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National Geochemical Survey of Australia: Field Manual

Megan Lech, Patrice de Caritat, Andrew McPherson

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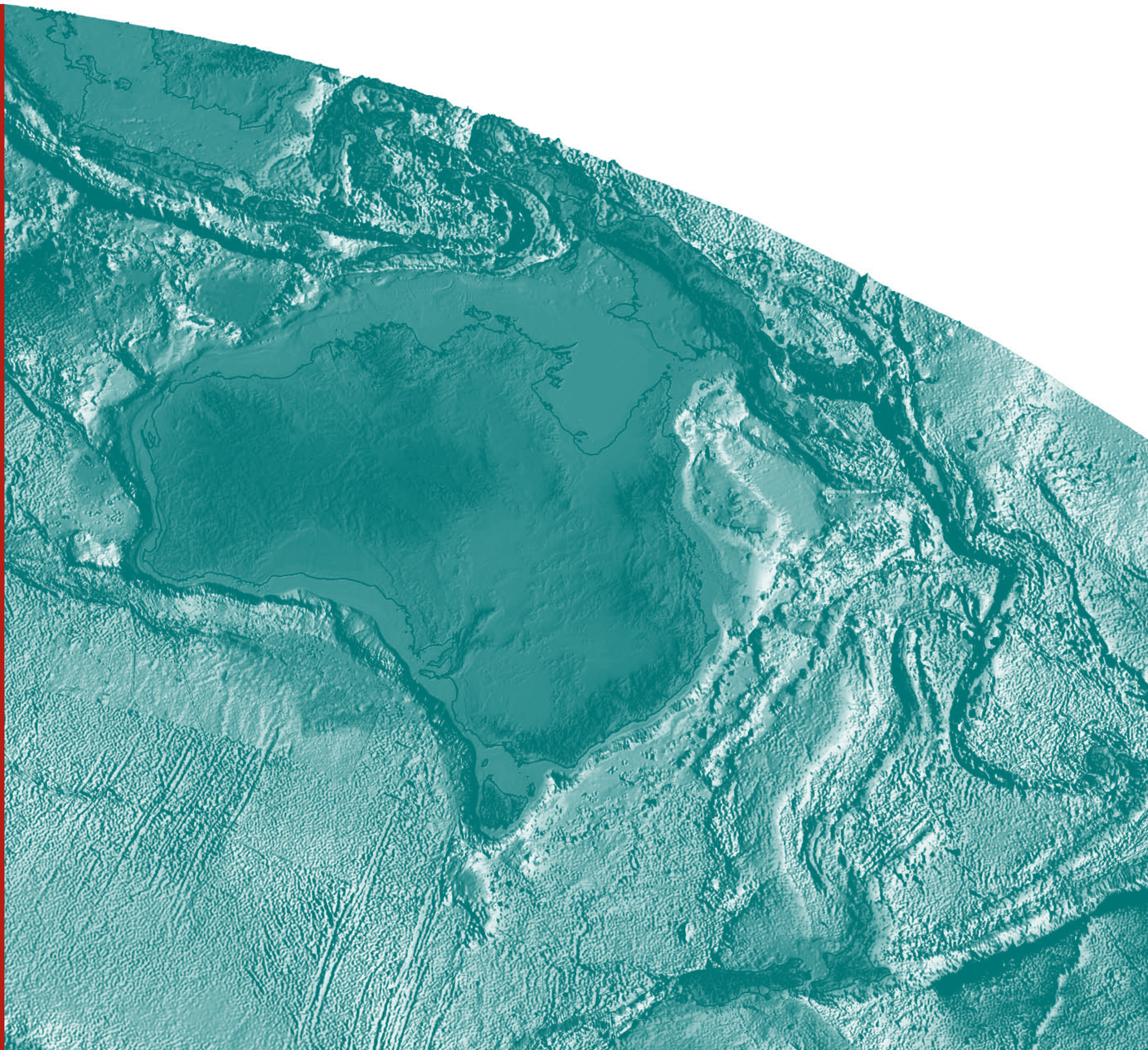

SPATIAL INFORMATION FOR THE NATION

National Geochemical Survey of Australia: Field Manual

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by

Megan Lech[1], Patrice de Caritat[1], Andrew McPherson[1]

Australian Government
Geoscience Australia

1. Geoscience Australia GPO Box 378 Canberra ACT 2601

Department of Industry, Tourism & Resources
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EXECUTIVE SUMMARY

The National Geochemical Survey of Australia (NGSA) project represents an essential component of the Australian Government's Onshore Energy Security Initiative (OESI). The NGSA will collect and analyse transported regolith samples representative of catchments covering most of Australia using field-tested methods. The project is a collaborative effort between Geoscience Australia (GA) and State and Territory geoscience agencies, which will provide an internally consistent geochemical dataset useful for:

(1) calibration and ground-truthing of airborne radiometrics surveys;
(2) filling gaps in current airborne radiometrics and geochemical coverages of Australia;
(3) multi-element characterisation and ranking of radiometric anomalies; and
(4) aid in first-order investigation of the nature of geothermal hot-spots.

The NGSA project therefore supports and adds value to other OESI projects. Additionally, the outputs of this project will have wider applications in mineral exploration and environmental assessment and management.

This report details:

(1) the methodology underpinning the determination of the theoretical sampling points using terrain and hydrological analysis; and

(2) the protocols for sample collection.

It will be used for knowledge transfer during in-field training sessions with the State and Territory field parties to whom it will be distributed, together with field equipment and consumables, thereby ensuring consistent sampling throughout the project. A digital data entry template has been designed to enable efficient and consistent in-field data capture, which will also streamline data entry into GA's corporate databases.

INTRODUCTION

A 5-year Onshore Energy Security Initiative (OESI) programme was announced in 2006 to enable Geoscience Australia (GA) to deliver high quality pre-competitive geoscience information relating to onshore energy prospectivity (Johnson, 2006). The National Geochemical Survey of Australia (NGSA), which is part of this programme (Baldwin, 2007), will collect transported regolith (sediment) samples from across the Australian continent and analyse their inorganic chemical composition. The NGSA will provide the only nation-wide, internally consistent geochemical dataset with state-of-the-art detection limits. It aims to:

1. Help calibrate and ground-truth the airborne radiometrics coverage of Australia (including addressing mother-daughter disequilibrium in the U-decay chain);
2. Fill gaps in the existing airborne radiometric and geochemical coverages of Australia with quality data;
3. Permit multi-element characterisation and ranking of radiometric anomalies (e.g., differentiation of U signatures from ‘hot’ granites, black shales or palaeochannels); and
4. Provide fundamental data to enable first-order characterisation of geothermal hot-spots.

As such, the NGSA project supports and adds value to a number of other OESI projects, particularly the Australia-Wide Airborne Geophysical Survey (AWAGS) project and the Geothermal Energy project. Additionally, the NGSA will have spin-off outcomes in mineral exploration for other commodities and natural resource management.

By its completion in 2011, the NGSA will deliver:

1. A geochemical dataset that is national in scope, internally consistent and acquired through the application of state-of-the-art methods and instrumentation;
2. A web-delivered geochemical atlas of Australia for some 60+ elements/parameters showing for the first time what the concentrations of these elements are in surface materials and how they vary spatially; and
3. Reports and papers on energy resource prospectivity and other implications.

Samples will be collected over the whole continent from approximately 1400 catchment-based sites, giving an average sample density of 1 site per 5500 km^2. Collaboration with State and Territory geoscience agencies is critical for the completion of the program, particularly regarding the sampling phase, which is the subject of this report.

PILOT PROJECTS

The methods for determining the sampling sites and collecting the samples have been refined through a series of collaborative pilot projects between GA, the Cooperative Research Centre for Landscape Environments and Mineral Exploration (CRC LEME) and State geoscience agencies. The surveys were conducted in the Riverina region of New South Wales (NSW) and Victoria, the Gawler region of South Australia and the Thomson region of NSW (Figure 1) from 2003-2007 (Caritat *et al.* 2004a; Caritat *et al.* 2004b; Lech *et al.* 2004; Caritat *et al.* 2005a; Caritat *et al.* 2005b; Caritat *et al.* 2006a; Caritat *et al.* 2006b; Greenfield *et al.* 2006a; Greenfield *et al.* 2006b; Lech *et al.* 2006; Caritat *et al.* 2007, Lech & Caritat, 2007).

The pilot studies were purposely conducted in regions with varying climate, relief, drainage definition and thickness/nature of regolith cover. Up to six size fractions, various depth ranges as well as complete soil profiles were sampled. Partial leaches (including Mobile Metal Ions), heavy mineral fractions, and other sampling media (e.g., soil, groundwater, vegetation) were tested during the pilot projects.

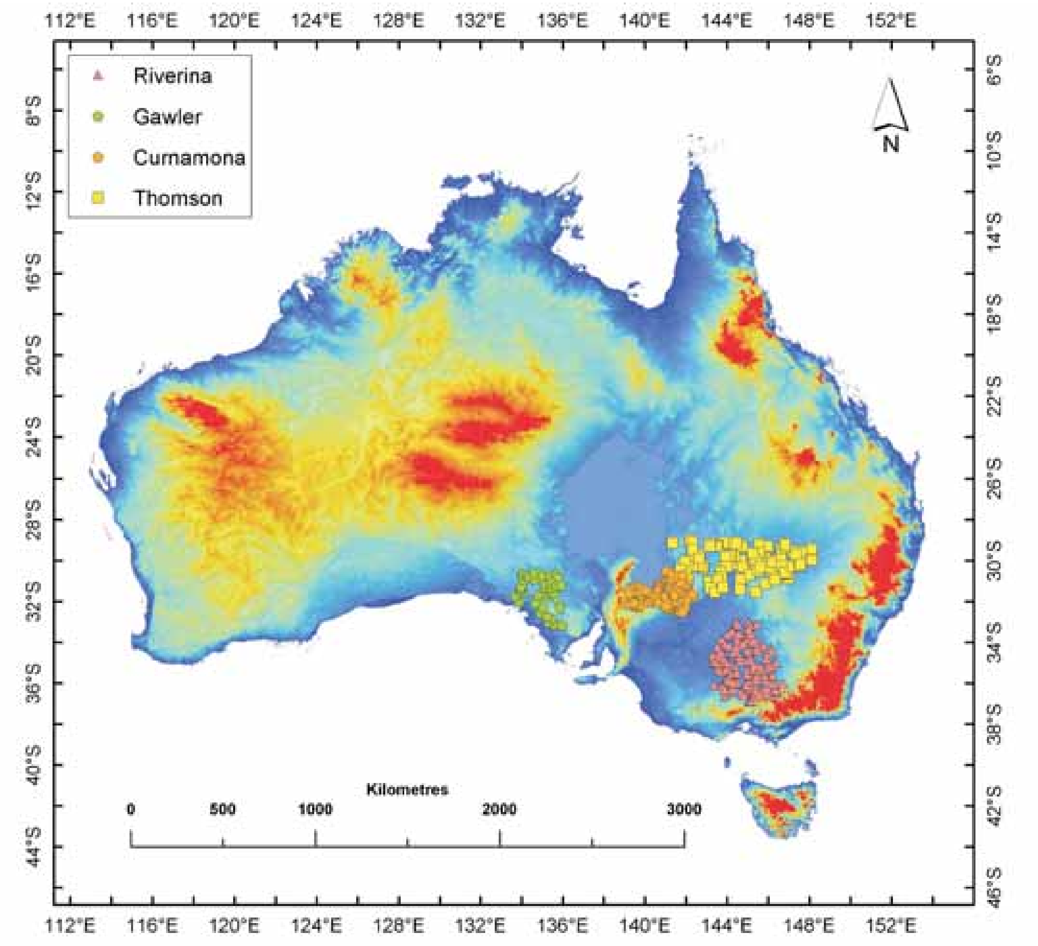

Figure 1: Clusters of points indicating the location of pilot projects conducted by GA, CRC LEME and State geoscience agencies.

The pilot studies have demonstrated that:

1. The lateral dispersion of elements is generally no greater than the catchment scale;
2. The chemical variability is greater between sample sites than between various size fractions at the same site (e.g., < 75 µm and < 2 mm);
3. Geochemical signatures reflecting bedrock lithology (e.g., ultramafic rocks or various igneous rock types) or mineralisation (e.g., Au and base metal occurrences) are recognisable in the surface regolith even through thick sedimentary and/or aeolian cover; and
4. The geochemical maps for U and Th correspond closely to the distributions shown by independent methods (e.g., airborne radiometric surveys).

OUTLINE OF THE NGSA PROJECT

The sampling protocol for the NGSA project was adapted from Äyräs and Reimann (1995), itself the basis for the Forum of European Geological Surveys (FOREGS) geochemical mapping field manual (Salminen *et al.* 1998), in light of lessons learned during the pilot projects. The main sampling medium that will be targeted during the NGSA (and the pilot projects) is transported regolith, more specifically overbank (or floodplain) sediments in the lower portion of (large) catchments. These are deposited as fine-grained sediments in low-energy environments, generally by receding floodwaters. They provide a sampling medium that is ubiquitous and comparable throughout Australia and beyond.

This sampling medium was selected because it is more likely than other media to represent an average composition of the entire catchment, enabling cost-effective sampling of large areas (Ottesen *et al.* 1989; Bølviken *et al.* 2004). It also exhibits a high geochemical signal-to-noise contrast due to the fine-grained nature of the material. Consequently, overbank sediments are commonly used in geochemical surveys (e.g., McConnell *et al.* 1993; Eden and Bjørklund 1996; Volden *et al* 1997; Swennen *et al.* 1998; Pavlovic *et al.* 2004). Where overbank sediments are absent, transported materials are targeted, e.g., fine sediments in depositional environments or regolith from the swales of dunes in aeolian environments.

The ultra-low sampling density chosen for the NGSA, an average of ~1 site/5500 km^2, provides a cost-effective way to cover the immense area of mainland Australia (~7.7M km^2). By taking advantage of natural mixing of materials derived from various source lithologies within catchments, and the subsequent deposition of the target sampling material (overbank sediments) in low-energy environments near their outlets, it is possible represent the average, background geochemical composition of large catchments (typically 1000 to 10,000 km^2). The validity of this sampling density was tested by decimating existing, higher-density geochemical datasets to the target density (see example in Figure 2). In this example, outlet points were derived from catchments at the desired density. From the existing geochemical dataset, the closest sample point was substituted for the target sample site. Major geochemical trends are still clearly visible in the decimated data, ensuring that such patterns will be revealed by the NGSA approach.

