FEEDLOT DESIGN AND CONSTRUCTION

7. Site investigations

AUTHORS: Peter Watts and Rod Davis

Introduction

Feasibility studies, planning, design and construction all require reliable and relevant data about the ground conditions of a potential site.

A site investigation is the overall process for the collection of information, appraisal of data, assessment and reporting.

This data must be gained competently, in a timely manner and to a degree which is adequate and appropriate to each stage of design and development. In this way risk and liability are minimised, the potential for economic and safe design is maximised and the project is more likely to be completed on time and within budget.

Inadequate site investigations may lead to the wrong choice of design, incorrect dimensioning, inadequate foundation solution, encroachment on neighbouring properties or easements (road reserves, pipelines, overhead supply lines), ill-judged or dangerous execution of ground construction work as well as damage to neighbouring buildings or other structures. The economic cost can be enormous.

The approach to be adopted for a particular site investigation, its extent and the techniques used will all depend upon the site-specific circumstances, and the experience and judgement of those involved.

RTK-GPS is commonly used survey equipment.

Design objectives

Site investigations should be conducted and managed to ensure that

- the design requirements are understood
- the lot feeder understands the importance of having an accurate knowledge of the site and sub-soil conditions
- competent advice is obtained from appropriately qualified personnel with relevant experience
- physical investigations are conducted to collect all relevant samples and data required for design and construction (e.g. geotechnical, environmental, topographic constraints)
- natural and manmade features are accurately recorded
- in-situ soils are adequately characterised.

Mandatory requirements

Conduct a 'Dial Before You Dig' search before any below-ground investigations at a site. This request is for plans of underground services at the location in which any ground penetration works are intended. The request will be referred to the relevant underground asset owners who will then forward plans of underground services, such as power cables, water and/or gas pipelines, and communication cables located on the site.

Design choices

There is no single way to carry out a site investigation and inevitably different approaches will be adopted for any particular development. The process of collection of information, appraisal of data, assessment and reporting will most likely be staged. The various stages for a site investigation include

Desktop study

A desktop study is one of the most valuable and cost-effective elements of a site investigation. At this stage the site is not visually appraised but a search is instigated for any information concerning the site, such as its environmental constraints, land resources, any previous investigations, former uses, any history of performance and any features in the area which may have influenced the site or which the proposed development may influence.

Information may be obtained from various sources such as maps and published documents, aerial imagery e.g. aerial photos, Google Earth, survey plans, state planning policy searches, online resources and from interviews and contacts.

In this stage, a preliminary assessment of the site's suitability can be assessed. For example, details about past and present land use, natural resources, geology, surface and groundwater environment, cultural heritage, archaeological values, contaminated land status and land use restrictions that may be relevant to the proposed development can be taken into account for future planning of the project.

Several sites can be evaluated in this way at minimal cost.

Permanent survey mark (PSM) and marker post.

Site survey

Surveying is a process for accurately determining the placement of natural and manmade features of a site.

Typically, the survey consists of establishing controls (bench marks), recording natural surface features, terrain of the location and any manmade features of significance. Generally, at least two surveys— a preliminary survey and a construction set-out survey— are required before construction can start.

Preliminary survey

A preliminary survey may include one or more of the following activities

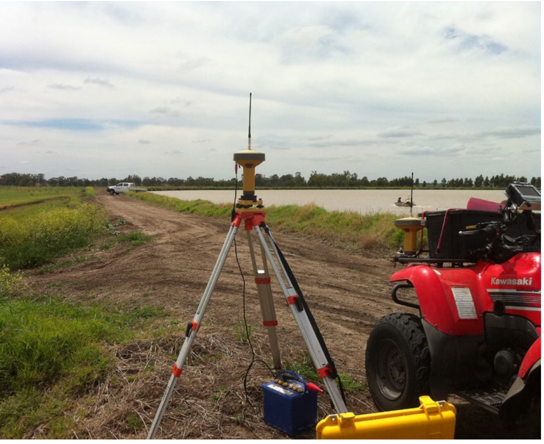
Cadastral survey – A cadastral or boundary survey locates the exact boundary of the property or lease area. A boundary survey will also show easements for utilities such as water, sewer, powerlines and telecommunication lines and identify any encroachments such as roadways, fences or buildings. For greenfield or brownfield sites, a boundary survey is important to ensure that the construction is done on the correct area of land.

