to read, so summaries of point data for particular topics have been extracted as a series of tables for each report.

Graphs of summary data have not been included in the reports. Instead, electronic versions of the tables have been supplied to ARC as Excel spreadsheets. These enable ARC staff to generate customised graphs, as and when needed for internal use or external publication.

5.3.5 Reports

Four reports have been supplied as part of the survey. The first two are:

- Methods Used to Survey Soil State in the Auckland Region 2007
- Soil State in the Auckland Region 2007

The second report is the essential document that ARC needs to have, as a source of information that could be presented in its regional state-of-environment report.

The other two reports are:

- Vegetation Associated with Land Uses in the Auckland Region 2007
- Vegetative Soil Conservation Cover in the Auckland Region 2007.

They are "add-on" documents which may be useful to have, as sources of information about ancillary topics such as retention/regeneration of natural cover, planting of exotic vegetation as a conservation measure, and revegetation's impact on soil disturbance.

A fifth report has been supplied comparing results of the 1999 and 2007 surveys. It is:

- Changes in Soil State and Disturbance from 1999-2007

6 Technical Conclusions

6.1 Survey procedure

6.1.1 Preliminary up-grade of 1999 point sample

Most data items from ARC's previous survey (1999) equate to standard items in the post-2003 survey format adopted by NLMF. However three differences are that data storage formats and codes altered due to introduction of on-screen data entry in 2003; land use-related soil disturbance is now recorded in greater detail (3 categories subdivided into 8); and amount of fresh disturbance is now measured for a 1 hectare area (centred on each sample point). For entirely compatible change detection i.e. types and amounts of fresh erosion, the following up-grades were carried out on 1999 data:

- Convert 1999 point sample codes to standard NMLF format, and supply as Excel spreadsheet,
- Re-locate freshly disturbed points (373 out of 4153) on ARC's 1999 aerial photo mosaics; re-classify land use-related soil disturbance into post-2003 NMLF categories; re-measure all soil disturbance to post-2003 NMLF standard,
- Supply NZMS 260 map grid references for sample points, to enable re-location of same points in NZTM map grid on ARC's GIS.

Code conversions took 2 days, soil disturbance measurement up-grade took 3 days, and matching grid references to point numbers took 2.5 days.

6.1.2 Photo-interpretation

The procedure for interpreting orthophotos was on-screen viewing through GIS software, with direct entry of data to a GIS-linked database. This system proved very satisfactory due to high quality of the orthophoto coverage, and good standard of the Arcview procedure set up on ARC's GIS by Myles Hicks. Setting up the procedure took 1 day of his time and 0.5 days of the contractor's time (parameter setting and procedure test).

Photo-interpretation, at 15 days for 5277 points, was done at an average rate of 352 points a day. Whilst this rate was facilitated by availability of good hardware and software, there were some hold-ups experienced during the last week of photo-interpretation, due to increasingly slow graphics refresh-rate of the computer terminal being used.

6.1.3 Data analysis

Point counts were obtained by importing data into Excel. The master spreadsheet was repeatedly sorted for desired combinations of data. This process enabled any errors in recording codes to be detected in the course of sorts. These were corrected in the master spreadsheet. Corrected data were then copied into working spreadsheets that were formatted to calculate totals, percentages and error margins. Sorts and checks took 2.5 days. Obtaining totals, percentages and error margins from the working spreadsheets took:

- 3 days for 2007 soil state and (region wide and by land use),
- 3 days for 2007 vegetation associated with each land use,
- 3 days for 2007 bare soil associated with vegetation cover.

Data analysis remains intensive, as the procedure is interactive rather than automatic. For instance, to calculate bare soil percentages and confidence intervals for all types of disturbance within a land use, requires 33 iterations of the "sort and calculate" procedure within the relevant spreadsheet.

Analysis of 2007 data proved straight-forward, but some problems were experienced with 1999 - 2007 comparisons. The 1999 dataset did not include:

- points on Great Barrier and Little Barrier (no aerial photo coverage),
- points in urban areas (1999 survey was rural points only at ARC's request).