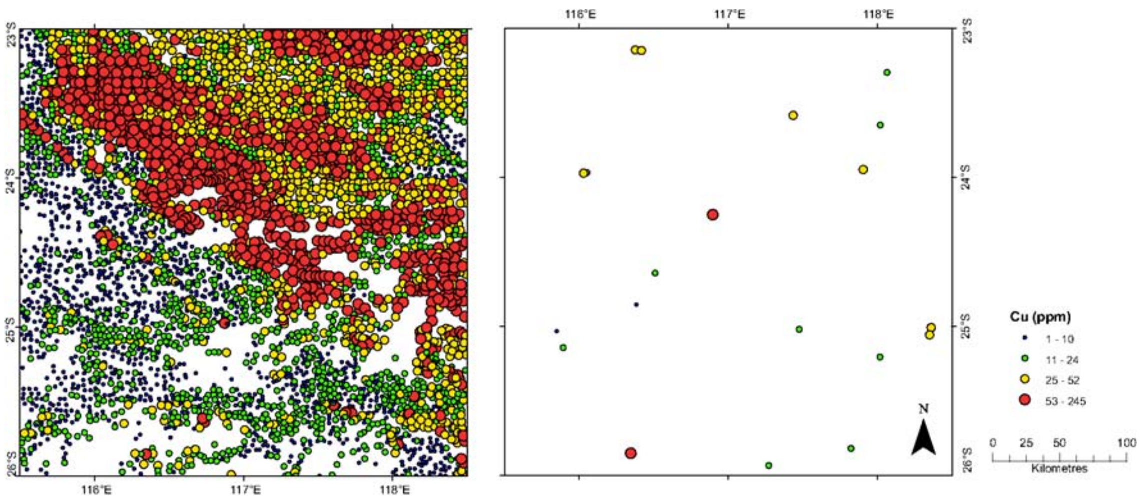

Figure 2: Concentrations of Cu (ppm) in stream sediments from Western Australia showing original data (left) and data decimated to a density of ~1 site/5000 km^2 (right) (Source: Geological Survey Western Australia)

The < 2 mm and < 75 μm fractions are chosen for analysis of the NGSA samples. The < 2 mm fraction represents the bulk sample (minus larger rock, vegetal and animal fragments) and will be used to calibrate/ground truth the radiometrics. It was routinely used in other related geochemical surveys (Reimann, 1998, 2003). The < 75 μm fraction is representative of the finer (mostly silt- and clay-sized) sediment and regolith particles and exhibits a stronger geochemical contrast compared to background (signal-to-noise ratio). This fraction also requires no milling, and in most cases, minimal sieving. These are time-consuming preparation steps which may also introduce contamination.

The NGSA samples will be collected, prepared and analysed using standardised methods which will produce a high quality, internally consistent geochemical dataset. This report contains comprehensive instructions for site determination, sample collection and digital data entry. Details of sample preparation and analysis are presented in a separate report (Caritat and Lech, 2007).

THEORETICAL DETERMINATION OF SAMPLING SITES

Identification of target sites for sample collection employed a method involving the derivation of drainage catchments from a national scale digital elevation model followed by the generation of theoretical (target) sampling sites near the outlet (or lowest point) of each catchment. The underpinning elevation model used was the GEODATA 9 Second Digital Elevation Model (DEM-9s) v.2 (ANZLIC unique identifier: ANZCW0703005624). From this dataset the Centre for Resource and Environmental Studies (CRES) at the Australian National University, Canberra, has derived the Australian Nested Catchments and Sub-Catchments (ANCS-C) at 500 km^2 scale (ANZLIC unique identifier: ANZCW1202000005) (Hutchinson *et al.* 2000). This dataset represents the most consistent, systematically-derived national scale drainage catchment coverage available for Australia. Colleagues at CRES applied the same algorithm to the DEM-9s using a larger target catchment area threshold of 5000 km^2. In this modelling the Pfafstetter scheme for deriving topographically defined hydrologic units at continental scales (Verdin and Verdin, 1999) was implemented in an effort to improve drainage definition. Unfortunately the scheme is still subject to error in environments where distributed or uncoordinated drainage patterns occur; situations not uncommon in the Australian landscape (Stein, 2004). In the absence of a perfect solution, the modelling process produced a coarse scale catchment coverage for the whole country that is suitable for the purposes of defining catchment outlet points.

The coarse scale dataset was examined to identify all catchments outside an optimal area range of 4000-6000 km^2 (i.e. mean of 5000 km^2 ± 20%). ESRI's ArcGIS® software (v.9.1) (ESRI, 2007) and the ArcHydro® Tools (v.1.2 beta) (Maidment and Djokic, 2000) were used to generate a higher resolution catchment coverage of Australia (threshold area 500 km^2) from the DEM-9s. The alternative high resolution dataset (ANCS-C) was not utilised as it was generated using a version of the DEM-9s that differed from that used to generate the coarse scale catchment coverage. The newly generated high resolution coverage was used to disaggregate over-sized polygons in CRES's coarse scale coverage in an attempt to bring them within the optimal area range. Polygons below the optimal area were, where appropriate, aggregated with neighbouring polygons to achieve the same goal of optimal area. Decisions on which polygons to aggregate or disaggregate were guided by information obtained from the following datasets:

- NATMAP Raster Premium 2005 (includes 1:250,000 scale topographic and cultural information for the whole of Australia, along with a Landsat 7 national mosaic (Geoscience Australia, 2007);
- 3-second (~90 m) Shuttle Radar Topography Mission (SRTM) v. 2 digital elevation model (produced by the National Geospatial-Intelligence Agency and NASA) (NASA, 2007).

Applying the method outlined above, an iterative series of edit, clean and build processes in ArcINFO® resulted in the national catchment coverage shown in Figure 3. This product, along with the DEM-9s, was used as an input to ArcHydro® to generate a point coverage representing the lowest point (outlet) of each catchment. Briefly this process included 'filling' of topographic depressions within catchments (internally draining sinks) and simulating surface water flow direction and flow accumulation. Finally, drainage point processing was conducted to determine outlet points (Djokic and Ye, 2000).

The theoretical (target) sampling sites resulting from the drainage modelling process were then culled to provide a representative and achievable set of sites. This process included defining a minimum threshold for representative area, which was set at 1000 km^2 (or 20% of the target catchment area of 5000 km^2). After several modelling iterations using threshold values of 100 km^2 and 500 km^2, the 1000 km^2 threshold was chosen because area values lower than this increased the survey sampling density to a scale where the number of sites and catchments would become impractical. A decision was also taken to sample only the Australian mainland plus Tasmania. The justification for this is that:

1. the majority of islands represented too small an area to be significant at the survey scale;
2. by their nature the islands would have to have included several catchments (not just one) which in total would still be too small an area;
3. many of the islands have a predictable dominant geochemical character (e.g. Mn on Groote Eylandt, Si on Fraser Island).

The target sampling site coverage was then manually checked and edited. This process identified and removed obsolete points (i.e. those within catchments of area $\leq$ 1000 km^2) and adjusted (as necessary) the location of valid sampling sites to optimise representativeness. Where a defined catchment showed obvious surficial hydrologic connection to a through-flowing trunk stream that was unrepresentative of that catchment, the sampling point was re-positioned as far downstream as practical on the surficial drainage (tributary) capturing the largest possible area of the catchment, but above the floodplain of the trunk stream. Following this rule minimised sampling of overbank or floodplain sediment of the trunk stream which probably better represents the larger drainage basin rather than the locally-defined catchment. Clearly, however, there is value in collecting some samples on the major floodplains for exactly this reason, and as such in several catchments where there was only ambiguous surficial hydrologic connection to the through-flowing trunk stream sample sites were located on the floodplain of the trunk stream. The logic applied is similar to that for internally draining catchments terminating in a salt lake or other sink, where it is sub-optimal (but sometimes necessary) to locate a sampling site in a drainage depression. However, in most cases there is sufficient surficial hydrologic connection to the lowest point in the catchment to make site placement within closed depressions unnecessary.

Particular attention was paid to issues relating to land accessibility and possible sources of contamination (especially anthropogenic - e.g. industrial facilities, major roads, etc.). Data used to provide guidance in repositioning the target sample sites were the same as those listed previously. The method resulted in a target sampling site dataset as illustrated in Figure 4. The sites identified using these techniques are not on a uniform grid and their position and distribution are primarily controlled by natural drainage systems. In-field protocols for final site determination and detailed sampling procedures are documented in Appendix 1.

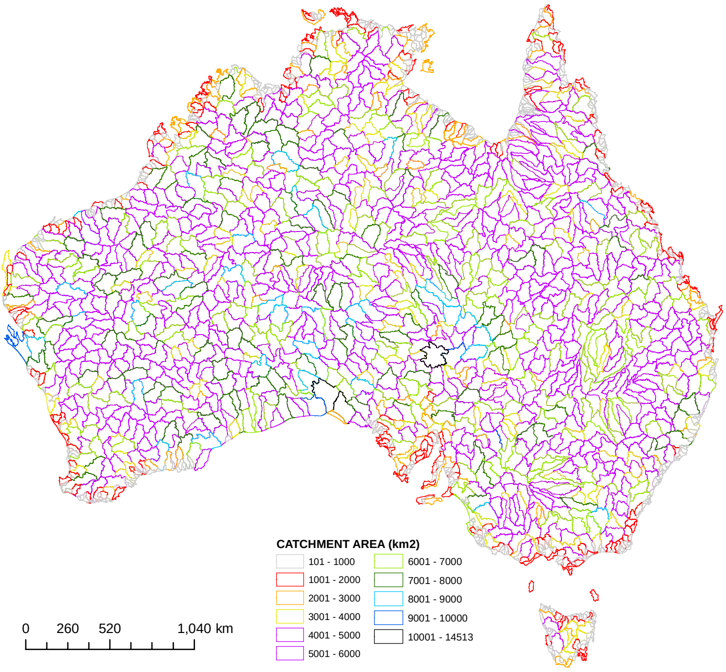

Figure 3: Defined drainage catchments used for the determination of target sampling sites for the National Geochemical Survey of Australia.

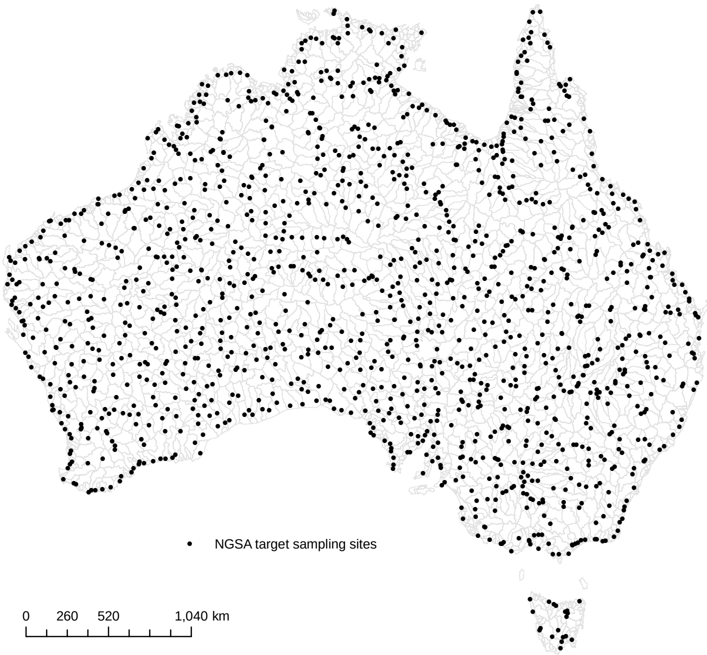

Figure 4: Defined target sampling sites for the National Geochemical Survey of Australia.

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APPENDIX 1: SOIL SAMPLING PROCEDURES FOR NGSA

General criteria for in-field site selection

Once a field party arrives at the theoretical sampling site, a number of decisions have to be taken to finalise where the holes will be augered to collect samples. The following criteria have been developed for this purpose:

- Sample at a representative location (avoid those sites that are locally atypical);
- Where multiple stream branches of equivalent size/importance are contained within a defined catchment, samples are to be collected downstream of the confluence, but above the floodplain of any trunk stream that flows through the catchment;
- To avoid contamination, sample at least:
    - 200 m upstream/upslope of roads (particularly major roads);
    - 100 m upstream/upslope of buildings, dams;
    - 50 m upstream/upslope of fields, paddocks; and
    - 10 m upstream/upslope of fences;
- If it is not possible to move upstream/upslope from areas of possible contamination/disturbance, move at least twice the recommended distance in a direction perpendicular to the main slope or, as a last resort, downstream/downslope from it;
- Where possible, avoid sites that are obviously disturbed by human activities such as camping sites (e.g., presence of fire places, cans and/or bottles), graded areas, levelled fields (for irrigation), mines (disused or active), landfills, rehabilitated sites, etc.;
- Sampling near or within an open cluster of established (mature) trees will increase the likelihood that the land surface is at 'natural' level (no massive recent erosion, no major land rehabilitation);
- Obtain access permission to private land, national parks and reserves prior to sampling. Otherwise, move the sample location slightly (preferably upstream), bearing in mind the size of the catchment being sampled;
- Try to sample on natural drainages as artificial drainage/irrigation channels may not necessarily represent the natural flow of water and sediments;
- Where defined creeks are present, sample the floodplain/overbank sediment (not within the channel or on top of the banks/levees);
- Where there are no defined creeks, sample at the lowest practical point in the catchment. Ensure that the regolith material sampled is (1) *transported* and (2) in a *depositional environment* (e.g., sheet wash/sheet flow or colluvial, etc.) and **not** *in situ* on weathered bedrock; and
- In sand dune-dominated terrain where no creeks are present, sample at the lowest point in the catchment in the swale of a dune, as this is where the finer-grained sediments accumulate. It is becoming clear that most dune systems in Australia are fairly stationary and well vegetated (Fitzsimmons, 2006). A study by Sheard *et al.* (2006) found that the sand dunes in the Great Victoria Desert have been stable for about 70 ka and secondary migration of Au into the dune occurred within 10-20 ka. This indicates that dune swales are an appropriate sampling location where overbank sediments are absent.
- Radiation screen the site prior to digging and do not collect if the monitor registers a value > **5 µSv/hr** (this is covered in more detail in the Radiation Safety section of Appendix 1).

General comments on sample collection

- Be mindful of contamination by sunscreen (e.g., Zn), watches, jewellery such as rings (e.g., Au, Ag) by wearing gloves (e.g., natural leather) while handling the sampling material;
- When the surface sample is collected, use the white plastic scoop (rather than steel shovel);
- Avoid cross-contamination by ‘conditioning’ all digging tools (augers, shovel, crowbar and scoop) with the soil at the site to remove remnants of soil from the previous site. This ‘conditioning’ is done by inserting or rubbing the tools in the soil at the site (e.g., sinking the crowbar in the ground a few times, using the augers on site a few times, etc.) before retrieving the samples;
- Take measures to preserve the selected site until the sample is taken (i.e., don’t drive or walk over the area to be sampled);
- For all aspects of field work, the field parties must refer to the Occupational Health and Safety procedures of their organisation (this is covered in more detail later in Appendix 1).
- Be sure to refill all holes for the safety of people and stock and restore the surface as much as possible to pre-existing conditions; and

Sampling equipment

The majority of the equipment required to collect the samples is provided by the NGSA project, and is listed below.