A cadastral survey should be carried out by a suitably qualified land surveyor who is licensed to perform in the relevant state.

The PSM should be accessible by GPS and able to have tripod mounted above it.

Feature and topographic survey – A feature and topographic survey details all information about the site. It is used to determine and locate the natural and manmade features and improvements on the site. This survey is used by designers to collate factors such as

- ground level and contours
- existing structures
- adjoining structures
- fences
- utility services



RTK-GPS survey base station and rover mounted on ATV

- drains
- trees
- drainage lines.

This can be important at existing feedlot sites where poor records are available, particularly for features such as water pipelines. The information is useful in determining the degree of 'cut and fill' required in the preparation of the feedlot site.

Control marks

Survey marks called bench marks (BM) for vertical and horizontal control should be installed. These can be temporary (TBM) or permanent survey marks (PSM) but should be sited in an area where they are least likely to be disturbed or removed during the construction phase of the project. They also need to be accessible for GPS units and to mount a tripod over. Further surveys can be based upon these benchmarks. Installing several benchmartks will allow for redundancy if some are destroyed during construction.

Vertical control determines the elevation with respect to sea level or a level reference surface or datum from a known PSM, and is used to accurately coordinate vertical positional data for 'cut and fill' earthwork operations. The datum (vertical level) of the bench mark system is taken from the PSM (Australian height datum - AHD - if known) or an arbitrary datum. Horizontal datum may be arbitrary or MGA 94.

Construction set-out survey

A poorly located Temporary Bench Mark (TBM) sited near to infrastructure not affected by earthworks.

A total station may not be able to see a target on this TBM from all directions. RTK-GPS accuracy may also be reduced as the pole may screen satellite location.

A set-out survey is used to transform the engineering design with precision accuracy onto the exact position at the site, and is important when preparing for any type of construction work.

A set-out survey involves transferring a design onto the land itself so the construction contractors can follow it during construction. During the process, key points are established and markers used to guide the construction process and ensure accuracy. The contractor may have individual preferences set-out (e.g. centreline versus embankment toe) and therefore should be consulted.

Survey techniques

Modern equipment such as Total Stations (which are basically electronic theodolites with built-in electronic distance meters) and GPS are used to measure and capture data that will later be downloaded into mapping software.

Real Time Kinematic (RTK) satellite navigation is a technique used to enhance the precision of position data derived from satellite-based positioning systems, being usable in conjunction with GPS. RTK-GPS is being becoming increasingly used for large detail and contour surveys as well as a variety of other engineering applications.

RTK-GPS systems offer a typical nominal accuracy of less than 1 cm horizontally and vertically. However, RTK-GPS requires a clear view of the sky with no obstructions from about 5 degrees elevation and up. GPS surveying under trees or near buildings results in reduced accuracy. Hence, TBMs must be located carefully.

As machine guidance is now a widely adopted technique in earthwork operations due to its accuracy and ease of use, survey data may be integrated into the construction contractor's equipment. The engineering design data can be transferred (imported) into GPS machine guidance systems. RTK-GPS-based machine guidance systems require input data from a 3D model of the existing and planned surfaces topography, to allow correct horizontal and vertical control.

Light Detection and Ranging (LiDAR) is an aerial survey technique that is often used to capture large survey areas in a relatively short period of time.

The process works by measuring the time taken for light to travel from a transmitter located on the aircraft to the ground and back to the receiver. As long as the light source can make contact with a surface, the corresponding height can be recorded. This allows the survey to penetrate through light to medium vegetated areas but not extremely dense vegetation or solid structures such as a shed roof.

After completion of the aerial survey, data is mathematically modelled to determine the ground surface. Where a solid structure is encountered, the underlying ground surface is interpolated using the surrounding points.