These omissions precluded region-wide comparison of all 5277 points. Nevertheless "cut-down" comparisons of change in soil state and land use were attained for 3912 points on rural land in mainland Auckland, which were recorded at both dates.

An additional problem with the comparisons for fresh soil disturbance, was that the 2007 survey measured two additional categories (for consistency with NLMF procedure). These were:

- unsealed farm tracks,
- unsealed rural roads.

These categories had to be isolated from comparisons, in order to work out whether there had been an increase in bare soil attributable to previously measured categories (farming or forestry practices; natural processes of erosion and deposition) since 1999.

The above problems are not expected to recur in a future survey, so long as all points can be re-sampled from new aerial photography, and so long as the same NLMF categories are used for data recording.

1999-2007 comparisons took 6 days (including 2 days for re-analysis of 1999 soils state to the current NLMF format).

6.1.4 Field check

To expedite field check, points were randomly selected by computer but discarded if not within viewing distance of public roads, until the required number of points (n=100) was obtained. Generating random points for field check and printing screen dumps of the selected points with road overlays took 1.5 days. Field checks took 4 days.

Geographic spread of the selected points was somewhat uneven as a consequence; however they remained random with respect to the range of data items recorded. This achieved the field check's purpose - ascertaining accuracy of photo-interpretation - without the expense of hiring an aircraft or helicopter. Five points on islands of the Hauraki Gulf were left unchecked, to avoid the time and cost entailed in boat access. Analysis of field checks took an additional 1 day. The field check procedure was straight-forward, and its results are discussed later in this report (Section 6.2).

6.1.5 Report preparation

Report preparation (42 summary tables plus accompanying text) took:

	Draft	Final
Report 1	3.5 days	2 days
Report 2	3 days	6 days
Report 3	2 days	3.5 days
Report 4	2 days	2 days
Comparison	1 day	2 days

i.e. a total 27 days. This includes several half days discussing drafts with ARC's Project Leader Land, Amy Taylor. Report finalisation remains a time-consuming part of the survey; particularly any alteration of summary tables (which entails re-running calculation spreadsheets, and accounts for much of the time spent finalising Report 2.

6.1.6 Overall comments on survey procedure

This is the first time that a regional council's point sample has been repeated, so the ARC contract has been somewhat of a "test case" which will be viewed with interest by other councils.

Most aspects of the 2007 survey proceeded smoothly, in accordance with now-established NLMF procedure. ARC's request for Report 2's summary tables to be altered from the format previously used for other councils, entailed some extra work but has resulted in an improved format, which may be adopted by NLMF.

Data comparisons between the previous and current point sample were achieved, but not without problems. Key lessons for the contractors - and for other councils contemplating re-survey - are that:

- For region-wide change detection, all points need to be measured at both dates,
- Data analysis is more straightforward if the same soil disturbance categories are recorded each time, so that they don't have to be combined or sub-divided to enable comparisons.

Solutions to these problems were developed for ARC's re-survey, but they entailed spending more time on data analysis and report-writing. The problems can now be avoided in future re-surveys, and it would be best to do so, not just from a time and cost perspective; but more importantly in terms of providing councils with comparisons that are easily made, and easy to follow.

6.2 Photo-interpretation accuracy

This section presents results of field checks at 100 randomly selected points. They indicate reliability of photo-interpreted data stored for 5277 points in the sample.

6.2.1 Land use

Correct at 91 points. Photo-interpretation errors are:

- urban open space recorded as urban housing (3 points),
- urban housing recorded as urban open space (2 points),
- horticulture (plant nursery) recorded as kiwifruit vineyard (1 point),
- planted scrub (lifestyle subdivision) recorded as sparse drystock pasture (1 point),

- dairy pasture recorded as drystock (1 point),
- wildling pines recorded as natural forest (1 point).