- Shovel
- Crowbar
- Tanaka JEA-50 petrol-driven power auger with 6 inch bit
- Stainless steel hand auger kit
- 25.4 x 35.6 cm (150 µm thick) plastic sample bags (4/site)
- 30.5 x 45.7 cm calico (cotton) bags (2/site) with draw string
- Tyvek tags with printed sample number for inserting into plastic bags
- Paper field sample forms (for backup)
- Inoculo™ pH testing kit (1 kit per ~50 analyses/25 sites)
- Munsell™ Colour Chart
- 1M HCl (carbonate reaction test) in 45 mL dropper
- Pop-top water bottle for moist Munsell colour
- Pry bars (for scraping caked soil off auger, as needed)
- Folding ruler (to measure depth to bottom sample)
- White plastic scoop (metal free)
- Hard bristle brush (for cleaning plastic scoop)
- Stapler and staples
- Permanent black markers, pens and pencils
- Flat bastard metal file (for sharpening hand auger blade as necessary)
- Plastic ground sheet/tarpaulin
- Leather gloves
- Dust masks
- Ear plugs
- Safety glasses
- Knee pads
- High tensile bolts & nuts (for auger bit attachment in the event of failure)
- “Radiation Alert® Monitor 4” radiation monitor (+ 9V battery, CD and case)
- Materials Safety Data Sheets (MSDS) for pH kits and HCl
- Toolbox and aluminium case for small equipment

Additionally, the following equipment needs to be taken:

- Field-ruggedised notebook or laptop computer (CPU), charger/spare batteries, inverter, backup system, portable storage devise (USB memory stick) for backup of field data and photos.
- GPS, charger/spare batteries, cable to download waypoints to CPU
- Digital camera, charger/spare batteries, storage media, cable to download photos to CPU
- Jerry can with unleaded fuel
- Two-stroke oil for mixing with unleaded fuel (fuel to oil ratio 25:1)
- First aid kit
- Communication equipment like CB radios and satellite phone is also desirable for communication with landholders and daily back-to-base log-in calls.

Sample collection

At each site, two ~10-cm thick intervals are sampled. The first sample is taken from 0 to 10 cm (just below the root zone, if present) and is the 'top outlet sediment' (TOS). The second sample is taken within a depth range of ~60 to 90 cm and is the 'bottom outlet sediment' (BOS). For each interval, two bags of ~2-3 kg of material are collected. The contents of the 2 TOS bags will be thoroughly mixed during sample preparation (likewise for the 2 BOS bags) so it is not necessary to make both bags absolutely equivalent. More detail on sampling procedures for the above sample types are provided below. A sample collection check sheet (Appendix 2) has been provided to ensure all important steps have been followed throughout sample collection.

Sampling of the TOS

- Using the shovel remove surface vegetation and organic litter, and scrape off the root layer (if any) to clear an area of ~50 x 80 cm.
- Loosen the soil down to 10 cm depth with the crowbar over an area of ~30 x 60 cm.
- It is possible that some samples may experience minor contamination from paint flakes coming off the crowbar. This is not considered to be a significant concern, but where possible, try to avoid collecting soil with paint contamination.
- Find the 2 pre-labelled plastic bags for the TOS (both labelled 2007 19 xxxx 001, where xxxx is a 4-digit site identification code). Ensure plastic bags have a loose tag inside them and that this has the 7-digit sample ID (minus 200719) printed on it. Also find the corresponding pre-labelled calico bag (2007 19 xxxx 001).
- With the white plastic scoop, collect and transfer the 0-10 cm sample interval into the 2 plastic sample bags, ensuring the full ~30 x 60 cm area and depth profile to 10 cm is sampled (composite sample). Collect 2-3 kg of sample in each bag (bag 1/2 to 2/3 full).
- Fold the top of the bags over several times and staple twice.
- Place the 2 TOS samples in the labelled calico bag and close with tie string.

Sampling of the BOS

- With the power or hand auger drill 3 to 6 holes in a ~10 x 10 m area to ensure a sample representative of the location is taken.
- Once the holes are all at the required (and same) starting depth (typically 60-90 cm), clean out the bottom of the holes with a gloved hand to ensure no loose material remains.
- Find the 2 pre-labelled plastic bags for the BOS (both labelled 2007 19 xxxx 002, where xxxx is a 4-digit site identification code). Ensure plastic bags have a loose label inside them and that this has the same sample ID printed on it. Also find the corresponding pre-labelled calico bag (2007 19 xxxx 002).
- With a clean (pre-conditioned) *hand* auger, collect the regolith material in approximately equal proportions from each hole (composite sample) and place into the plastic sample bags. As with the TOS, collect 2-3 kg of sample in each bag (bag 1/2 to 2/3 full). Only sample

bottom material that has been disaggregated by the mechanical auger as a last resource—we normally want to always collect the bottom sample with the manual, stainless steel hand auger.

- On rare occasions, the material can not be retrieved with the hand auger (e.g., to loose or too hard). In these cases, carefully loosen the material with the power auger or crowbar and collect the sample by reaching down the holes with a gloved hand. **NB:** *It is important to ensure that no soil falls down the hole (from surface or sidewalls) and contaminates the BOS sample.*
- Where the soil is too hard for power or hand auger combinations, or the soil is sandy and falls back down the hole, a trench must be dug (~50 cm wide and between 70 and 150 cm long) to the desired depth using the shovel and crowbar.
    - o Just before reaching the desired depth, clean out the trench with the white plastic scoop;
    - o Use the crowbar to then loosen the soil at the collection interval; and
    - o Collect the disaggregated material from several locations across the trench floor with the cleaned white plastic scoop.
- At some locations, indurations like hardpans may occur at or before reaching the targeted sample depth. Try several holes to ensure it is not an isolated case. If widespread, the samples should be collected *above* the hardpans to avoid secondary modifications of the sampling medium sought.
- Fold the top of the bags over several times and staple twice.
- Place the 2 BOS samples in the labelled calico bag and close with tie string.

Check the radiation level of the TOS and BOS samples prior to transport. If the monitor registers a value < **5 µSv/hr** the appropriate value range should be recorded in the digital data entry template. If the value is > **5 µSv/hr** the sample should be returned to where it was collected (this is covered in more detail later in the Radiation Safety section of Appendix 1).

Field measurements

Munsell colour

Soil colour is important as it gives information about mineral content, soil moisture and oxidation state. Red soils are more oxidised and contain more Fe-oxyhydroxides, whereas yellower soils contain more goethite. Fe-oxyhydroxides may absorb or adsorb trace metals.

Munsell soil colour is determined in the field using a Munsell™ soil colour chart (Figure A1) (Munsell Color Company, 1975) according to standard protocols outlined by Northcote (1979). Moist and dry colours are recorded on the digital entry template as hue, value and chroma (e.g., 7YR5/4).

Figure A1: Soil Munsell colour chart

Soil colour is determined on a freshly broken soil aggregate held as close as possible to the colour chip. Where soil colour does not match any colour chip, the closest chip colour is used. Care should be taken to ensure the broken surface is not smeared as this may result in an incorrect colour of the soil matrix. The aggregate is then moistened with a few drops of water and soil colour recorded once the visible moisture film disappeared from the soil aggregate's surface. **NB:** If the soil is too moist for a dry colour then only record the moist colour. **NB:** For soil that does not have a homogeneous colour, e.g. because they are mottled or contain nodules, record the dominant soil matrix colour.

Field pH

pH provides information that can be related to element mobility and stability within regolith materials. It can be correlated with various chemical and environmental factors that influence soils and plants. It must be recognised, however, that soil pH can vary markedly within a short distance.

The Inoculo™ Soil pH Testing Kit (Figure A2) designed by the CSIRO Division of Soils is used to determine in-field soil pH measurements as follows:

- Remove any coarse fragments greater than 2 mm (if necessary)
- A teaspoon of soil is placed on the white plastic tray provided in the test kit
- A few drops of the green dye indicator liquid are added to the soil
- Use the mixing straw to mix the indicator liquid and soil to form a paste
- Lightly dust a little of the white $BaSO_4$ powder over the moist soil
- Although the colour of the $BaSO_4$ powder changes immediately, it should be left a few minutes before the colour is matched to the accompanying indicator card to determine the pH value
- The colour best matching the dominant colour of the $BaSO_4$ powder is recorded (e.g., 5YR 4/6)

Figure A2. Inoculo™ soil pH test kit

Determination of shape and abundance of coarse fragments and segregations

Coarse fragments are those greater than 2 mm in size (McDonald *et al.* 1990). They include unattached rock fragments and other fragments like charcoal and shells (see Appendix 3), and are not pedogenic in origin. *Segregations* refer to discrete pedogenic aggregations, such as nodules and concretions, which have accumulated in the soil/regolith due to concentration by chemical or biological processes (see Appendix 3). **NB:** Charcoal in the sample may be an indication of contamination.

The charts in **Figure** A3 and A4 are used to provide a visual estimate of the shape and abundance of coarse fragments and segregations within a regolith profile.

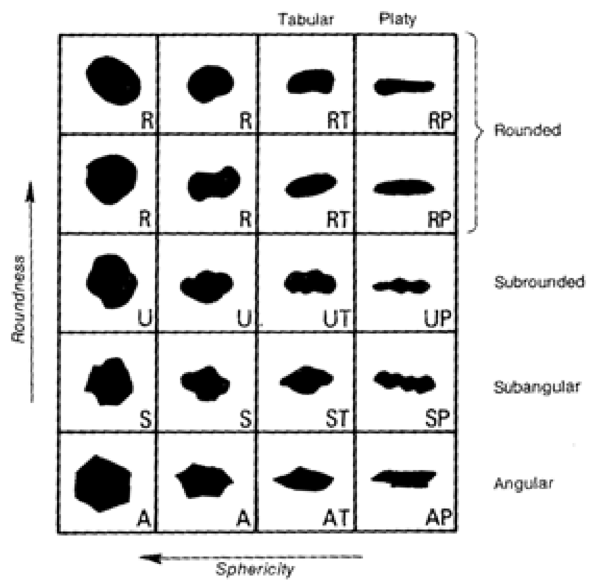


Figure A3. Visual guide for estimating the shape of coarse fragments (McDonald et al. 1990, modified after Powers, 1953).

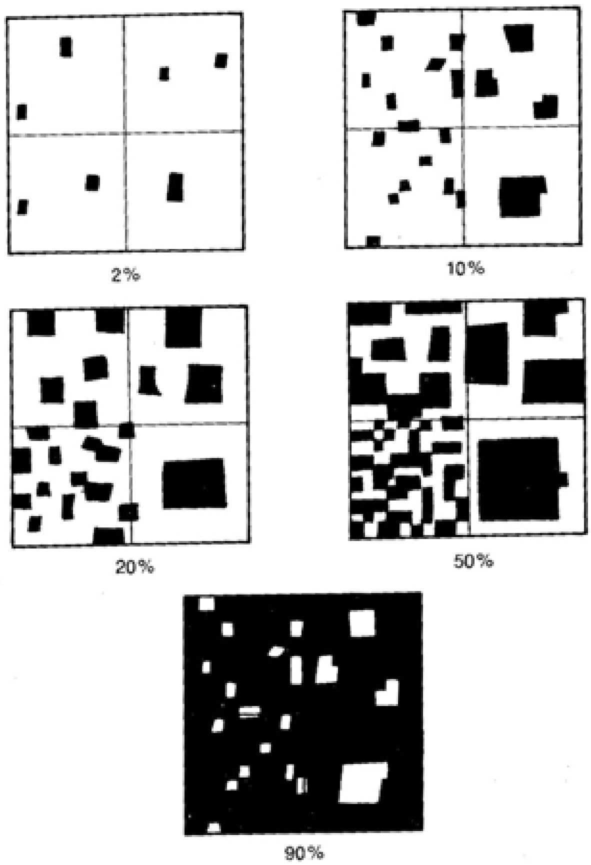


Figure A4. Visual guide for estimating the abundance of coarse fragments (McDonald *et al.* 1990).

Occupational Health & Safety precautions for sample collection

It is important to ensure the safety of all field party members while conducting field work. Relevant personal protective equipment (PPE) such as enclosed leather boots, broad brimmed hats, long pants and shirts to protect against the sun, etc. should be worn at all times during sample collection. At least one field party member should be first-aid trained. Refer to your State or Territory field safety procedures for more detailed information. The NEPC (1999a,b) documents are freely available on the web and contain information regarding protection of health and the environment during field investigations. They also refer to relevant State, Territory and Commonwealth legislation.

Specifically relating to soil sampling it is recommended that field party members:

1. use gloves when handling soil samples;
2. wear a dust mask and safety goggles if face is to come into close contact with the soil;
3. wear eye and ear protection when using the power auger.

Power Auger

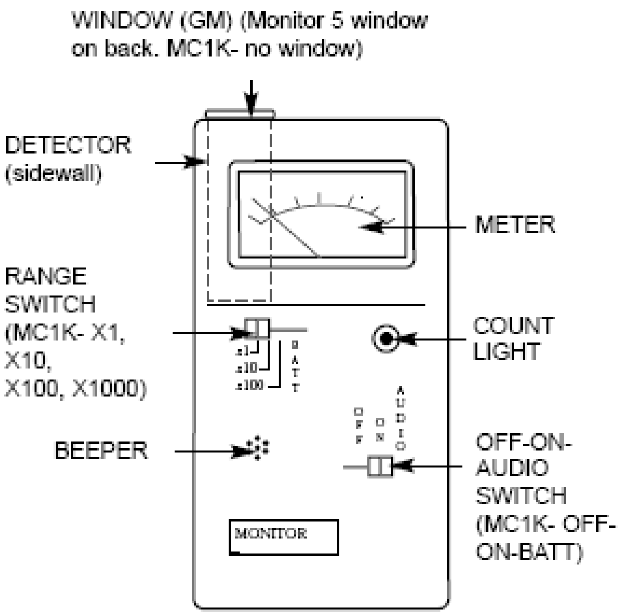
The checklist below relates to the operation of the Tanaka JEA-50 two-person 2-stroke petrol-driven auger used to drill holes for sample acquisition. *It is essential that the operator's manual provided with the auger is read and understood prior to use*, as it contains information on the safe operation and maintenance of this equipment. In addition the following points should be understood.

- Wear appropriate PPE: gloves, eye and hearing protection, protective footwear; tie back or remove loose clothing and restrain loose/long hair.
- Inspect for and inquire about underground hazards/utilities (DIAL BEFORE YOU DIG).
- Assess the soil type before digging.

- Operate equipment safely (e.g. bend at the knees when operating the auger; ensure thumbs are not locked inside the auger handlebar frame).
- Never leave machine unattended when running.
- Make sure engine has cooled down prior to refueling. Avoid ignition sources when fueling/refueling.
- Immediately report damaged equipment to Supervisor. Secure and label damaged equipment and do not use.
- Secure all equipment prior to transportation.

Radiation Safety
In accordance with GA's Radiation Safety Policy, it is a requirement for all geological samples to be tested for radioactive emission before they enter the ACT. The field kit provided includes a "Radiation Alert® Monitor 4" radiation monitor. Details of the monitor and its operation are given in an abridged form below however *the full operation manual should be read and understood prior to use* of the monitor. The manual (SE International, 2007) is provided on the CD enclosed with the monitor. **NB**: This equipment has already been properly calibrated, but requires re-calibration every 12 months. Should the field sampling not be complete by the end of April 2008 recalibration of the monitor by a suitably qualified service provider will be the responsibility of the relevant State/Territory.

When a ray or particle of ionizing radiation enters or passes through the Geiger-Mueller (GM) tube within the unit, it is sensed electronically and displayed by a red count light. When the switch is in the AUDIO position, the instrument will also beep with each radiation event. About 5 to 25 counts at random intervals (depending on your location and altitude) can be expected every minute from naturally occurring background radiation. This equates to values of approximately 0.13 – 0.2 microSieverts per hour (µSv/hr). In line with Geoscience Australia's Radiation Safety Policy, a conservative threshold value relative to the ARPANSA upper limits for occupational exposure (ARPANSA, 2002) has been adopted for field sampling in this project, and on this basis **samples with measured values of > 5 µSv/hr should NOT be collected**.



