CERTIFIED PROFESSIONAL SOIL SCIENTIST

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Guidelines for Soil Survey along Linear Features

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Introduction

This document should be used in conjunction with the Australian Soil and Land Survey Handbook Series, in particular the Field Handbook – the 'yellow book' (NCST 2009) and the Guidelines for Surveying – the 'blue book' (McKenzie et al. 2008). The latter publication and its predecessor (Gunn et al. 1988) provide details of methods of soil survey for 'conventional' surveys – typically map sheets or large, non-linear areas. This document addresses the soil survey techniques required for linear features such as pipeline, rail, road, irrigation channel and powerline corridors. These linear infrastructure are generally 10-100 m wide. Consequently the specifications for site intensity are different to conventional survey specifications. Investigations involving corridor widths greater than 100 m wide, should adopt a standard area based sampling methodology from McKenzie et al. (2008).

Soil survey should be undertaken by suitably qualified persons. Such persons would be competent in undertaking land and soil resource assessment as per the documents indicated in the reference section. Certification as a Certified Professional Soil Scientist (CPSS) with a core competency in soil survey would provide evidence of being suitably qualified.

Purpose

Linear infrastructure developments require soils information to facilitate construction and to avoid or manage adverse environmental outcomes. Adverse environmental outcomes include both off-site impacts (e.g. erosion leading to decreased aquatic values) and on-site impacts (e.g. compaction), which could also limit the productive capacity of the land (i.e. change the land use suitability as a result of the development). Relevant data to capture would include:

- Abundance and size of stones, hard segregations and where appropriate, depth to rock
- Presence and depth to reactive (shrink-swell) clays
- Susceptibility to and presence of water erosion, including sheet, rill and tunnel and gully erosion
- Susceptibility to wind erosion and the generation of dust
- Topsoil depth and fertility in relation to post-disturbance rehabilitation
- Saline and/or strongly acid or alkaline materials
- Potential or actual acid sulfate soils
- Presence of shallow groundwater, seepage or waterlogging
- Susceptibility to compaction

The list above is by no means exhaustive and there are many other soil and attributes that may be relevant, depending on the specific purposes of the survey. It is however generally true that it is less expensive to capture more data at once than collect the same data in multiple exercises. Soils information is also collected by geotechnical investigations. While that information is complementary to the information collected by the soil survey methodology and may be of benefit, it is normally collected at set intervals and is difficult to apply to the management of soils due to the difference in the intent and standards used in geotechnical investigations. Soil mapping based on landscape (geology/landform/vegetation) features may provide a basis for interpolating between geotechnical sites.

Intent

Soil mapping (soil mapping units) that reflect the variation in parent material, landform, drainage and other soil/land attributes provide the basis of soil management units that can be identified and used in construction and rehabilitation activities. The soil properties of interest and how these are expressed in soil management units will depend on the type of activity proposed. However, the benefit of comprehensively identifying and mapping basic land resource information (in the form of soil mapping units) is that data/information can be reinterpreted for particular management requirements.

The most common issues that arise when planning and conducting such a survey are questions of required scale, site intensity, sampling and type of map units. These matters are addressed below.

Mapping scale and site intensity

Map scale and site intensity are two different attributes, which in conventional surveys are linked. The scale of a map is reflected in its cartographic production and historically was limited by things such as the scale of aerial photography used to create the linework and the methods by which the linework was transferred onto a geographically correct stable medium. The advent of digital imagery and desktop GIS means these are not the limitations they once were. There remains however a basic limit to the size of a feature that can be resolved at a given printed map scale.

Site intensity is a function of the field survey – typically expressed as the number of sites per hectare or square kilometre. It is a purely mathematical derivation. Map scale and site intensity are specifications that reflect the integrity of the spatial information presented. Different scales are recommended for different uses e.g. soils information for an environmental impact statement may be required at 1:250 000 while that for construction purposes may be 1:5000 i.e. information at different scales may be required at different stages of a project. The intensity of observations associated with each scale is a means of ensuring the accuracy and reliability of the information. Specifications for traditional surveys are outlined in Table 14.4 in McKenzie et al. (2008). The rule of thumb historically was one site described per square centimetre of map area. For example, on a 1:100 000 scale map, 1cm^2 is 1000 m x 1000 m, so the required site intensity was approximately 1 site/100ha. A range of site intensities is given in McKenzie et al. (2008) because the intensity of sites will vary with the complexity of the landscape. Complex landscapes may require a greater intensity of sites than more uniform landscapes.