Land use changes subsequent to photography were identified at a further 18 points:

- sparse vegetable crop now dense (1 point),
- harvested grain crop now dairy pasture (1 point),
- sparse dairy pasture now dense (3 points),
- dairy pasture now drystock (1 point),
- sparse drystock pasture now dense (7 points),
- unimproved drystock pasture now improved (1 point),
- sparse drystock pasture now natural scrub (1 point - secondary cover has taken over),
- open-canopy pines now close-canopy (1 point),
- pines now harvested (1 point),
- orchard now urban open space (1 point),

6.2.2 Associated secondary vegetation

Correct at 90 points. Photo-interpretation errors are:

- 2 points where secondary vegetation (mangroves, coniferous shelterbelt) omitted,
- 2 points where surrounding secondary vegetation (drystock pasture, natural forest) recorded instead of rural buildings and yards,
- 4 points where minority component of secondary vegetation recorded in place of majority component (natural scrub instead of exotic, exotic scrub instead of unimproved pasture, exotic scrub instead of natural trees, exotic scrub instead of broadleaved exotic trees),
- 2 points where secondary vegetation misclassified (natural scrub as exotic scrub).

Secondary vegetation changes subsequent to photography were identified at a further 6 points:

- 1 point with sparse drystock pasture, now dense,
- 2 points with dense exotic scrub, now sparse or cleared,

- 2 points with sparse natural scrub, one now dense, one cleared,
- 1 point with natural scrub, now recorded as primary cover

6.2.3 Landforms

Correct at 86 points. Photo-interpretation errors are:

- floodplain recorded as drained wetland (1 point),
- terrace recorded as downland (2 points),
- downland recorded as terrace (3 points),
- downland recorded as dune flat (1 point),
- downland recorded as coastal terrace (1 point),
- downland recorded as hillslope (1 point),
- hillslope recorded as downland (4 points),
- steepland recorded as hillslope (1 point).

Landform changes subsequent to photography were identified at 0 points.

6.2.4 Soil state

Correct at 93 points. Photo-interpretation errors are:

- stable surfaces recorded as erosion-prone (1 point),
- erosion-prone surfaces recorded as stable (5 points),
- eroding surface recorded as erosion-prone (1 point).

Soil state changes subsequent to photography were identified at a further 6 points:

- bare eroding surface now revegetating eroded (5 points),
- revegetating surface now vegetated erosion-prone (1 point).

6.2.5 Disturbance type

Correct at 93 points. Photo-interpretation errors are:

- 1 point with earthwork recorded as track,
- 1 point with unsealed road recorded as track,

- 1 point with bark mulch recorded as cultivation,
- 2 points with small slumps recorded as landslides,
- 2 points with estuarine deposition omitted.

Disturbance changes subsequent to photography were identified at 13 points:

- 2 points with fresh earthworks,
- 5 points where earthworks had revegetated,
- 1 point with fresh grazing pressure,
- 2 points where soil exposed by grazing pressure had revegetated,
- 1 point with fresh cultivation of soil,
- 1 point where an unsealed track had been sealed,
- 1 point where streambank scour was revegetating

6.2.6 Bare soil

Bare soil could not be measured in the course of a rapid field check, but obvious discrepancies were noted. Presence or absence of bare soil is correctly recorded at 98 points. Photo-interpretation errors are:

- 2 points with unrecorded estuarine deposition.

Bare soil changes subsequent to photography were identified at another 18 points:

- 4 points with fresh bare soil due to disturbance by land use,
- 1 point where existing bare soil had expanded due to additional land use disturbance,
- 8 points where bare soil had revegetated after disturbance by land use,
- 4 points where bare soil was revegetating after disturbance by land use,
- 1 point where bare soil was revegetating after natural disturbance.

6.2.7 Overall comments on photo-interpretation accuracy

Accuracy is in the 90 to 95% range for all parameters except landform type. With this exception, accuracy is at least as good as, and in some instances better than, other point sample surveys recently carried out for regional councils' state of environment monitoring, which are typically in the 85% to 95% range.