PRECAUTIONS

- Handle the radiation monitor carefully as you would a camera.
- Avoid exposing the instrument to liquids, moisture, and corrosive gases; also avoid extreme temperatures or direct sunlight (i.e., car dashboards) for extended periods.
- The mica window of the GM tube can be easily damaged if struck directly. **DO NOT INSERT ANYTHING THROUGH THE SCREEN.**
- To avoid contamination, do not touch the instrument to the surface being tested.
- This instrument may be sensitive to and may not operate in radio frequency, microwave, electrostatic, and magnetic fields.

OPERATION

- Set the range switch in the X1 position. If the meter goes off scale, move the range switch to the next higher setting, X10 or X100. *(Note: Refer to specifications for operating ranges).*

a) <u>**Checking Sites**</u> **- PRIOR TO commencement of digging at a site, hold the monitor with the window pointing to the ground at a distance of approximately 20 cm from the ground surface where the hole is to be located. Hold in position for 10 seconds.**

If the monitor registers a value of:

- **≤ 5 µSv/hr** (i.e. the needle goes no further than the highest mark on the top scale of the meter with the range switch set to X1) **-** the site is suitable for sampling. If the needle does hit the top of the scale on X1, and you want to check whether the value is > 5 µSv/hr, set the range switch to X10 and observe whether the needle moves above the zero mark on the top scale.
- **> 5 µSv/hr** (i.e. the needle goes above the zero mark on the top scale of the meter with the range switch set to X1 <u>AND</u> the needle goes above the zero mark on the top scale with the range switch set to X10) **-** a sample should **NOT** be collected and the site should be re-located.

b) <u>**Checking Samples**</u> **– As samples are collected from a site, perform the same operation on ALL samples by holding the monitor with the window facing the sample at a distance of approximately 20 cm from the sample. Hold in position for 10 seconds.**

If the monitor registers a value of:

- **≤ 5 µSv/hr** (i.e. the needle goes no further than the highest mark on the top scale of the meter with the range switch set to X1). If the needle does hit the top of the scale on X1, and you want to check whether the value is > 5 µSv/hr, set the range switch to X10 and observe whether the needle moves above the zero mark on the top scale.

THEN

- The sample is suitable for transport. Select the appropriate option from the drop-down list in the digital data entry template, then label and pack sample as instructed.

If the monitor registers a value of:

- **> 5 µSv/hr** (i.e. the needle goes above the zero mark on the top scale of the meter with the range switch set to X1 <u>AND</u> the needle goes above the zero mark on the top scale with the range switch set to X10)

THEN

- The sample should be returned to where it was collected, and the following criteria used to re-sample, remembering to conduct radiation checks on ALL samples.

    - ❖ If one or both of the <u>TOS</u> samples exceed 5 μSv/hr then a new sample should be excavated several metres from the existing site and recollected using the same bags.

    - ❖ If one or both of the <u>BOS</u> samples exceed 5 μSv/hr then at least 2 new holes will need to be drilled a few metres from the existing site and the sample(s) recollected using the same bags.

    - ❖ If one (or more) of the <u>TOS and BOS</u> samples exceed 5 μSv/hr then the site should be **relocated** and the samples recollected using the same bags.

Sample numbering

All samples should be numbered according to the Geoscience Australia standard:

2007 19 0001 xxx

Year
NGSA project number
Site number

Sample type
xxx = 001 (TOS)
xxx = 002 (BOS)

All NGSA sample IDs start with the year 2007, even if some are collected in 2008. Allocation of site numbers is randomised which helps to: 1) avoid regional bias in the geochemical analyses, 2) distinguish real anomalies from false ones, and 3) enable the determination of meaningful estimates of variance as the duplicates are not analysed sequentially (Plant, 1973). The field party will have a pre-randomised pile of bags so just use the top bag when arriving at a new site.

A list with the sequence of random numbers will also be provided. This can be used to double check that the sample numbers are being used in the correct sequence. It can also be used to record what sample numbers have been given out if there is more than one field party working concurrently.

<u>Discarded sample numbers</u>: If for some reason a sample number is removed (i.e., the sample was collected but a better site was found), it is important to record this information in the data entry template so the sample is not assumed lost.

<u>Hand labelling plastic bags:</u> If, for some reason, the sample bag is damaged, use a clean, unlabelled plastic bag to double bag the damage sample bag. Ensure that the sample number is recorded on the outer bag. It is important that the bags have a labelled tag within the bag too, even if it means slipping a piece of hand labelled paper inside. **NB:** *It is likely that permanent marker on the plastic bags will rub off during transit so it is very important that a tag is placed in each bag.*

Collection of field duplicates

Ten percent (10%) of sites will be re-sampled as field duplicates. A field duplicate aims to characterise the robustness of the sampling sites, and is usually the weakest link (greatest error) in any geochemical project. A field duplicate is to be collected at every sample site where the plastic sample bag has a red label on it. The calico bag will contain a note inside reminding the samplers to take a field duplicate at this. A note will also be included in the following bag. After the site with the red labelled bag has been sampled, walk approximately 100 metres up the catchment and resample using exactly the same procedures. In the digital data template (described below) make sure the site that was taken as a duplicate has recorded the site number to which it relates. If the samplers forget to take the duplicate at the identified site, take the duplicate at the following site but be sure to record this in the digital data template.

In-field navigation

The following gives an idea of what technology and datasets may be useful for in-field navigation and sample site selection. These were refined during various field seasons and are guidelines only; common sense should prevail when in doubt.

A digital navigation system consisting of a palmtop, field-ruggedised notebook or laptop computer (CPU) and a GPS is ideal; communication between the GPS and the CPU via Bluetooth or other link is useful for navigating to a target sample site. Ability to overlay digital topographic maps, satellite imagery, radiometrics and/or catchment boundaries help with determining access roads to the location and also ensure that the site selected is in a depositional setting and within the correct catchment. Field parties use CPU and GPS setups provided by their agencies.

Laminated regional scale maps with sample point locations, topographic information and catchment boundaries can also be used to provide an overview of site accessibility and for day-to-day planning.

Digital data entry template

A digital data entry template (Figure A5) has been developed to record all relevant site and sample information on Microsoft Excel™ spreadsheets using the Microsoft Windows operating system. The information to be captured was modified from Salminen *et al.* (1988) to suit Australian conditions. The template is in line with GA's corporate data model (CDM) database and has appropriate drop-down lists from GA's "FIELD SITES" database to reduce typing errors, ensure consistency between users and allow bulk uploading. It allows cross-validation for various fields to help ensure the information entered is correct. Comments are available for most of the fields and can be used as a reference for entering data. The template conforms to sampling technique criteria outlined in the 'International reporting template for the public reporting of exploration results, mineral resources and mineral reserves' (CRIRSCO, 2006).

Appendix 3 contains detailed column descriptions, column formats and data entry validations that will guide the user through the entry of data into the template.

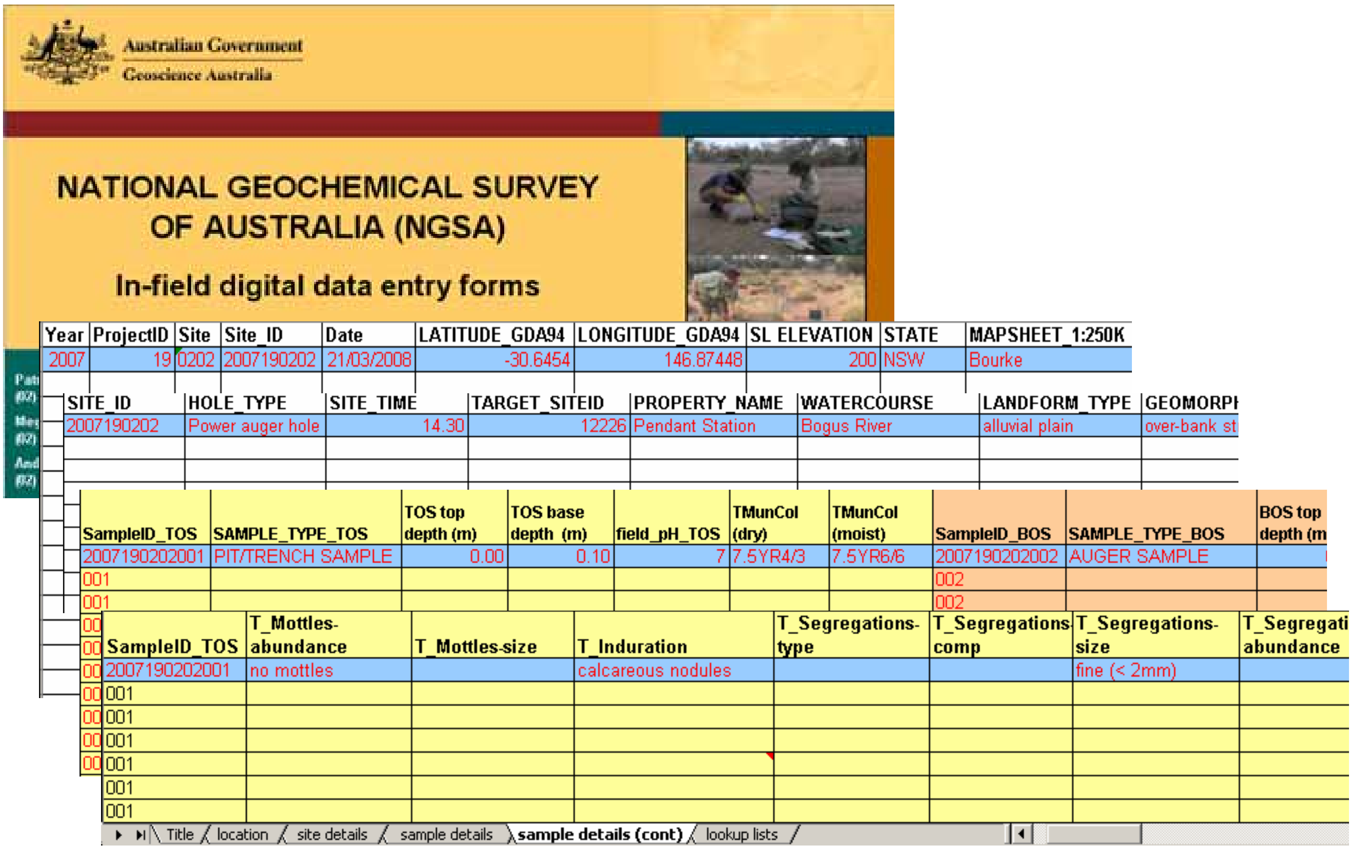


Figure A5: In-field digital data entry forms.

In the data entry template (Figure A5), columns coloured in yellow relate to the Top Outlet Sediment (TOS) and those in orange relate to the Bottom Outlet Sediment (BOS). Those that are white relate to the sample site. Where appropriate the classifications used are from the *RTMAP regolith database field book and users guide* (Pain *et al.* 2003) and the *Australian Soil and Land Survey Field Handbook* (McDonald *et al.* 1990). These sources are now well established as authoritative for land and soil surveys.

Information captured includes: date, GPS location, regolith landscape position, geomorphic processes, field parameters such as Munsell colour and field pH. For extended definitions on landform type and geomorphic process and land use types, refer to Appendices 4, 5 and 6.

The digital data will be bulk loaded into the "FIELD GEOLOGY" database at GA. This is a mandatory step before samples can be placed in the queue for in-house geochemical analysis.

If, by chance, there is an equipment failure and the digital data entry template is inaccessible, a backup data entry template (Appendix 7) can be printed out and manually filled in. Appendix 8 contains all the appropriate lookups that mirror the digital template lookups and will aid in manual entry of the backup data entry template.

General comments for in-field site documentation:

- Digital photos are to be recorded in the field. Please use jpg format where possible and a resolution of about 3200 x 2400 pixels (file size ~2 Mb).
- Ensure the camera's batteries are fresh and replacements are available. Before going in the field, set the camera's date and time, so this metadata can be used in case of identification issues later on.
- Take a close-up photo of the sample bag label immediately before the site photos. This will aid in identifying the photos at the end of a day.
- Take a photo showing the holes with a shovel or crowbar down the hole to indicate depth. Take a few photos that are representative of the landscape. At least one of these should be taken toward the main drainage (river, creek) if appropriate, and another upslope (toward the centre of the catchment or the upland areas). The photos will be loaded into GA's multimedia database.
- Photos should be relabelled with the site ID as a prefix (e.g., 2007190001) followed by an underscore (_) and a unique identifier (e.g., the camera's default running number), for instance: **20007190001_dscn0001.jpg**. It is useful to do this on a daily basis when the various sites visited are still fresh in people's memory!
- Sample sites should be saved as waypoints in the GPS and be labelled with GA's site number (e.g., 2007190001).
- **NB:** If site cannot be sampled for whatever reason (e.g., access, above radiation guidelines etc) then this needs to be recorded in the data entry template. Record the Target_SiteID (TSxxxx) on the site details worksheet and add in the reason the sample could not be taken in the Comments field.

Freighting of samples

The regolith samples that have been collected are fragile. There were cases in the pilot projects where samples were punctured resulting in sample loss and contamination during transit. It is therefore very important to ensure that samples are adequately protected in the 20 litre sample drums provided.

APPENDIX 2: FIELD SAMPLING PROCEDURE CHECK SHEET

HAVE YOU:		**8**	Collected the bottom sample from least 3 holes?
1	Used the Field Manual to determine a suitable site location?	**9**	Taken 2-3 kg of TOS and BOS sample? (i.e., 2 full bags for each)
2	Gained permission to sample at this site?	**10**	Placed correct Tyvek label inside each bag?
3	Checked site for obvious signs of contamination & maintained the integrity of the site before sampling?	**11**	Checked that all plastic bags have the same SampleID as the calico bag they are placed into?
4	Screened the site for radiation? [NB: If > 5 µSv/hr, reselect sample site as per Field Manual]	**12**	Screened the samples for radiation? [NB: If > 5 µSv/hr, return the sample & reselect sample site as per Field Manual]
5	Cleaned/conditioned the equipment to reduce chance of cross-contamination?	**13**	Photographed the site (sample bag, general view of site, holes)?
6	Read all instructions and manuals, and used the correct PPE for the job? (e.g., for close soil contact or use of power auger)	**14**	Refilled the holes to ensure safety of others/stock?
7	Worn gloves at all times while handling the samples and sample bags?	**15**	Taken a sample duplicate after the plastic bags with red labels? Is the Site_ID to which this duplicate relates documented in the digital data entry template?