A free survey approach to site selection is appropriate for scales from 1:25,000-100,000 or smaller, but for more detailed investigations at scales of <1:25 000, a grid survey approach, weighted by disturbance and soil management risks is likely to provide more useful information i.e. observations at predetermined intervals. This does depend however on the prior knowledge of an area before site assessment is carried out. Where there is no existing knowledge, a rigid grid survey is best; however, where existing knowledge is significant (e.g. after expert air-photo interpretation in an area where the soil surveyor understands well the stratigraphy and/or soil landscape model or where there is high quality existing data), less rigid site selection would be an advantage (but not necessarily less sites).

An underpinning principle in traditional 'free' surveys (as against a grid survey) has also been that the intensity of sites will vary with the complexity of the landscape – thus the overall site intensity/scale might be met for a survey area, but the actual site intensity will vary within different parts of the survey area. This basic principle also applies to linear corridors, but for civil infrastructure related activities, the appropriate site intensity and soil mapping scale may also vary depending on the level of expected earthworks, disturbance and nature of the infrastructure. Soils which pose a high environmental risk based on the activity will justify a higher intensity of survey. The scale of required data may also vary at different stages within an infrastructure project e.g at an initial investigation stage, 1:100 000 data may be sufficient; at the construction/rehabilitation phase though, 1:10,000 to 1:50,000 scale data may be necessary. These issues make the matter of defining an appropriate scale in linear corridors more complex than in conventional surveys.

Translating specifications to linear infrastructure

The specifications outlined in McKenzie et al. (2008) were designed for traditional surveys that delimited irregular rounded and elongated polygons in survey areas that were typically square or rectangular (map sheets). These specifications are not appropriate for linear infrastructure, for example at 1:100,000 scale, one site/100 ha would be equivalent to one site per 25 km if the linear corridor was 40 m wide. However, given that these specifications have been widely accepted, it is useful to translate these to be more appropriate for linear infrastructure.

A simple approach is to assume that a polygon is a square (Traill et al. 2012). For example, at a scale of 1:100,000, one site per 100 ha is one site in 1000 m x 1000 m. In translating to linear infrastructure, assume that the corridor is just one side of the square, i.e. 1000 m. Thus the specification of 1 site per 100 ha becomes 1 site per 1000 m of corridor. Similarly, the recommended minimum polygon size is 0.4 cm^2 and at 1:100 000 that is 40 ha or 400 000 m^2 or approximately 632 m x 632 m. Consequently, the minimum delimited length becomes 632 m, rounded to say 600 m. Table 1 provides the range of site intensities for different scales. It also indicates the maximum distance allowable without site data. This is relevant, as in certain, justifiable instances, it may be reasonable to increase the distance between sites – for instance, in highly uniform landscapes for which there is good prior knowledge regarding the soil types. Similarly, if complex landscapes are encountered – for instance around creek crossings – it may be necessary to decrease the spacing between sites.

Table 1 Scale, site intensity and maximum distance delimited for linear infrastructure

Scale	Site per length of linear infrastructure	Maximum distance delimited without direct site data
1:10,000	90-200 m	500 m
1:25,000	200-500 m	1000 m
1;50,000	500-1000 m	2000 m
1:100,000	1000-2000 m	5000 m

If the degree of soil disturbance is large and/or there is prior knowledge of a high likelihood of significant soil management problems, then the site density should be increased. Table 2 provides an example of how site density may change with differing types of disturbance. Table 1 and 2 should be used in conjunction to determine the appropriate site intensity for a given linear corridor. In these tables, minor disturbance is defined as works in which the land disturbance is limited in depth and/or width. For example, power poles or similar, installation of shallow (<1 m depth) pipes or cables where the surface area disturbed is <5m wide. Major disturbance includes activities that involve significant earthworks e.g roads, trenches and similar that involve excavation to depths >1m and/or surface disturbance of areas >5 m in width. Such works may involve generation of waste spoil.