In order to tie the survey points to a horizontal and vertical datum, several control points are located around the boundary of the flight path. These control points are captured during the aerial survey and are captured again by ground surveyors. Similar to the RTK-GPS process, benchmarks should also be installed on the site so that follow-up ground surveying can be tied back into the previous data.

A common vertical accuracy for LiDAR surveying is 0.1m, but the level of accuracy can change depending on what is required. To guarantee quality results, LiDAR has to be undertaken in favourable weather conditions (day or night) when there is no rain and minimal cloud coverage.

Geotechnical investigations

Geotechnical investigations obtain information on the physical properties of soil, rock and/or shallow groundwater around a site to assess suitability of material for construction and to allow accurate design of earthworks and foundations.

The most common methods of observing the soils below the surface, obtaining samples and determining physical properties of the soils and rocks include

- excavation of test pits/trenches using a backhoe and various sized excavators
- hand augers
- drilling/boring, i.e. rotary, hollow-stem auger, continuous-flight auger.

Test pits/open cuts have the advantage of displaying the soil profile more clearly. The soil should be laid out around the test pit in the order of extraction so that the profile can be described accurately and appropriate samples taken for subsequent laboratory testing. Test pits and open cuts are usually 3–5m in depth but this depends on the size of the equipment being used and design requirements.

Test pit excavation. Separate the soil horizons or changes in soil texture during excavation to allow soil samples to be collected from each type of material encountered.

Excavated test pit illustrating changes in soil texture down the profile.

The test pit or bore hole should extend at least 0.5 m below the anticipated earthworks cut or pile depth.

Shallow groundwater intersected during excavation.

Soil sampling rig using spiral auger

The soil sample should be taken straight off the auger and its depth recorded.

For safety reasons, no one should enter an unstable pit.

Drilling augers tend to mix the different layers of the soil profile together and may not be suited for all applications.

Evidence is sought of natural groundwater seepage (e.g. springs). In extended dry periods, local knowledge should be used to determine if any springs may break out in wet weather.

If water is encountered during investigations, its depth should be recorded. Rising water levels should also be noted as they tend to indicate the presence of pervious layers that should be investigated further before construction.

If rock is encountered during investigations, study and record the type of rock, its condition (i.e. cracked, jointed or weathered) and its depth. The presence of rock can pose problems during construction and can also provide 'seams' along which water might escape in the construction of a dam.

Geotechnical investigation should be undertaken in accordance with AS1726 – Geotechnical Site Investigations. Collection of information and its appraisal should continue during the construction works to confirm the geology and soil types of the proposed feedlot site.

Typically a geotechnical investigation is undertaken by a suitability qualified and experienced geotechnical engineer or a company specialising in geotechnical investigations.

Location of test pits

The approximate location of test pits over the proposed construction site should be decided before the site visit, based on information from soil maps and the probable location of all earthworks plus potential borrow pits. Test pits or boreholes will characterise the variability and extent of on-site soils, and could look at locations that may also contain material suitable for the construction of pen and road surfaces (e.g. gravel) and/or sand for concrete, and clay for embankments.

Once completed, the test pits should be photographed and their locations marked on a site plan for future reference; GPS units provide a quick and accurate method for marking test pits and other locations.

The location of each borehole or test pit should be accurately surveyed and recorded to assist when comparing relative levels (RL) and slope grades to those expected in the subject landscape. The expected accuracy (ie. $\pm$ x metres) of the GPS or survey equipment used should also be recorded.

Soil sample collection

Depths of soil layers and descriptions using the nomenclature of the Australian Standard for 'Geotechnical site investigations AS 1726 – 1993', should be logged for all soil types encountered. Particular attention should be paid to the description of soil consistency and structure and if encountered, any auger refusal on shallow rock. Shallow water tables and the presence of fill should be noted.

The size of the sample should be based on the number and type of tests to be performed.