APPENDIX 3: EXPLANATION OF COLUMNS FOR THE DIGITAL DATA ENTRY TEMPLATE

Location Worksheet

Field	Description	Format	Validation
Year	Year of sampling	2007	will only allow 2007
ProjectID	The GA assigned project ID for the databases	19	will only allow #19
Site	The number assigned to the sample site. This is obtained from a list of randomly assigned numbers provided to the State/Territory.	Text to allow "zeros" before numbers	4 characters long
Site_ID	As above	Concatenation of year, projectID & site	nil
Duplicate	If the site taken is a duplicate. Record the Site_ID for which this duplicate relates to	Must be 9 digits long	nil
Date	The date of sampling	date is in dd/mm/yyyy format	must be between 01/02/2007 & 01/02/2010
Latitude_GDA94	Latitude of the sample site captured in GDA94	6-digit negative numeric	value between -44 & -9
Longitude_GDA94	Longitude of the sample site captured in GDA94	8-digit positive numeric	value between 108 & 156
SL Elevation	Elevation above mean sea level	Numeric (metres)	nil
State	State or Territory where site is located	Use lookup provided	nil
Mapsheet_1:250K	Name of 1:250K map sheet on which the site is located e.g., Bourke, Robinson Ranges	limited to 50 characters	cannot exceed 50 characters

Site details worksheet

Field	Description	Format	Validation
Site_ID	Automatically transferred from locations worksheet.	nil	nil
Hole_Type	Refers to the dominant method of digging the entire hole. This will generally be hand auger hole, power auger hole or soil pit. This field is a GA database requirement.	Use partial lookup provided	nil
Site_Time	Time of arrival at sample site in 24 hour notation. **NB:** This will help with relabelling of photos.	Text with format hh:mm	nil
Target_SiteID	Target number assigned to the GA prescribed sampling site. In the format: 4-digit number with TS as the prefix	TSxxxx	6 characters long
Property_Name	The name of the station, national park, etc. where the sample was collected.	limited to 50 characters	cannot exceed 50 characters
Watercourse	Name of creek, river, etc. by which the sample was taken. e.g., Bogan River, Mulga Creek. Do not complete if there is no water course nearby.	limited to 50 characters	cannot exceed 50 characters
Landform_Type	Obtained from the RTMAP classification scheme (See Appendix 4). **NB:** This is site specific and not related to the entire catchment. The dominant landform type within a 75 m radius around the sampling site, i.e., as it would be mapped for a 1:25,000 regolith landform map.	Use lookup provided	nil
Geomorph_Pr	The dominant geomorphic process derived using the RTMAP classification scheme. These processes form/modify landform units. (See Appendix 5). **NB:** This is *site specific* and not related to the entire catchment. The dominant landform type within a 75 m radius around the sampling site, i.e., as it would be mapped for a 1:25,000 regolith landform map.	Use lookup provided	nil
Geomorph_Pr2	Use if more than one active geomorphic process evident at site. Described as per Geomorph_Pr.	Use lookup provided	nil

Landuse_type_ site	The dominant landuse type *for the sample site*. **NB:** If cropping or livestock selected from landuse_type lookup then add more details in the landuse_subtype_site column.	Use lookup provided	nil
Landuse_subtype_site	Detailed landuse *for the sample site*. This is used if cropping or livestock is selected from landuse_type lookup. If unknown, leave blank.	Use lookup provided	nil
Landuse_type_catch	The dominant landuse type *for the entire catchment*. **NB:** If cropping or livestock selected from landuse_type lookup then add more details in the landuse_subtype_catch column.	Use lookup provided	nil
Landuse_subtype_catch	Detailed landuse *for the entire catchment*. This is used if cropping or livestock is selected from landuse_type lookup. If unknown, leave blank.	Use lookup provided	nil
Contamination	Note any possible sources of contamination or disturbance, e.g., 100 m down slope of rubbish dump. Further scenarios are supplied in Appendix 1.	limited to 100 characters	cannot exceed 100 characters
Entered by	The name of the person recording the information at the site of sampling.	Initial of given name & up to 7 letters surname e.g., pdecarit or amcphers or mlech	entry between 3 and 8 characters
Comments	Anything else that might be relevant about the field site that could later be useful when interpreting the geochemistry.	limited to 250 characters	cannot exceed 250 characters

Sample details worksheet

Field	Description	Format	Validation
SampleID_TOS	Automatically transferred from locations worksheet. Site ID + "001" which recognises samples as the Top Outlet Sediment (TOS).	Concatenation of site_ID and TOS identifier “001”	nil
Sample_Type_TOS	Mandatory for GA databases. Sample type for the TOS. Generally as the TOS is taken from a hole created by a shovel, it is a PIT/TRENCH SAMPLE. Definitions for GA’s sample type lookup are as follows: AUGER SAMPLE: Sample collected by hand or mechanical auger which enable samples to be taken at intervals down profile. For example regolith, soil or sediment. FLOAT: Sample taken of an isolated rock fragment, displaced from its original outcrop. Typically derived from weathering of bedrock. LAG: Deposit, commonly thin, or fragments larger than sand size, spread over the land surface. Its most common origin is as the coarse material left behind after fine material has been transported away by wind, or less commonly, sheet flow. PIT/TRENCH SAMPLE: Samples taken at depth from a regolith and/or soil profile. This includes profiles that are exposed by gullies, costeans, railway cuttings, trenches or rivers as well as those profiles dug as a pit. SURFACE REGOLITH SAMPLE: Samples of regolith taken at the ground surface including soil material and organic matter. VEGETATION: Any part of a plant whether it be moss, grass, sedge, or the roots, bark, twigs or leaves of trees and shrubs.	Use the partial lookup provided	nil
top_depth_TOS (m)	Start depth for the TOS. Measured in metres and mostly starts at zero.	numeric to 2 decimal places	must be between 0 and 2 m

base_depth_TOS (m)	End depth for the TOS sample in metres. Measured in metres and is generally 0.1 m.	numeric to 2 decimal places	must be between 0 and 2 m
field_pH_TOS	pH of the TOS sample. Use Inoculo™ Soil pH testing kit applying the methods described in Appendix 1.	Use lookup provided	nil
TMunCol_dry	TOS Munsell Colour determined on the raw sample. It should be on the dominant matrix colour (not the mottles). If soil is already moist (e.g., from rain), disregard this field. Use the method for colour determination as described in Appendix 1.	Use lookup provided	nil
TMunCol_moist	TOS Munsell Colour determined on the moistened sample. It should be on the dominant matrix colour (not the mottles). As per dry sample, use the method for colour determination as described in Appendix 1.	Use lookup provided	nil
Radiation Screen	Has the sample been radiation screened using the "Monitor 4 Radiation Alert Monitor" provided? **NB:** If screening has not been done then samples cannot be accepted by Geoscience Australia due to OH&S requirements.	Y or N	
SampleID_BOS	Automatically transferred from locations worksheet. Site ID + "002" which recognises samples as the Bottom Outlet Sediment (BOS)	Concatenation of site_ID and BOS identifier "002"	nil
Sample_Type_BOS	Sample type for the BOS. Generally as the BOS is an AUGER SAMPLE or a PIT/TRENCH SAMPLE. Definitions for GA's sample type lookup are as follows: AUGER SAMPLE: Sample collected by hand or mechanical auger which enable samples to be taken at intervals down profile. For example regolith, soil or sediment. FLOAT: Sample taken of an isolated rock fragment, displaced from its original outcrop. Typically derived from weathering of bedrock. LAG: Deposit, commonly thin, or fragments of larger than sand size, spread over the land surface. Its most common origin is as the coarse material left behind after fine material has been transported away by wind, or less commonly, sheet flow.	Use the partial lookup provided	nil

	PIT/TRENCH SAMPLE: Samples taken at depth from a regolith and/or soil profile. This includes profiles that are exposed by gullies, costeans, railway cuttings, trenches or rivers as well as those profiles dug as a pit. SURFACE REGOLITH SAMPLE: Samples of regolith taken at the ground surface including soil material and organic matter. VEGETATION: Any part of a plant whether it be moss, grass, sedge, or the roots, bark, twigs or leaves of trees and shrubs.		
top_depth_BOS (m)	Start depth for the BOS in metres. Usually between 0.60 - 0.80 m	numeric to 2 decimal places	must be between 0.2 and 2 m
base_depth_BOS (m)	End depth for the BOS sample in metres. Usually between 0.75-0.90 m	numeric to 2 decimal places	must be between 0.3 and 2 m
field_pH_BOS	pH of the BOS sample. Use Inoculo™ Soil pH testing kit applying the methods described in Appendix 1.	Use lookup provided	nil
BMunCol_dry	BOS Munsell Colour determined on the raw sample. It should be on the dominant matrix colour (not the mottles). If soil is already moist (e.g., from rain), disregard this field. Use the method for colour determination as described in Appendix 1.	Use lookup provided	nil
BMunCol_moist	BOS Munsell Colour determined on the moistened sample. It should be on the dominant matrix colour (not the mottles). As per dry sample, use the method for colour determination as described in Appendix 1.	Use lookup provided	nil
Radiation Screen	Has the sample been radiation screened using the "Monitor 4 Radiation Alert Monitor" provided? **NB:** If screening has not been done then samples cannot be accepted by Geoscience Australia due to OH&S requirements.	Y or N	
Induration	Regolith material that has been hardened by heat, pressure, or the addition of a cementing agent not commonly contained within the original material e.g., development of hardpans or duricrust (Eggleton *et al.,* 2001).	use lookup provided	nil

Depth to Induration	If induration is present, record the depth to the top of the induration.	nil	nil
No. of holes augered	Enter the number of holes augered. This number should be greater than 3 as it makes the geochemical sampling more representative. (If a trench was dug then leave blank).	nil	nil

Sample details worksheet (cont.)

Field	Description	Format	Validation
SampleID_TOS	Automatically transferred from locations worksheet. Site ID + "001" which recognises samples as the Top Outlet Sediment (TOS).	Concatenation of site_ID and TOS identifier "001"	nil
T_Mottles-abundance	Mottles are the streaks, blotches or spots of subdominant colours found within a soil matrix (McDonald *et al.* 1990). A visual estimation for the TOS as a % can be determined using the visual guide for estimating the abundance of course fragments (Figure A4).	Use lookup provided	nil
T_Mottles-size	The size of the mottles present in the TOS along their greatest dimension, unless they are streaks where the width is used.	Use lookup provided	nil
T_Segregations-type	Segregations refer to discrete groups (like nodules and concretions) that have accumulated TOS due to concentration, generally by chemical or biological action. These are pedogenic in origin.	Use lookup provided	nil
T_Segregations-comp	Record the composition of the segregations (concretions, pisoliths, nodules) that have accumulated in the TOS.	Use lookup provided	nil
T_Segregations-size	Determine the size (fine-coarse) for the maximum dimension of equidimensional segregations (concretions, pisoliths, nodules) or the minimum dimension for linear features (tubules) in the TOS.	Use lookup provided	nil
T_Segregations-abundance	A visual estimation in the TOS as a % can be determined using Figure A4.	Use lookup provided	nil

T_Efferves_test	The effervescence reaction test for the TOS determines whether the soil reacts to HCl and generates tiny gas bubbles. To perform effervescence test, put 2-3 drops of 1M HCl (carbonates) on a thumbnail size piece of soil.	Use lookup provided	nil
T_Effervesce	Quantifies the effervescence (release of tiny gas bubbles) for the TOS as follows: NO REACTION: no audible or visible effervescence SLIGHT REACTION: slightly audible but no visible effervescence MODERATELY REACTIVE: audible & slightly visible effervescence HIGHLY REACTIVE: moderate visible effervescence VERY HIGHLY REACTIVE: strong visible effervescence	Use lookup provided	nil
T_frags_lith	The dominant lithology of the coarse fragments/particles greater than 2 mm in size (McDonald *et al.* 1990) within the TOS horizon.	Use lookup provided	nil
T_frags_abundance	The abundance of the coarse fragments/particles greater than 2 mm in size (McDonald *et al.* 1990) within the TOS horizon.	Use lookup provided	nil
T_frags_size	The size of coarse fragments/particles greater than 2 mm in size (McDonald *et al.* 1990) within the TOS. The average maximum dimension of used to determine in which class the fragment belongs. The regolith clasts are not considered to be pedogenic in origin and are present within a soil/regolith profile. They include unattached rock fragments and other fragments like charcoal and shells.	Use coarse fragments_size lookup provided	nil
T_frags_shape	Determine the shape of fragments within TOS using a visual guide (Figure A3). Coarse fragments/particles are greater than 2 mm in size (McDonald *et al.* 1990). The fragments are not considered to be pedogenic in origin and are present within a soil/regolith profile. They include unattached rock fragments and other fragments like charcoal and shells.	use lookup provided	nil

SampleID_BOS	Automatically transferred from locations worksheet. Site ID + "002" which recognises samples as the Top Outlet Sediment (BOS).	Concatenation of site_ID and BOS identifier "002"	nil
B_Mottles-abundance	Mottles are the streaks, blotches or spots of subdominant colours found within a soil matrix (McDonald *et al.* 1990). A visual estimation for the TOS as a % can be determined using the visual guide for estimating the abundance of course fragments (Figure A4)	Use lookup provided	nil
B_Mottles-size	The size of the mottles present in the BOS along their greatest dimension, unless they are streaks where the width is used.	Use lookup provided	nil
B_Segregations-type	Segregations refer to discrete groups (like nodules and concretions) that have accumulated BOS due to concentration, generally by chemical or biological action. These are pedogenic in origin.	Use lookup provided	nil
B_Segregations-comp	Record the composition of the segregations (concretions, pisoliths, nodules) that have accumulated in the BOS.	Use lookup provided	nil
B_Segregations-size	Determine the size (fine-coarse) for the maximum dimension of equidimensional segregations (concretions, pisoliths, nodules) or the minimum dimension for linear features (tubules) in the BOS.	Use lookup provided	nil
B_Segregations-abundance	A visual estimation in the BOS as a % can be determined using Figure A4.	Use lookup provided	nil
B_Efferves_test	The effervescence reaction test for the BOS determines whether the soil reacts to HCl and generates tiny gas bubbles. To perform effervescence test, put 2-3 drops of 1M HCl (carbonates) on a thumbnail size piece of soil.	Use lookup provided	nil

B_Effervesce	Quantifies the effervescence (release of tiny gas bubbles) for the BOS. NO REACTION: no audible or visible effervescence SLIGHT REACTION: slightly audible but no visible effervescence MODERATELY REACTIVE: audible & slightly visible effervescence HIGHLY REACTIVE: moderate visible effervescence VERY HIGHLY REACTIVE: strong visible effervescence	Use lookup provided	nil
B_frags_lith	The dominant lithology of the coarse fragments/particles greater than 2 mm in size (McDonald *et al.* 1990) within the BOS horizon.	Use lookup provided	nil
B_frags_abundance	The abundance of the coarse fragments/particles greater than 2 mm in size (McDonald *et al.* 1990) within the BOS horizon.	Use lookup provided	nil
B_frags_size	The size of coarse fragments/particles greater than 2 mm in size (McDonald *et al.* 1990) within the BOS. The average maximum dimension of used to determine in which class the fragment belongs. The regolith clasts are not considered to be pedogenic in origin and are present within a soil/regolith profile. They include unattached rock fragments and other fragments like charcoal and shells.	Use coarse fragments_size lookup provided	nil
B_frags_shape	Determine the shape of fragments within BOS using a visual guide (Figure A3). Coarse fragments/particles are greater than 2 mm in size (McDonald *et al.* 1990). The fragments are not considered to be pedogenic in origin and are present within a soil/regolith profile. They include unattached rock fragments and other fragments like charcoal and shells.	Use lookup provided	nil

APPENDIX 4: LANDFORM TYPES

The contents of this section are modified after "The Australian Soil and Land Survey Field Handbook" (McDonald *et al.* 1990).