Few errors are repeated more than once in the course of a hundred points. This being the case, it is unlikely that this error incidence will cause problems for any future analysis or re-survey of the point sample, because any misclassified point is usually incorporated into a large subtotal of correctly classified points. There need be no attempt to correct data for photo-interpretation errors - indeed it would be impossible to make consistent corrections without visiting every sample point – it is more practical to cite field check results as indicating classification accuracy for the region-wide point sample.

The obvious exceptions are landform codes, at 86% accuracy. Clearly there has been some confusion here, in particular of downlands with other landforms. The reason is that orthophotos cannot be viewed stereoscopically when interpreting them on a computer screen. Subtle changes in relief, for instance where downlands are close to footslopes, terrace edges and stream floodways, are hard to detect.

Caution needs to be exercised, if the point sample data are analysed according to landform. If a more accurate landform map becomes available and can be overlaid in the Council's GIS, it may be worth substituting its landform identifications into the database. Until that happens the sample provides, at best, an approximate guide to the proportion of landforms present region-wide, or in any particular part of the region.

Changes subsequent to photography are not a problem. The sample is intended to provide a snapshot of the region in 2007, the year of photography. There need be no attempt to adjust data for subsequent changes, which should be detected by re-survey in a future year.

6.3 Representativeness of results

Statistical error analysis has been carried out for all tables in the survey reports, to ascertain how closely sample data match the region's soil state, associated vegetation, vegetative soil conservation cover, and bare soil percentages.

6.3.1 Soil state, soil disturbance, and bare soil (second report)

For soil state and disturbance region-wide there is 95% confidence that 2007 point sample data are representative of true figures to +-1.3% or better. For soil state and disturbance by land use there is also 95% confidence that point sample data are representative of true figures to +-1.2% or better.

For bare soil region-wide there is 95% confidence that 2007 cluster measurements around sample points represent true figures to +-0.29% or better. For bare soil by land use there is 95% confidence that cluster measurements represent true figures to +-0.15% or better.

6.3.2 Land use and associated vegetation (third report)

For land use and associated vegetation region-wide, there is 95% confidence that 2007 point sample data are representative of true figures to 1.3% or better, because primary and secondary cover are expresses as percentages of the region.

For vegetation associated with individual land uses, margins of error are typically within the 1% to 5% range, because primary and secondary cover are expressed as percentages of each land use, not the region. At 95% confidence they indicate the kinds of vegetation that are associated with each land use in 2007.

High margins of error are associated firstly with land uses where sample point numbers are low because they occupy a small percentage of the region. This is the case for exotic scrub (2.3%), coastal vegetation (0.5%), and wetland vegetation (2.1%). Secondly, primary or secondary cover components which are associated with a widespread land use but are uncommon. An example is coastal vegetation associated with natural forest (1 point out of 383). In these instances, there is certainty that the primary / secondary cover is a small component of associated vegetation, and its error margin is large relative to the percentage, simply because the percentage is so small.

6.3.3 Vegetative soil conservation cover and associated bare soil (fourth report)

For vegetative soil conservation cover associated with each land use, margins of error are similar to those for associated vegetation in the third reports tables, so are not repeated in the fourth reports tables. At 95% confidence they indicate extent and standard of vegetative soil conservation cover within each land use in 2007.

For bare soil under various categories and standards of soil conservation cover, margins of error are generally less than 1% (Tables 4.2 to 4.10). At 95% confidence they indicate reductions in bare soil where most (but not all) categories of soil conservation cover are present.

Instances where error margins for bare soil are in the 1 to 10% range are caused by one or two points in a category having a bare soil percentage that greatly differs from the rest. This can occur in two situations. The first is where there are enough points to establish a statistical distribution. Here a high error margin reflects genuine spread in the data. A typical example is sparse primary cover under intensive uses (43 points). Most of the points are partly covered by emerging crops, but some are freshly cultivated and still have close to 100% bare soil. The second situation is where a category's point numbers fall below n=10. Here, the error margin can be wide because there are not enough points to establish a reliable statistical distribution. An example is rank grass secondary cover in natural forest (5 points), where a single anomalous point distorts the distribution for bare soil. There are simply too few points in the sub-sample to be confident that it indicates either the average value or the likely spread.