Table 1. Unified Soil Classification System (Standards Australia 1993)

Major divisions			Group symbol	Group name
Coarse grained soils more than 50% retained on No. 200 (0.075 mm) sieve	gravel > 50% of coarse fraction retained on No. 4 (4.75 mm) sieve	clean gravel <5% smaller than No. 200 sieve	GW	well graded gravel, fine to coarse gravel
			GP	poorly graded gravel
		gravel with >12% fines	GM	silty gravel
			GC	clayey gravel
	sand ≥ 50% of coarse fraction passes No. 4 sieve	clean sand	SW	well graded sand, fine to coarse sand
			SP	poorly-graded sand
		sand with >12% fines	SM	silty sand
			SC	clayey sand
Fine grained soils more than 50% passes No. 200 (0.075 mm) sieve	silt and clay liquid limit < 50	inorganic	ML	silt
			CL	clay
		organic	OL	organic silt, organic clay
	silt and clay liquid limit ≥ 50	inorganic	MH	silt of high plasticity, elastic silt
			CH	clay of high plasticity, fat clay
		organic	OH	organic clay, organic silt
Highly organic soils			Pt	

Laboratory tests

Soil samples collected during site investigation are usually preserved and protected against any possible disturbance or moisture changes and sent to a soil testing laboratory for determination of various geological and engineering properties. The following engineering tests are recommended on the collected soil samples

- Engineering classification of soils (USCS classification); see Table 1
- Liquid limit, plastic limit, plasticity index tests and linear shrinkage to classify fine-grained soils (clays and silts) and other geotechnical correlations
- Particle size analysis (by sieve analysis for coarse-grained fraction of soils, by hydrometer test for fine-grained fraction of soils)
- Optimum moisture content (OMC) and maximum dry density (MDD)
- Soaked CBR value for pen surfacing and/or road material
- Hydraulic conductivity for pen and pond lining material
- Slaking and dispersion – Emerson class number. Slaking and dispersion is a structural stability indicator and is important from the perspective of embankment stability and erosion.

A materials quality test should be conducted in accordance with relevant Australian Standards, as detailed in Table 2.

Table 2 – Recommended engineering tests for soil samples

Test	Australian Standard
Engineering Classification - USCS	AS1726
Particle size distribution (grading)	AS1152
Soaked CBR Value	AS 1289.6.1.1-1998
Liquid Limit	AS 1289.3.1.1-2009
Plasticity Index (PI)	AS 1289.3.3.1-2009
PI × % Passing 425µm Sieve	AS 1289.3.3.1-2009
Emerson Class Number	AS 1289.3.8.1
Linear Shrinkage (LS)	AS 1289.3.4.1
LS × % Passing 425µm Sieve	AS 1289.3.4.1
Dry Density/Moisture content relationship	AS 1289.5.2.1-2007
Dry Density Ratio	AS 1289.5.4.2-2007
Optimum Moisture Content (OMC)	AS 1289.5.4.1-2003
Hilf Density Ratio	AS 1289.5.7.1-2006
Hydraulic Conductivity	AS 1289.6.7.1; AS 1289.6.7.2; AS 1289.6.7.3.

These recommended engineering tests are used to determine the soil properties required for each material used in

- pen and road surface construction, and composting and/or stockpiling areas; see *Section 17 – Pen and road surfaces*
- clay liners for holding ponds and sedimentation basins; see *Section 12 – Holding pond design*

If a sample fails any of the preliminary tests for the intended use, the material represented by the sample should be rejected as unsuitable for the intended works.

Further information of material suitability for pen foundations and pond construction can be found in *Section 17 - Pen and road surfaces* and *Section 12 - Holding pond design*.

Laboratory testing should be conducted by a company specialising in soil testing and with National Association of Testing Authorities, Australia (NATA) accreditation for the relevant tests to be performed.

Common site problems may include

- excavation walls caving in
- drilling difficulties
- loss of sample during retrieval
- knowing when to stop a hole, or what and when to test and sample
- misidentification of samples and sampling locations
- breakdown and breakage of equipment
- environmental impacts of construction activities on wildlife, vegetation, waterways and inclement weather
- working close to earthmoving equipment, trucks and overhead loads
- hazards encountered when undertaking ground penetration.