Mode of Activity	**Land-forming agent**	**Name**	**Definition**
alluvial deposition	flowing water	alluvial landforms	A complex landform pattern on valley floors with active, inactive or relict erosion and aggradation by channelled and over-bank stream flow.
		alluvial plain	A level, or gently sloping, or slightly undulating land surface produced by extensive deposition of alluvium, generally adjacent to a river that periodically overflows its banks; it may be situated on a flood plain, a delta, or an alluvial fan.
		flood plain	Alluvial plain characterised by frequently active aggradation by over-bank stream flow (i.e., by flooding more often than every 50 years) and erosion by channelled stream flow.
		anastomosing plain	Flood plain on which the stream channels join and divide, as do the veins on a leaf. Flood plain with slowly migrating, deep alluvial channels, usually moderately spaced, forming a divergent to unidirectional integrated reticulated network. There is frequently active aggradation by over-bank and channelled stream flow.
		bar plain	Flood plain having sub-parallel stream channels which both aggrade and erode so as to develop a generally corrugated surface with numerous bars. Flood plain with numerous rapidly migrating shallow alluvial channels forming a unidirectional integrated reticulated network. There is frequently active aggradation and erosion by channelled stream flow.
		covered plain	Flood plain with a number of alluvial channels which are widely-spaced (i.e., a little under a km), migrating, more or less parallel, and deep (i.e., width-depth ratio <20:1). Aggradation by over-bank stream flow occurs at least once every 50 years, providing further alluvial cover.
		meander plain	Flood plain aggraded and eroded by meandering streams. Flood plain with widely spaced, rapidly migrating, moderately deep alluvial stream channels that form a unidirectional integrated non-tributary network. There is frequently active aggradation and erosion by channelled stream flow with subordinate aggradation by over-bank stream flow.
		floodout	Flat inclined radially away from a point on the margin or at the end of a stream channel, aggraded by over-bank stream flow, or by channelled stream flow associated with channels developed within the over-bank part.
		stream channel	

		alluvial terrace	Former flood plain on which erosion and aggradation by channelled and over-bank stream flow is slightly active or inactive because of deepening or enlargement of the stream channel has lowered the level of flooding. A pattern that includes a significant active flood plain, or former flood plains at more than one level, becomes terraced land.
		stagnant alluvial plain	Alluvial plain on which erosion and aggradation by channelled and over-bank stream flow is slightly active or inactive because of reduced water supply, without apparent incision or channel enlargement that would lower the level of stream action.
		terraced land	Landform pattern including one or more terraces and often a flood plain. Relief is low or very low (9 – 90 m). Terrace plains or terrace flats occur at stated heights above the top of the stream bank.
		alluvial swamp	Almost level, closed or almost closed depression with a seasonal or permanent water table at or above the surface, commonly aggraded by overbank stream flow and sometimes biological (peat) accumulation.
coastal and marine activity	waves, tides, channel flow and wind	coastal lands	Level to gently undulating landform pattern of extremely low relief eroded or aggraded by waves, tides, overbank or channel flow, or wind. The landform pattern may be either active or relict.
		beach ridge plain	Level to gently undulating landform pattern of extremely low relief on which stream channels are absent or very rare; it consists of relict parallel linear ridges built up by waves and modified by wind.
		chenier plain	Level to gently undulating landform pattern of extremely low relief on which stream channels are very rare. The pattern consists of relict, parallel linear ridges built by waves, separated by and built over flats aggraded by tides or over bank stream flow.
		coral reef	Continuously active or relict landform pattern built up to the sea level of the present day or of a former time by corals and other organisms. It is mainly level, with moderately inclined to precipitous slopes below sea level. Stream channels are generally absent, but there may occasionally be fixed deep erosional tidal stream channels forming a disintegrated non-tributary pattern.
		marine plain	Plain eroded or aggraded by waves, tides, or submarine currents, and aggraded by deposition of material from suspension and solution in sea water, elevated above sea level by earth movements or eustasy, and little modified by subaerial agents such as stream flow or wind.
		tidal flat	Level landform pattern with extremely low relief and slowly migrating deep alluvial stream channels which form dendritic tributary patterns; it is aggraded by frequently active tides.
		coastal dunes	Level to rolling landform pattern of very low to extremely low relief without stream channels, built up or locally excavated, eroded or aggraded by wind. This landform pattern occurs in usually restricted coastal locations.

		coastal plain	Level landform pattern with extremely low relief either with or without stream channels, built up by coastal, usually tidal, processes.
		beach	Short, low, very wide slope, gently or moderately inclined, built up or eroded by waves, forming the shore of a lake or sea.
		delta	Flood plain projecting into a sea or lake, with slowly migrating deep alluvial channels, usually moderately spaced, typically forming a divergent distributary network. This landform is aggraded by frequently active over-bank and channelled stream flow that is modified by tides.
aeolian deposition	wind	aeolian landforms	Landform pattern built up or locally excavated, eroded or aggraded by wind. Mabbutt (1977) provides a useful summary of the variety of aeolian landforms found in arid climates.
		aeolian dunes	Low mounds, ridges, banks, or hills of loose, windblown granular material (generally sand, in some places volcanic ash), either bare or covered with vegetation, capable of being moved from place to place by wind but always retaining their own characteristic shape.
		longitudinal dunefield	Dune field characterised by long narrow sand dunes and wide flat swales. The dunes are oriented parallel with the direction of the prevailing wind, and in cross section one slope is typically steeper than the other is.
		transverse dunefield	Dune field characterised by long narrow sand dunes and wide flat swales. The dunes are oriented normal to the direction of the prevailing wind, and in cross section the windward slope is typically steeper than the lee slope.
		irregular dunefield	Dune field with a mixture of longitudinal and transverse dunes, as well as other more complicated forms.
		source bordering dune	A dune formed adjacent to the source of the wind blown material. Most commonly the source is a river or floodplain which supplies aeolian sediment during periods of low or no flow.
		lunette	Elongated, gently curved, low ridge built up by wind on the margin of a playa, typically with a moderate, wave-modified slope towards the playa and a gentle outer slope.
		aeolian sheet	A sheet of aeolian material, generally sand, formed when wind moulding of the surface is prevented either by vegetation, or more usually because the sand grains are too coarse. They are commonly associated with sources that give coarse sand grains, such as alluvial plains, or weathering of coarse-grained granite, as in the Yilgarn of Western Australia.
		climbing sheet	
erosion	water, gravity	erosional landforms	Landform pattern of very low to high relief and very gentle to steep slopes. The pattern is eroded by continuously active to slightly active or inactive geomorphic processes.
		erosional plain	Level to undulating or, rarely, rolling landform pattern of extremely low relief (< 9 m) eroded by continuously active to slightly active or inactive geomorphic processes.

		pediment	Gently inclined to level (< 1% slope) landform pattern of extremely low relief, typically with numerous rapidly migrating, very shallow incipient stream channels that form a centrifugal to diverging integrated reticulated pattern. It is eroded, and locally aggraded, by frequently active channelled stream flow or sheet flow, with subordinate wind erosion. Pediments characteristically lie down-slope from adjacent hills with markedly steeper slopes.
		pediplain	Level to very gently inclined landform pattern with extremely low relief and no stream channels, eroded by slightly active sheet flow and wind. Largely relict from more effective erosion by stream flow in incipient channels as on a pediment.
		peneplain	Level to gently undulating landform pattern with extremely low relief and sparse slowly migrating alluvial stream channels that form a non-directional integrated tributary pattern. It is eroded by slightly active sheet flow, creep, and channelled and over bank stream flow.
		etchplain	Level to undulating or, rarely, rolling landform pattern of extremely low relief, formed by deep weathering and then erosion of the resulting weathered regolith. Removal of the weathered material may be either partial or complete (see also Ollier 1984).
		rises	Landform pattern of very low relief (9 - 30 m) and very gentle to steep slopes. The fixed erosional stream channels are closely to very widely spaced and form a dendritic to convergent, integrated or interrupted tributary pattern. The pattern is eroded by continuously active to slightly active creep and sheet flow.
		residual rise	Landform facet of very low relief (9 - 30 m) and very gentle to steep slopes. This term is used to refer to an isolated rise surrounded by other landforms.
		low hills	Landform pattern of low relief (30 - 90 m) and gentle to very steep slopes, typically with fixed erosional stream channels, closely to very widely spaced, which form a dendritic or convergent integrated tributary pattern. There is continuously active sheet flow, creep, and channelled stream flow.
		residual low hill	Landform of low relief (30 - 90 m) and gentle to very steep slopes. This term is used to refer to an isolated low hill surrounded by other landforms.
		hills	Landform pattern of high relief (90 - 300 m) with gently sloping to precipitous slopes. Fixed, shallow erosional stream channels, closely to very widely spaced, form a dendritic or convergent integrated tributary network. There is continuously active erosion by wash and creep and, in some cases, rarely active erosion by landslides.
		mountains	Landform pattern of very high relief (> 300 m) with moderate to precipitous slopes and fixed erosional stream channels which are closely to very widely spaced and form a dendritic of diverging integrated tributary network. There is continuously active erosion by collapse, landslide, sheet flow, creep, and channelled stream flow.

		escarpment	Steep to precipitous landform pattern forming a linearly extensive, straight or sinuous inclined surface which separates terrains at different altitudes, that above the escarpment commonly being a plateau. Relief within the landform pattern may be high (hilly) or low (planar). An included cliff or scarp often marks the upper margin.
		badlands	Landform pattern of low to extremely low relief (< 90 m) and steep to precipitous slopes, typically with numerous fixed erosional stream channels which form a dendritic to parallel integrated tributary network. There is continuously active erosion by collapse, landslide, sheetflow, creep and channelled stream flow.
		drainage depression	Depression cut into a surface by erosional processes. This term should be used only in cases where a single depression or valley is incised into a plateau or other surface, and where the scale of mapping does not allow the depression to be subdivided into its component parts (e.g., rises, floodplain).
mainly depositional	water flow, gravity	fan	Level (< 1% slope) to moderately inclined complex landform pattern of extremely low relief with a generally fan-shaped plan form. The channels form a centrifugal to divergent, integrated, reticulated to distributary pattern.
		alluvial fan	Level (< 1% slope) to very gently inclined complex landform pattern of extremely low relief with a generally fan-shaped plan form. The rapidly migrating alluvial stream channels are shallow to moderately deep, locally numerous, but elsewhere widely spaced. The channels form a centrifugal to divergent, integrated, reticulated to distributary pattern. The landform pattern includes areas that are bar plains, being aggraded or eroded by frequently active channelled stream flow, and other areas comprising terraces or stagnant alluvial plains with slopes that are greater than usual, formed by channelled stream flow but now relict. Incision in the up-slope area may give rise to an erosional stream bed between scarps.
		colluvial fan	Very gently to moderately inclined complex landform pattern of extremely low relief with a generally fan-shaped plan form. Divergent stream channels are commonly present, but the dominant process is colluvial deposition of materials. The pattern is usually steeper than an alluvial fan.
		sheet-flood fan	Level (< 1% slope) to very gently inclined landform pattern of extremely low relief with numerous rapidly migrating very shallow incipient stream channels forming a divergent to unidirectional, integrated or interrupted reticulated pattern. Frequently active sheet flow and channelled stream flow, with subordinate wind erosion aggrade the landform pattern.
glacial activity	ice	glacial landforms	This term covers a wide range of landforms that are produced by glacial processes. In Australia most landforms of this type are all relict, with the exception of Heard Island. For more details, see Fairbridge (1968) or Davies (1969).
		depositional glacial landforms	This collective term includes features such as moraines of various kinds, as well as irregular landforms made up of glacial deposits. For more details, see Fairbridge (1968) or Davies (1969).

		erosional glacial landforms	Glacial erosion produces a variety of streamlined forms such as cirques and U-shaped valleys. For more details, see Fairbridge (1968) or Davies (1969).
solution	water	karst	Landform pattern of unspecified relief and slope (for specification use terms such as “Karst rolling hills”) typically with fixed deep erosional stream channels forming a non-directional disintegrated tributary pattern and many closed depressions without stream channels. It is eroded by continuously active solution and rarely active collapse, the products being removed through underground channels.
erosion, deposition	humans	made land	Landform pattern typically of very low or extremely low relief and with slopes in the classes level and very steep. Sparse, fixed deep artificial steam channels form a non-directional interrupted tributary pattern. The landform pattern is eroded and aggraded, and locally built up or excavated, by rarely active human agency.
rapid excavation	meteor impact	meteor crater	Rare landform pattern comprising a circular closed depression with a raised margin, it is typically of low to high relief and has a large range of slope values, without stream channels, or with a peripheral integrated pattern of centrifugal tributary streams. The pattern is excavated, heaved up and built up by a meteor impact and now relict.
erosional and depositional	water, wind	plain	Level to undulating or, rarely, rolling landform pattern of extremely low relief (< 9 m). Some types of plains are described under alluvial landforms, and some are also described under erosional landforms.
		depositional plain	Level landform pattern with extremely low relief formed by unspecified depositional processes.
		lacustrine plain	Level landform pattern with extremely low relief formerly occupied by a lake but now partly or completely dry. It is relict after aggradation by waves and by deposition of material from suspension and solution in standing water. The landform pattern is usually bounded by wave-formed cliffs, rock platforms, beaches, berms and lunettes that may be included or excluded.
		playa plain	Level landform pattern with extremely low relief, typically without stream channels, aggraded by rarely active sheet flow and modified by wind, waves, and soil phenomena. Playa plains are sediment sinks and are the lowest parts of the landscape.
		sand plain	Level landform pattern with extremely low relief, typically without stream channels, aggraded by active wind deposition and rarely active sheet flow.
		plateau	Level to rolling landform pattern of plains, rises or low hills standing above a cliff, scarp or escarpment that extends around a large part of its perimeter. A bounding scarp or cliff may be included or excluded; a bounding escarpment would be an adjacent landform pattern.
		plateau edge	The cliff, scarp or escarpment that extends around a large part of the perimeter of a plateau.
		plateau surface	The low relief surface of a plateau.

		unknown	
volcanic	volcanic eruption	volcano	Typically very high and very steep landform pattern without stream channels, or with erosional stream channels forming a centrifugal or radial tributary pattern. The landform is built up by volcanism, and modified by erosional agents.
		caldera	Rare landform pattern typically of very high relief and steep to precipitous slopes. It is without stream channels or has fixed erosional channels forming a centripetal integrated tributary pattern. The landform has subsided or was excavated as a result of volcanism.
		cone (volcanic)	Typically low to high relief and very steep landform pattern without stream channels, or with erosional rills forming a radial tributary pattern. The landform is built up by volcanism, and slightly modified by erosional agents.
		lava plain	Level to undulating landform pattern of very low to extremely low relief typically with widely spaced fixed stream channels which form a non-directional integrated or interrupted tributary pattern. The landform pattern is aggraded by volcanism (lava flow) that is generally relict; it is subject to erosion by continuously active sheet flow, creep, and channelled stream flow.
		ash plain	Level to undulating landform pattern of very low to extremely low relief typically with widely spaced fixed stream channels that form an integrated or interrupted tributary pattern. The landform pattern is aggraded by volcanism (ash fall) that is generally relict; it is subject to erosion by continuously active sheet flow, creep, and channelled stream flow.
		lava flow	A landform produced on the land surface by flowing magma. It is generally relict, and subject to erosion by continuously active sheet flow, creep, and channelled stream flow.
		lava plateau	A plateau aggraded by volcanism (lava flow) that is generally relict, and subject to erosion by continuously active sheet flow, creep, and channelled stream flow.