6.3.4 1999 - 2007 changes in soil state, soil disturbance and bare soil.

Because the 2007 dataset includes points that were not sampled in 1999 (no aerial photos, or within urban limits), the comparisons are for rural land in mainland Auckland, not region-wide. Subject to this constraint, there is 95% confidence that the changes in soil state are statistically significant i.e. outside both dates' error margins. An additional constraint to comparison of soil disturbance and bare soil, is that the 2007 dataset includes two extra categories (unsealed roads and unsealed tracks). When these two are removed, there is still 95% confidence that the changes are statistically significant i.e. outside both dates' error margins, for land use disturbance as a whole, and also for natural process disturbance as a whole.

1999 – 2007 changes for particular disturbance types e.g. cultivation, landslides, have been detected both regionwide, and within specific land uses. However, most such changes remain within the sample error margins i.e. are not statistically significant.

Two important technical conclusions for point sample re-survey are that:

- Re-survey every 5 to 10 years can detect significant changes in land use disturbance (aggregated) and natural disturbance (aggregated),
- A longer interval will be required, to detect significant change at the level of particular disturbance types.

6.3.5 Overall comments on statistical representativeness of results

- The point sample is sufficiently representative to draw conclusions about soil state, soil disturbance and bare soil region-wide, and for land uses within the region in 2007. It is sufficiently representative to draw conclusions about 1999 - 2007 changes on rural land in mainland Auckland (where there are comparable points from the 1999 point sample).
- The point sample is sufficiently representative to draw conclusions about land use and associated vegetation region-wide in 2007. It is sufficiently representative to draw conclusions about 1999 - 2007 changes on rural land in

mainland Auckland (where there are comparable points from the 1999 point sample).

- It is sufficiently representative to draw conclusions about vegetation associated with individual land uses in 2007, but error margins are too wide to make 1999 - 2007 comparisons at the level of an individual land use.
- It is sufficiently representative to draw conclusions about extent and standard of vegetative soil conservation cover associated with individual land uses in 2007, but error margins are too wide to make 1999 - 2007 comparisons at the level of an individual land use.
- The point sample is sufficiently representative to draw conclusions about bare soil associated with various standards of soil conservation cover in 2007, including reductions in bare soil where soil conservation cover is present compared with where it is absent.

6.4 Extraction of regional sub-sets

Data for 5277 points region-wide are stored in the ARC's GIS for future use. From a statistical viewpoint, it is safe to conduct sub-regional analyses of soil state, soil disturbance and bare soil for local authority districts, large territorial areas, catchments, or sub-catchment management zones where number of points exceeds 100. Error margins will generally be less than 1%.

Similarly, it is safe to conduct sub-regional analyses of land use and associated vegetation, so long as the number of points exceeds approximately 500. Error margins will generally be in the 1-5% range.

In short, the point sample has been designed to provide statistical data for the Auckland region as a whole. It is sufficiently large, that it can also provide valid data for reasonably large subdivisions within it. However, to attempt a data analysis for soil state / bare soil in an area of land any smaller than 100 km2, or for land use / vegetation cover in an area smaller than 500km2, would be pushing the sample beyond the purpose for which it is intended.

7 Glossary of Terms

Absent (secondary cover)

No other vegetation type appears in association with the primary vegetation.

Bare soil

Soil that does not have a vegetative cover.

Conservation use

For the purpose of this report conservation use encompasses land in the rural areas under natural forest, natural scrub, exotic scrub, coastal grass and scrub, wetlands and mangroves, irrespective of land ownership.

Dense (primary cover)

Vegetation that provides complete ground cover (in the case of grassland or intensive uses) or has closed canopy (in the case of trees or scrub).

Disturbed soil

Soil that is no longer intact, as a consequence of land use, or removal through natural processes. Points recorded as disturbed are not always completely bare; there may be a proportion of bare soil.

Eroded surfaces

Unstable land surfaces, recently disturbed. Contain revegetating erosion scars that have usually occurred in the decade prior to photography.