Table 2 Example site intensity for different linear disturbances with corridor width up to 100 m

Type, location and length of disturbance	Average site intensity (m/site)
Major disturbance where subsoil is exposed, generally within urban areas or close to (<500m) sensitive receivers, or where frequent changes in potentially erodible/stable soil types occurs, or linear acid sulfate soil disturbances (refer to Ahern et al. 1998); ≤10 kms in overall length of disturbance/corridor	50 - (Very High) - 200 metres (High) intensity
Minor disturbances within urban areas with subsoil disturbance, major disturbances in non-urban areas close to (<500 m) numerous sensitive receivers, >10 kms in overall length of disturbance/corridor	200 (High) -500 metres (moderately high) intensity
Minor disturbances within urban areas, major disturbances in non-urban areas and not close to (>500 m) sensitive receivers, or where there is a clear repetitive pattern of soil type changes, >10 kms in overall length of disturbance/corridor	500 (moderately high) – 1000 metres (medium) intensity
Reconnaissance surveys (used as a guide to planning, with indicative corridor width greater than 100 m)	>1000 metres (low) intensity

Tables 14.2 and 14.3 in McKenzie et al. (2008) describe the different types of sites that may be used in a survey. These vary from detailed profile descriptions with soil samples taken for laboratory analysis, to check sites with only surface features recorded. The proportion of each site type will vary with the complexity of the soils/ landscape and the amount of historical data available for the area. As a guide however, Table 3 should be used to determine the proportion of site types.

Table 3 Site investigation types

Site type	% of sites	Comment
Representative profile	5-10%	Detailed descriptions of one or more representative profiles of all soil types (more for major soils) with full suite of laboratory analyses to 1.5 m, rock or to proposed trench depth if >1.5 m. A representative profile site is generally selected from previously described detailed profile description sites.
Detailed profile description	25-50%	Detailed profile descriptions to 1.5 m or rock, or to proposed trench or excavation depth for pipelines or channels if depth >1.5 m. Description to 0.3m beyond depth of disturbance if the latter is < 1.5 m.
Less detailed description	20-50%	Less detailed soil profile description to sufficient depth to identify the soil type and correlate to soils already described in the area. Description of salient soil features for soil classification, suitability assessment, topsoil assessment, etc.
Check sites	Up to 20%	Surface feature check sites (e.g colour, texture, cracking) in large uniform areas and to establish map unit boundaries. Check sites should have a minimum of data recorded to confirm the mapped soil type, such as location, landform, vegetation, surface characteristics, surface horizon characteristics, relevant notes, correlated/classified soil type, etc.

There are a number of basic attributes that should be described at all site types. These include location (MGA, GDA94), date, person describing the site, landform, geology, vegetation, microrelief, erosion, presence of salinity, surface coarse fragments, rock outcrop, land use and if possible lithology (otherwise geology) .

Soil profile descriptions

Soil profile descriptions are to follow the standards/terminology described in the Australian soil survey and land survey field handbook (NCST 2009) and record details of:

- Soil surface condition,
- horizon depths,
- horizon designation,
- boundary distinctness,
- field texture,
- colour,
- mottles,
- coarse fragments,
- structure,
- segregations,
- field tests (e.g. pH, salinity, dispersion).

Other attributes such as consistence (strength & water status), pans and water repellence should be assessed if relevant.

Good quality photographs of representative profiles and landscapes should be obtained during the survey. All sites should be classified using the Australia Soil Classification Revised Edition (Isbell 2002).

Sampling for laboratory analysis

Representative profiles of each soil type (more for major soils) are to be sampled for laboratory analysis of relevant properties. Any site sampled should have a detailed profile description.

Standard sample depths are 0-10, 20-30, 50-60, 80-90, 110-120, 140-150 cm, etc down the profile, for uniform or gradational soils. These depths should be modified though to ensure that significant horizon boundaries are not crossed in the sample e.g. an A2/B2 boundary (particularly for texture contrast soils) or with pH inversion Vertosols. Field tests for pH and EC will assist in the determination of these boundaries. Samples should not be bulked between sites and no sample interval should exceed 30 cm. There are many arguments for sampling by standard depth versus by horizon and there is no strict requirement for either. A consistent approach should however be used throughout the survey.

Surface (0-10 cm) bulk samples should be taken for fertility analysis from at least 9 points within a 10 m radius of a fully described and sampled site location. Various methods may be employed for bulk surface sampling e.g circular radius, triangle, square grid etc. Irregular and 'different' features such as wheel tracks, small depressions, animal camps and other forms of disturbance should be avoided. Bulk samples should be mixed thoroughly on a clean surface prior to sub-sampling.