APPENDIX 5: GEOMORPHIC PROCESSES

The contents of this section are taken from "RTMAP" (Pain *et al.* 2003)

Geomorphic processes are those that form or modify landform units. They can refer to either present or past activity. This means that processes occurring now as well as those responsible for the evolution of a regolith terrain unit can be entered into the database. An active/relict (A/R) code is used to distinguish the two. Brief definitions are included here. For more detailed descriptions of these processes the user is referred to a textbook on geomorphology, such as Chorley *et al.* (1984). Other suitable references are given at various points.

Geomorphic Process	**Definition**
Gravity	Any geomorphic process that acts mainly as a result of gravity. For more details see Selby (1982).
Vertical collapse	Collapse of large fragments of rock and/or soil, commonly from cliff faces. The collapsed materials accumulate where they fall, and may be acted on by other processes.
Particle fall	More-or-less free fall of small particles of rock and/or soil from or near vertical faces.
Creep	Slow movement of rock and/or soil particles down slope under the influence of gravity. Creep operates at rates of a few millimetres per year, with wetting and drying, shrinking and swelling, and freezing and thawing all contributing to the down slope movement of material.
Landslide	Translational movement of material along a shear plane under the influence of gravity. The moving material may be either a single coherent mass, or it may consist of a number of sliding fragments. In this type of movement, the material generally maintains its orientation relative to the land surface. The resulting deposit contains unbroken blocks or rafts of material.
Mudflow	Turbulent movement of material down slope under the influence of gravity. In this type of movement the moving mass tumbles, rolls and flows down slope. The resulting deposit is a mixture of material of all sizes, with no obvious orientation or indication of original structure.
Water	The movement and deposition of material through the agency of water. For more details see Morisawa (1985).
Channelled stream flow	Erosion, transport and deposition of material in stream channels. These commonly give well-sorted deposits that are confined to river channels, either modern or relict (channel deposits).
Over-bank stream flow	Erosion, transport and deposition of material on flood plains and other areas adjacent to rivers by water which has flowed out of a confined channel (over-bank deposits).
Sheet flow, sheet wash, surface wash	Erosion, transport and deposition of material by sheets of water flowing over the ground surface. This unconfined flow occurs on hill slopes and on low angle landform units. It commonly removes fine material, leaving coarser material behind as a lag deposit.

Waves	Erosion, transport and deposition of material by wave action either on the seacoast or along lake edges. For more details on coastal processes see Davies (1980).
Tides	Erosion, transport and deposition of material by movement of tidal currents.
Detrital deposition in still water	Deposition of detrital material from a body of standing water onto the floor of the basin. In terrestrial landscapes this occurs in lakes. Sources of detrital material include channel flow into the lake, and wave action along lake edges.
Rill/gully erosion	Linear erosion by water, producing steep sided channels. Rills are less than 0.3 m deep and gullies are more than 0.3 m deep.
Ice	Erosion, transport and deposition of material by moving ice. For more details see Davies (1969).
Frost	Freezing and thawing of water which leads to shattering and movement of rock fragments, and disturbance of soil material. Processes include solifluction, and the development of patterned ground.
Glacial erosion	Erosion and transport of material by glacial ice, giving rise to distinctive landforms such as U-shaped valleys and cirques.
Glacial deposition	Deposition of material from melting ice. The general term moraine refers to the deposits.
Wind	Erosion, transport and deposition of material by wind. For more details see Mabbutt (1977).
Wind erosion (deflation)	Erosion of material by the action of wind. This may involve entrainment of sand and dust particles, and their movement to other locations. It also includes the action of sand corrosion to produce ventifacts.
Sand deposition (wind)	Deposition of sand by wind to form various landform types including dunes and sand sheets.
Dust deposition (wind)	Deposition of dust being transported by wind in the atmosphere as suspended load. This process is responsible for deposition of loess. Where the dust is composed of clay pellets, it forms a special kind of loess, sometimes called parna in Australia.
Diastrophism; earth movements	Diastrophic movements are those that result directly or indirectly in relative or absolute changes of position, level or attitude of rocks forming the earth's crust. This includes uplift and faulting.
Volcanism	Volcanism refers to the group of processes generated by volcanic activity on the land surface (see Ollier 1988).
Lava flow	The flow of molten rock across the land surface.
Ash flow	The flow of volcanic ash material across the land surface. This includes nuée ardentes. The resulting deposits are sometimes called ignimbrites.
Ash fall	The fall of volcanic ash on to the land surface, typically leading to mantles of volcanic ash (tephra) over all parts of the landscape.
Biological agents	Formation or changes in the shape of landforms by animals or plants, for example, the development of coral reefs.
Human agents	Formation or changes in the shape of landforms by human activity.
Impact by meteors	Formation or changes in the shape of landforms by meteorite impact, typically to produce craters.

APPENDIX 6: LANDUSE LOOKUP DESCRIPTIONS

The descriptions below pertain to the land use lookup. They were modified from the Bureau of Rural Sciences (2007).

Class 1 - Conservation and Natural Environments

1.1.0 Nature conservation

Tertiary classes 1.1.1 - 1.1.6 are based on the Collaborative Australian Protected Areas Database (CAPAD) classification (Cresswell and Thomas 1997). Includes nature conservation areas (nature reserves, wilderness areas, nature parks), areas of managed resource protection (catchment areas, traditional indigenous lands) and areas of minimal land use (defence lands, stock routes, areas under rehabilitation or unused due to land degradation).

Class 2 - Production from Relatively Natural Environments

2.1.0 Grazing natural vegetation

Land uses based on grazing by domestic stock on native vegetation where there has been limited or no deliberate attempt at pasture modification. Some change in species composition may have occurred.

2.2.0 Production forestry

Commercial production from native forests and related activities on public and private land. **NB:** Environmental and indirect production uses associated with retained native forest (eg prevention of land degradation, wind-breaks, shade and shelter) are included in an appropriate class under 1. Conservation and natural environments.

Class 3 - Production from Dryland Agriculture and Plantations

3.1.0 Plantation forestry

Land on which plantations of trees or shrubs (native or exotic species) have been established for production or environmental and resource protection purposes. This includes farm forestry. Where planted trees are grown in conjunction with pasture, fodder or crop production, class allocation should be made on the basis of either prime use or multiple class attribution.

3.2.0 Grazing modified pastures

Pasture and forage production, both annual and perennial, based on significant active modification or replacement of the initial native vegetation. Land under pasture at the time of mapping may be in a rotation system so that at another time the same area may be, for example, under cropping. Land in a rotation system should be classified according to the land use at the time of mapping. Suggested tertiary classes for legume and grass pasture types can be fitted to the pasture attributes collected through the Australian Bureau of Statistics (ABS) Agricultural Census.

3.3.0 Cropping

Land under cropping at the time of mapping may be in a rotation system so that at another time the same area may be, for example, under pasture. Land in a rotation system should be classified according to the land use at the time of mapping. Cropping can vary markedly over relatively short distances in response to change in the nature of the land and the preferences of the land manager. It may also change over time in response to market conditions. Fodder production, such as lucerne hay, is treated as a crop as there is no harvesting by stock. At the tertiary level it is suggested that classes be based on commodities / commodity groups that relate to ABS level 2 agricultural commodity categories. Crops categories are: Cereals, beverage and spice crops, hay and silage, oil seeds, sugar, cotton, tobacco and legumes. **NB:** These are classified further using the Landuse_Subtype category in the digital data entry template.

3.4.0 Perennial horticulture

Crop plants living for more than two years that are intensively cultivated, usually involving a relatively high degree of nutrient, weed and moisture control. Suggested tertiary classes are based on the ABS commodities Level 2 categories that relate to horticulture. They are: tree fruits, oleaginous (oil) fruits, tree nuts, vine fruits, shrub nuts, fruits and berries, flowers and bulbs, and vegetables and herbs.

3.5.0 Seasonal horticulture

Crop plants living for less than two years that are intensively cultivated, usually involving a relatively high degree of nutrient, weed and moisture control. Suggested tertiary classes are based on the ABS commodities Level 2 agricultural commodity categories that relate to horticulture. They are: fruits, nuts, flowers and bulbs, and vegetables and herbs.

3.6.0 Land in transition

Areas where the land use is unknown and cannot reasonably be inferred from the surrounding land use. For example: degraded land (severely degraded land not undergoing active rehabilitation), abandoned land, land under rehabilitation, and land of no defined use.

Class 4 - Production from Irrigated Agriculture and Plantations

4.1.0 Irrigated plantation forestry

Land on which irrigated plantations of trees or shrubs have been established for production or environmental and resource protection purposes. This includes farm forestry e.g., hardwood production, softwood production.

4.2.0 Irrigated modified pastures

Irrigated pasture production, both annual and perennial, based on a significant degree of modification or replacement of the native vegetation. This class may include land in a rotation system that at other times may be under cropping. Land in a rotation system should be classified according to the land use at the time of mapping. Cropping/pasture rotation regimes are treated as land management practices. Pastures include: woody fodder plants, legumes, and sown grasses.

4.3.0 Irrigated cropping

Land under irrigated cropping. This class may include land in a rotation system that at other times may be under pasture. Land in a rotation system should be classified according to the land use at the time of mapping. Cropping/pasture rotation regimes are treated as land management practice. Crop types as per dryland cropping. NB: These are classified further using the Landuse_Subtype category in the digital data entry template.

4.4.0 Irrigated perennial horticulture

Irrigated crop plants living for more than two years that are intensively cultivated, usually involving a relatively high degree of nutrient, weed and moisture control. They are: tree fruits, oleaginous (oil) fruits, tree nuts, vine fruits, shrub nuts, fruits and berries, flowers and bulbs, and vegetables and herbs.

4.5.0 Irrigated seasonal horticulture

Irrigated crop plants living for less than two years that are intensively cultivated, usually involving a relatively high degree of nutrient, weed and moisture control. They are: fruits, nuts, flowers and bulbs, and vegetables and herbs.

4.6.0 Irrigated land in transition

Areas where irrigated production may have been carried out but land use is unknown and cannot reasonably be inferred from the surrounding land use. **NB:** Evidence or knowledge of irrigation use, or irrigation infrastructure, should be present. Land can be degraded, abandoned, under rehabilitation or have no defined use (irrigation).

Class 5 - Intensive uses

5.1.0 Intensive horticulture

Intensive forms of plant production e.g., glasshouses and shade houses.

5.2.0 Intensive animal production

Intensive forms of animal production (excludes associated grazing/pasture). Agricultural production facilities such as feedlots, piggeries etc may be included as tertiary classes. Production types are: dairy, cattle, sheep, poultry, pigs, aquaculture. **NB:** These are classified further using the Landuse_Subtype category in the digital data entry template.

5.3.0 Manufacturing and industrial

Factories, workshops, foundries, construction sites etc. This includes the processing of primary produce eg sawmills, pulp mills, abattoirs etc.

5.4.0 Residential

Residential includes urban (houses, flats, hotels etc), rural residential (peri-urban where agriculture is not primary source of income) and rural (areas with substantial amount of native vegetation with no agricultural development)

5.5.0 Services

Land allocated to the provision of commercial or public services resulting in substantial interference to the natural environment. Where services are provided on land that retains natural cover, an appropriate classification under (i) Conservation and Natural Environments should be applied (eg 1.1.7; 1.3). Services include: commercial (shops, markets etc), public (education and community services), recreation and cultural (parks, camping grounds, pools, museums, places of worship etc), defence facilities (unless significant natural cover is retained) and research facilities.

5.6.0 Utilities

Utilities such as electricity generation/transmission and gas treatment, storage and transmission.

5.7.0 Transport and communication

Includes airports/aerodromes, roads, railways, ports and navigation and communication uses (like radar stations).

5.8.0 Mining

Mines, quarries and tailings.

5.9.0 Waste treatment and disposal

Waste material and disposal facilities associated with industrial, urban and agricultural activities e.g., stormwater, landfill, incinerators and sewage.

Class 6 - Water

6.1.0 Lake

Feature relates to uses in 1. Conservation and Natural Environments, 2. Production from Relatively Natural Environments, and 5. Intensive Uses.

6.2.0 Reservoir/dam

Includes water storages, evaporation basins and effluent ponds.

6.3.0 River

Feature relates to uses in 1. Conservation and Natural Environments, 2. Production from Relatively Natural Environments, and 5. Intensive Uses.

6.4.0 Channel/aqueduct

Includes supply and drainage channel/aqueducts.

6.5.0 Marsh/wetland

Feature relates to uses in 1. Conservation and Natural Environments, 2. Production from Relatively Natural Environments, and 5. Intensive Uses.

6.6.0 Estuary/coastal waters

Feature relates to uses in 1. Conservation and Natural Environments, 2. Production from Relatively Natural Environments, and 5. Intensive Uses.

APPENDIX 7: BACKUP DATA ENTRY TEMPLATE

NATIONAL GEOCHEMICAL SURVEY OF AUSTRALIA (NGSA)

SITE_ID: **2007 19 _ _ _ _**

Date _ _/_ _/_ _ _ _ (dd/mm/yyyy)
Time: Entered by:

LOCATION

LATITUDE_GDA94: -___________°S
LONGITUDE_GDA94: _____________ °E
SL ELEVATION: __________ m
MAPSHEET_1:250K: _________________
STATE: _________________

SITE DETAILS

HOLE_TYPE 🄻: ____________
PROPERTY_NAME: _____________________
TARGET_SITEID: TS _ _ _ _
WATERCOURSE: __________________
LANDFORM_TYPE 🄻: ____________
GEOMORPH_PR 🄻: ____________
GEOMORPH_PR2 🄻: ____________

Site
LANDUSE_TYPE_SITE 🄻: ________________
LANDUSE_SUBTYPE_SITE 🄻: ________________

Catchment
LANDUSE_TYPE_CATCH 🄻: ________________
LANDUSE_SUBTYPE_CATCH 🄻: ________________

Sources of Contamination:

Comments:

SAMPLE DETAILS

Top Outlet Sediment (TOS) SITE_ID+001	*Bottom Outlet Sediment (BOS) SITE_ID+002*
TOS ___ - ____m	BOS ____ - ____ m
SAMPLE_TYPE 🄻: AUGER ☐, PIT/TRENCH ☐ (tick)	SAMPLE_TYPE 🄻: AUGER ☐, PIT/TRENCH ☐ (tick)
field_pH_TOS 🄻: _________	field_pH_BOS 🄻: _________
TMunCol_dry 🄻: _________	BMunCol_dry 🄻: _________
TMunCol_moist 🄻: _________	BMunCol_moist 🄻: _________
Radiation screen: Yes, ≤5 µSv/hr ☐ (tick)	**Radiation screen: Yes, ≤5 µSv/hr ☐ (tick)**

Induration? 🄻: _____________________
Depth to induration: ______ (m)
No. of holes augered:

SAMPLE DETAILS (CONT)