Eroding surfaces

Unstable land surfaces, freshly disturbed. Contain bare erosion scars that have usually occurred in the year prior to photography.

Erosion-prone surfaces

Unstable land surfaces, inactive, vegetated. Show signs of past erosion but are currently not eroded or eroding, erosion scars have healed and are well vegetated. Has usually occurred at least a decade prior to photography.

Extensive (secondary cover)

Patches of other vegetation which are widespread amongst a dominant vegetation (primary cover).

Extensively disturbed surfaces

Areas of land where soil has been removed in whole or part, re-contoured, or covered by buildings, pavements or water.

Harvested (primary cover)

Vegetation that has been removed from a site e.g. the felling of trees or scrub; vegetable, grain or forage crops from land under intensive use; hay and silage cutting in grassland.

Intact soil

Soil free from disturbance by natural processes or land use (including machine disturbance in the course of land use).

Land use disturbance

Where soil is disturbed through human activity, for example by cultivation, grazing or silviculture.

Natural disturbance

Where soil is disturbed through erosion and deposition, for example by mass movement, running water, wind or coastal processes.

Non-vegetative (secondary cover)

Rural buildings, yards and tracks that are associated with primary vegetation.

Other use

For the purpose of this report, other use includes urban areas, also land occupied by buildings, yards and major roads in rural areas, water bodies and coastal features.

Primary vegetative cover

The dominant vegetation observed at a sample point

Rural land

For the purpose of this report rural land includes the land in rural areas that is used for commercial purposes (intensive uses, dairy pasture, drystock pasture and forestry plantation); also land under conservation uses (natural forest, natural scrub, exotic scrub, coastal grass and scrub, wetlands and mangroves).

Rural use

For the purpose of this report rural use encompasses the land in rural areas under intensive uses, dairy pasture, drystock pasture and forest plantation.

Rural buildings

Farmhouses, agricultural sheds, industrial buildings in rural land, residences on lifestyle blocks; includes associated yards and tracks; and sample points where most of the area is occupied by rural roads and associated earthworks.

Scattered (secondary cover)

Patches of other vegetation which are infrequent amongst dominant vegetation (primary cover).

Secondary vegetative cover

The next most prevalent vegetation observed at a sample point after primary vegetative cover (dominant vegetation).

Soil accumulation

Addition of soil particles by decomposition of organic matter, weathering of regolith, deposition of soil from upslope erosion, deposition of sediment transported from up-river, deposition of wind-blown dust around growing plants, or deposition from air-fall volcanic ash.

Soil disturbance

The concept of whether soils are at risk of moving from their place of formation. Disturbance may be by rural uses such as farming and forestry, or recontouring/removal of soil by machinery, or by natural movement of soil on-site, or natural removal of soil off-site.

Soil erosion

Removal of soil particles by wind, overland flow of runoff, rills and gullies, stream bank scour and collapse, and mass movement (landslides, earthflows, slumps and debris avalanches).

Soil intactness

The concept of whether soils are staying in their place of formation. How well a region's soil is being kept in place as a resource for farming, forestry and conservation. A decrease in soil intactness occurs when soil is disturbed by land use, or by natural processes of erosion and deposition, or by re-contouring /removal.

Soil state

Whether soil is stable, erosion-prone, eroded or eroding.

Sparse (primary cover)

Vegetation that does not provide complete ground cover (in the case of grassland or intensive uses), or does not have closed canopy (in the case of trees or scrub).

Stable surfaces

Land surfaces that show no sign of past erosion, have a smooth appearance and are completely vegetated (unless topsoil is disturbed by land use).

Unclassifiable land

Land where sample points cannot be classified due to absence of aerial photography or cloud cover or deep shadow on aerial photos.

Urban areas

Areas that are occupied by urban infrastructure, housing and amenities (including urban open space).

Vegetated soil

Soil that has a vegetative cover i.e. not bare.

Vegetative soil conservation cover

Vegetation that is capable of reducing soil erosion or trapping deposited soil; either through providing topsoil with a protective ground cover, or through providing subsoil with root reinforcement.

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