Laboratory analysis should be undertaken by a suitably experienced and NATA accredited soil laboratory – preferably a laboratory that is ASPAC accredited in the relevant methods. Standard analyses for each sample include:

- pH, electrical conductivity, chloride
- exchangeable cations, cation exchange capacity, and exchangeable sodium percentage using methods appropriate to the soil type (See Factsheet on Measuring soil cation exchange capacity and exchangeable cations)
- fertility suite including organic carbon, total nitrogen, available P (using an appropriate method for the soil type) and micronutrients (Cu, Mn, B etc) - topsoil only bulked surface sample
- particle size analysis
- Emerson tests
- air dry moisture content

Depth functions of pH, EC and Cl (i.e. sample every 10cm) can be very useful in determining management options, particularly in relation to topsoil stripping depth in clays and texture contrast soils. Specific and targeted sampling may be required if soils are likely to have properties that are difficult to manage e.g. sodic, magnesic, high salinity and/or strongly acid.

Mapping units

The mapping units and map reference constructed during a survey should conform to the standard method used in Australia i.e around a geomorphic framework. This enables easy correlation to and maximum use of prior data in an area. Specific soil attributes maps or soil management plans relevant to the proposed corridor activity can also be produced e.g a map of gilgaied areas, soil depth, wetness, rock outcrop etc; and are often the most useful products derived from a survey. While all soils descriptions should be classified to the ASC, it is not necessary to produce a map based on the ASC, unless it provides value to the outcome of the work e.g a map of Hydrosols or Vertosols may be relevant. The soil types described should be correlated whenever possible to named soils in a district, but once again, production of a map using those soil names should only occur when it provides value to the interpretation and use of the data. For the purposes of communication, it may be useful to produce a map using plain English descriptions of soils. If well designed, this may also be used as a basis for rehabilitation plans. For example, creating soil groups such as shallow stony sands, deep non-stony sands, sodic cracking clays and non-sodic cracking clays. Any such groupings should have a direct relationship to aspects of the corridor development and soil management.

Digital (raster based) soil mapping techniques may be well suited to linear infrastructure projects as management prescriptions are often based around specific properties of soils such as A horizon depth, stoniness or depth to bedrock. Use of such methods should however follow appropriate standards and include clear estimates of accuracy.

Presentation of survey information

The way in which a soil survey report is written will depend on the needs of a client and objective of the survey but some common principles apply across all reports. The 'raw' soil information collected can be presented as basic land resources information consistent with the standards of the profession. Interpreted data such as soil management information should be presented separately.

Maps produced for a survey should adhere to appropriate cartographic standards – all components should be legible and maps should always include a co-ordinate system, scale bar, north arrow and legend. All soil survey sites should be clearly marked and discriminated by site type e.g representative site, check site etc. Where appropriate, data outside of the corridor of interest should also be included e.g existing data from historical surveys. A typical map should have an ortho-photo or high resolution satellite imagery background with all related features of interest identified e.g roads, cadastral boundaries, corridor boundary etc.

Each soil type should be described in the report, along with a summary of laboratory results, management constraints and associated recommendations. Representative photos of each soil type and associated landscapes would be beneficial. Certified copies of laboratory reports of analysed samples should be included and any interpreted material e.g graphs of data; should clearly indicate the site/sample interval. Legible copies of field sheets or other electronic records should also be included.

Soil data published at scales larger than the respective average intensity at which it was collected (e.g 1:100 000, published at 1:25 000), should be avoided whenever possible. The site intensity should be stated on any published map and where different average site intensities are achieved throughout a survey extent, a reliability diagram should be produced to inform the reader. Keeping in mind the above-mentioned goal of not producing maps at a scale inconsistent with the data capture scale, the reality of linear corridors is they provide a cartographic challenge in comparison to conventional rectangular map sheets, thus the cartographic principles of map scale may not always be able to be adhered to for linear surveys. Thin corridors surveyed at low intensities may be illegible if they are printed at their correct cartographic scale. Thus it is important on any maps to indicate both the scale of the map and the scale of the underlying data, whether it be expressed as a conventional scale or as a site density (e.g. a site every X m).

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