Top Outlet Sediment (TOS)	*Bottom Outlet Sediment (BOS)*
T_Mottles-abundance 🄻: _____________________	B_Mottles-abundance 🄻: _____________________
T_Mottles-size 🄻: _____________________	B_Mottles-size 🄻: _____________________
T_Segregations-type 🄻: _____________________	B_Segregations-type 🄻: _____________________
T_Segregations-comp 🄻: _____________________	B_Segregations-comp 🄻: _____________________
T_Segregations-size 🄻: _____________________	B_Segregations-size 🄻: _____________________
T_Segregations-abundance 🄻: __________________	B_Segregations-abundance 🄻: __________________
T_efferves_test: HCl ☐ (tick)	B_efferves_test: HCl ☐ (tick)
T_effervesce (HCl) 🄻: _____________________	B_effervesce (HCl) 🄻: _____________________
T_frags-type 🄻: _____________________	B_frags-type 🄻: _____________________
T_frags-comp 🄻: _____________________	B_frags-comp 🄻: _____________________
T_frags-size 🄻: _____________________	B_frags-size 🄻: _____________________
T_frags-abundance 🄻: __________________	B_frags-abundance 🄻: __________________

Geoscience Australia Record No 2007/8 🄻 **= Lookup available, see appendix 8 for the appropriate lookups**

APPENDIX 8: DATABASE LOOKUPS

SAMPLE_TYPE (subset)
AUGER SAMPLE
FLOAT
LAG
PIT/TRENCH SAMPLE
SURFACE REGOLITH SAMPLE
VEGETATION

Mottles_size
coarse (15 - 30mm)
fine (< 5mm)
medium (5 - 15mm)
megamottles (> 100mm)
very coarse (30 - 100mm)

HOLE_TYPE (subset)
Costean or trench section
Hand auger hole
Pit
Power auger hole
Soil pit

Mottles_abundance
common (10 -20%)
few (2 - 10%)
many (20 -50%)
no mottles
very few (< 2%)

LANDUSE
1.0.0 Conservation and Natural Environments

2.1.0 Grazing natural vegetation
2.2.0 Production forestry of natural vegetation

3.1.0 Dryland Plantation forestry
3.2.0 Dryland Grazing modified pastures
3.3.0 Dryland Cropping
3.4.0 Dryland Perennial horticulture
3.5.0 Dryland Seasonal horticulture
3.6.0 Dryland Land in transition

4.1.0 Irrigated plantation forestry
4.2.0 Irrigated modified pastures
4.3.0 Irrigated cropping
4.4.0 Irrigated perennial horticulture
4.5.0 Irrigated seasonal horticulture
3.6.0 Irrigated land in transition

5.2.0 Intensive animal production
5.3.0 Manufacturing and industrial
5.4.0 Residential
5.5.0 Services
5.6.0 Utilities
5.8.0 Mining

6.1.0 Lake
6.2.0 Reservoir/dam
6.3.0 River
6.5.0 Marsh/wetland
6.6.0 Estuary/coastal waters

LANDUSE_SUBTYPE
3.3.0 Dryland Cropping
3.3.1 Dryland cereals
3.3.2 Dryland beverage & spice crops
3.3.3 Dryland hay & silage
3.3.4 Dryland oil seeds
3.3.5 Dryland sugar
3.3.6 Dryland cotton
3.3.7 Dryland tobacco
3.3.8 Dryland legumes

4.3.0 Irrigated cropping
4.3.1 Irrigated cereals
4.3.2 Irrigated beverage & spice crops
4.3.3 Irrigated hay & silage
4.3. 4 Irrigated oil seeds
4.3.5 Irrigated sugar
4.3.6 Irrigated cotton
4.3.7 Irrigated tobacco
4.3.8 Irrigated legumes

5.2.0 Intensive animal production
5.2.1 Dairy
5.2.2 Cattle
5.2.3 Sheep
5.2.4 Poultry
5.2. 5 Pigs
5.2.6 Aquaculture

LANDFORM_TYPE

alluvial plain
flood plain
anastomatic plain
bar plain
covered plain
meander plain
floodout
alluvial terrace
stagnant alluvial plain
terraced land
alluvial swamp

coastal lands
beach ridge
chenier plain
coral reef
marine plain
tidal flat
coastal dunes
coastal plain
beach
delta

aeolian landforms
aeolian dunes
longitudinal dunefield
transverse dunefield
irregular dunefield
source bordering dune
lunette
aeolian sheet
climbing sheet

erosional landforms
erosional plain
pediment
pediplain
peneplain
etchplain
rises
residual rise
low hills
residual low hills
hills
mountains
escarpment
badlands
drainage depression

plain
depositional plain
lacustrine plain
playa plain
sand plain
plateau
plateau edge
plateau surface

fan
alluvial fan
colluvial fan
sheet-flood fan

glacial features
depositional glacial features

erosional glacial features

karst

made land

meteor crater

volcano
caldera
cone (volcanic)
lava plain
ash plain
lava flow
lava plateau

unknown

GEOMORP_PR

water
tides
waves
channelled stream flow
over-bank stream flow
sheet flow,sheet or surface wash
detrital deposition still water
rilling/gullying
subsurface solution/piping

wind
wind erosion (deflation)
sand deposition (wind)
dust deposition (wind)
biological agents; coral
diastrophism; earth movements
frost
glacial deposition
glacial erosion

gravity
vertical collapse
particle fall
creep
landslide
mudflow

impact by meteors

human agents

volcanism
lava flow
ash flow
ash fall

MUNSELL	10R3/3	10Y4/1	10YR7/6	2.5Y8/1	2.5YR7/1	5G6/2	5Y6/2	5YR5/8	
10B2.5/1	10R3/4	10Y5/1	10YR7/8	2.5Y8/2	2.5YR7/2	5G7/1	5Y6/3	5YR6/1	
10B3/1	10R3/6	10Y6/1	10YR8/1	2.5Y8/3	2.5YR7/3	5G7/2	5Y6/4	5YR6/2	
10B4/1	10R4/1	10Y7/1	10YR8/2	2.5Y8/4	2.5YR7/4	5G8/1	5Y6/6	5YR6/3	
10B5/1	10R4/2	10Y8/1	10YR8/3	2.5Y8/6	2.5YR7/6	5G8/2	5Y6/8	5YR6/4	
10B6/1	10R4/3	10YR2/1	10YR8/4	2.5Y8/8	2.5YR7/8	5GY2.5/1	5Y7/1	5YR6/6	
10B7/1	10R4/4	10YR2/2	10YR8/6	2.5YR2.5/1	2.5YR8/1	5GY3/1	5Y7/2	5YR6/8	
10B8/1	10R4/6	10YR3/1	10YR8/8	2.5YR2.5/2	2.5YR8/2	5GY4/1	5Y7/3	5YR7/1	7.5YR5/6
10G2.5/1	10R4/8	10YR3/2	2.5Y2.5/1	2.5YR2.5/3	2.5YR8/3	5GY5/1	5Y7/4	5YR7/2	7.5YR5/8
10G3/1	10R5/1	10YR3/3	2.5Y3/1	2.5YR2.5/4	2.5YR8/4	5GY6/1	5Y7/6	5YR7/3	7.5YR6/1
10G4/1	10R5/2	10YR3/4	2.5Y3/2	2.5YR3/1	5B2.5/1	5GY7/1	5Y7/8	5YR7/4	7.5YR6/2
10G5/1	10R5/3	10YR3/6	2.5Y3/3	2.5YR3/2	5B3/1	5GY8/1	5Y8/1	5YR7/6	7.5YR6/3
10G6/1	10R5/4	10YR4/1	2.5Y4/1	2.5YR3/3	5B4/1	5PB2.5/1	5Y8/2	5YR7/8	7.5YR6/4
10G7/1	10R5/6	10YR4/2	2.5Y4/2	2.5YR3/4	5B5/1	5PB3/1	5Y8/3	5YR8/1	7.5YR6/6
10G8/1	10R5/8	10YR4/3	2.5Y4/3	2.5YR3/6	5B6/1	5PB4/1	5Y8/4	5YR8/2	7.5YR6/8
10GB2.5/1	10R6/1	10YR4/4	2.5Y4/4	2.5YR4/1	5B7/1	5PB5/1	5Y8/6	5YR8/3	7.5YR7/1
10GB3/1	10R6/2	10YR4/6	2.5Y5/1	2.5YR4/2	5B8/1	5PB6/1	5Y8/8	5YR8/4	7.5YR7/2
10GB4/1	10R6/3	10YR5/1	2.5Y5/2	2.5YR4/3	5BG2.5/1	5PB7/1	5YR2.5/1	7.5YR2.5/1	7.5YR7/3
10GB5/1	10R6/4	10YR5/2	2.5Y5/3	2.5YR4/4	5BG3/1	5PB8/1	5YR2.5/2	7.5YR2.5/2	7.5YR7/4
10GB6/1	10R6/6	10YR5/3	2.5Y5/4	2.5YR4/6	5BG4/1	5Y2.5/1	5YR3/1	7.5YR2.5/3	7.5YR7/6
10GB7/1	10R6/8	10YR5/4	2.5Y5/6	2.5YR4/8	5BG5/1	5Y2.5/2	5YR3/2	7.5YR3/1	7.5YR7/8
10GB8/1	10R7/1	10YR5/6	2.5Y6/1	2.5YR5/1	5BG6/1	5Y3/1	5YR3/3	7.5YR3/2	7.5YR8/1
10GY2.5/1	10R7/2	10YR5/8	2.5Y6/2	2.5YR5/2	5BG7/1	5Y3/2	5YR3/4	7.5YR3/3	7.5YR8/2
10GY3/1	10R7/3	10YR6/1	2.5Y6/3	2.5YR5/3	5BG8/1	5Y4/1	5YR4/1	7.5YR3/4	7.5YR8/3
10GY4/1	10R7/4	10YR6/2	2.5Y6/4	2.5YR5/4	5G2.5/1	5Y4/2	5YR4/2	7.5YR4/1	7.5YR8/4
10GY5/1	10R7/6	10YR6/3	2.5Y6/6	2.5YR5/6	5G2.5/2	5Y4/3	5YR4/3	7.5YR4/2	7.5YR8/6
10GY6/1	10R7/8	10YR6/4	2.5Y6/8	2.5YR5/8	5G3/1	5Y4/4	5YR4/4	7.5YR4/3	N2.5/
10GY7/1	10R8/1	10YR6/6	2.5Y7/1	2.5YR6/1	5G3/2	5Y5/1	5YR4/6	7.5YR4/4	N3/
10GY8/1	10R8/2	10YR6/8	2.5Y7/2	2.5YR6/2	5G4/1	5Y5/2	5YR5/1	7.5YR4/6	N4/
10R2.5/1	10R8/3	10YR7/1	2.5Y7/3	2.5YR6/3	5G4/2	5Y5/3	5YR5/2	7.5YR5/1	N5/
10R2.5/2	10R8/4	10YR7/2	2.5Y7/4	2.5YR6/4	5G5/1	5Y5/4	5YR5/3	7.5YR5/2	N6/
10R3/1	10Y2.5/1	10YR7/3	2.5Y7/6	2.5YR6/6	5G5/2	5Y5/6	5YR5/4	7.5YR5/3	N7/
10R3/2	10Y3/1	10YR7/4	2.5Y7/8	2.5YR6/8	5G6/1	5Y6/1	5YR5/6	7.5YR5/4	N8/

FIELD_pH

1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7
7.5
8
8.5
9
9.5
10
10.5
11
11.5
12

Induration (subset)

bauxitic induration
bauxitic, partially cemented
calcareous induration
calcareous, moderately cemented
calcrete
calcrete (bauxite)
clay hardpan
clay induration
completely cemented duricrust
duricrust
ferricrete
ferruginous hardpan
ferruginous induration
ferruginous, moderately cemented
gypcrete
gypseous induration
humic hardpan
humic induration
indurated material
massive ferricrete
moderately cemented duricrust
nodular ferricrete
partially cemented duricrust
silcrete
silcrete pods
silcrete sheet
siliceous hardpan
siliceous induration
siliceous, moderately cemented
silcrete pods
silcrete sheet
siliceous hardpan
siliceous induration
siliceous nodules
siliceous, moderately cemented

Segregations_abundance

common (10 - 20%)
few (2 - 10%)
many (20 - 50%)
no segregations
very few (< 2%)
very many (> 50%)

Segregations_composition

aluminous
argillaceous
calcareous
earthy
ferruginous
gypseous
manganiferous
organic
other
saline
unidentified

Segregations_size

coarse (6 - 20mm)
extremely coarse (> 60mm)
fine (< 2mm)
medium (2 - 6mm)
very coarse (20 - 60mm)

Segregations_type

concretions
fragments
nodules
pisoliths
tubules

segregations_effervescence

no reaction
slight reaction
moderately reactive
highly reactive
very highly reactive

effervescence reaction test

HCl
H2O2

coarse fragments_abundance

no coarse fragments (0)
very few (<2%)
few (2 - 10%)
common (10 - 20%)
many/moderate (20 - 50%)
abundant (50 - 90%)
very abundant (>90%)

coarse fragments_size

fine gravelly; small pebbles (2-6 mm)
medium gravelly; medium pebbles (6-20 mm)
coarse gravelly; large pebbles (20-60 mm)
cobbly; or cobbles (60-200 mm)
stony; stones (200-600 mm)
bouldery; or boulders (600 mm - 2 m)
large boulders (>2m)

coarse fragments in profile_shape

angular
subangular
subrounded
rounded
angular tabular
subangular tabular
subrounded tabular
rounded tabular
angular platy
subangular platy
subrounded platy
rounded platy

coarse fragments in profile_lithology

agglomerate
alkali feldspar granite
alkali feldspar syenite
amphibolite
andesite
anorthosite
aplite
arenite
argillite
arkose
basalt
basanite
biocarbonate
bomb, block tephra
breccia
calcrete
carbonatite
chalk
charcoal
charnockite
chert
chromitite
claystone
conglomerate
dacite
diamictite
diatomite
diorite
dolerite
dolostone
dunite
eclogite
evaporite
fanglomerate
ferricrete
flint
gabbro
gabbronorite
gneiss
gossan
grainstone
granite
granodiorite
granofels
granulite
grapestone
greenstone
greisen
greywacke
grus
harzburgite
hornblende gabbro
hornblendite
hornfels
ignimbrite
iron formation
ironstone
kimberlite
komatiite
lamproite
lamprophyre
latite
lherzolite
limestone
marble
marl
metasomatite
migmatite
monzodiorite
monzogabbro
monzogranite
monzonite
mudstone
mylonite
norite
obsidian
olivine hornblendite
ophiolite
opx alkali feldspar syenite
opx syenite
pegmatite
pelite
peralkaline rhyolite
peridotite
phosphorite
phyllite
plagioclase-bearing hornblendite
porcellanite
porphyry
psammite
pyroxene hornblende peridotite
pyroxene hornblendite
pyroxene peridotite
pyroxenite
quartz
quartz alkali feldspar syenite
quartz anorthosite
quartz diorite
quartz gabbro
quartz latite
quartz monzonite
quartz syenite
quartz trachyte
quartzite
quartzolite
quartz-rich granitoid
rhyodacite
rhyolite
sandstone
saprolite
schist
serpentinite
shale
shell
shoshonite
silcrete
siltstone
skarn
slate
sparagmite
spilite
syenite
tillite
tilloid
tonalite
trachyandesite
trachybasalt
trachydacite
trachyte
travertine
tuff
tuffite
turbidite
wehrlite