Safety

Activities associated with site investigations must comply with WHS and environmental management requirements which may be imposed through state/territory or federal legislation.

Activities must adhere to state/territory or federal legislation. However, as a general guide

- Barricades at least 900 mm high must be erected around a trench that is 1 m or more deep unless it is not possible or if only workers involved with the trench will be in the area, or another form of barrier exists e.g. excavated materials near the trench.
- Check whether trenches can be left open for future inspection by engineers/contractors or need to be refilled immediately.
- If a person is entering a trench more than 1.5 metres deep, it must be either
  - shored or shielded
  - benched – not higher than it is wide and no vertical face exceeding 1.5 metres
  - battered – angle not exceeding 45° and bottom vertical face not exceeding 1.5 metres
  - approved in writing by an engineer as safe to work in.
- Ladders used for access must be no more than 9 metres apart in the area of the trench where work will be carried out.
- Temporary fencing suitable to exclude livestock should be installed to prevent livestock falling in trenches.

Ground penetration works that are generally exempt from WHS and '*Dial before you dig*' considerations include

- using machinery or power tools to dig less than 150 mm deep
- digging less than 300 mm deep without machinery or power tools
- emergency excavation to mitigate death or prevent injury.

Geotechnical investigations, and to a lesser extent surveying, involve activities that will penetrate into the ground and potentially cause problems by encountering unseen objects.

Hazards include penetration of

- gas pipes
- water supply lines
- buried electrical cables
- buried communication cables
- any other buried utility infrastructure.

Safety barrier placed around excavated pit

Check for underground water pipes and electrical and communication cables.
"Dial before you dig"

Water supply and quality

Surface water and/or groundwater for the feedlot water supply should be evaluated with water samples collected from the intended supply to assess quality. Bores may need to be tested to determine yield and flow rate.

All tests should be carried out to the Australia Standard Code of AS2368-1990 – Test Pumping of Water Wells by a company specialising in bore flow testing and reporting.

Good quality water is clean, clear, odourless and without a high mineral content. Water quality is lowered by soluble salts, algae, pollution (e.g. dead animals, bird faeces or debris) and clay (in suspension). See *Section 5 – Water quality*.

Water samples collected during the site investigation must be preserved and sent to a water testing laboratory to determine water quality. Water quality is generally assessed on

- physical properties
- physiochemical properties – physical properties and chemical composition including salinity, hardness, and pH
- excess nutrients – excessive levels of nitrates can affect cattle health
- toxic compounds – heavy metals and fluoride can pose a health hazard to cattle
- microbiological agents – for example, faecal coliforms and cyanobacteria (blue-green algae).

See *Section 4 – Water requirements* and *Section 5 – Water quality* for more information on water quality guidelines.

Always seek advice from a suitably qualified and experienced animal health practitioner (e.g. nutritionist and/or veterinarian) to confirm the suitability of the water for the feedlot drinking water supply.

Electricity supply

The electrical power supply to the site should be confirmed by on-site inspection and through enquiries with the local utility provider. Evidence of the capacity and number of power supplies to the site should be sought. It can be useful to record pole numbers for discussion with power authorities.

Environmental

The following data should be collected to identify any potential constraints should a surface water body, wetland or significant vegetation be present on the site

- distance to the surface water body, wetland or significant vegetation
- site drainage patterns
- likely location where the contaminants of concern from the site may discharge into the surface water body or wetland
- flow direction and depth of any groundwater that potentially could be contaminated in relation to such water body or wetland
- classification of the water body.

The site should be searched to assess any potential contaminated land issues as a result of current and past practices on the site. For example

- cattle yards, and in particular old dips, may have pesticide residues
- inhabited or uninhabited buildings or workshops may have potential impacts from fuel storage, pesticide use and asbestos.

Quick online searches to assess a site's suitability should be carried out when conducting site investigations. These searches should investigate the environmental constraints, land and water resources and cultural heritage aspects of the site. The websites used should be specific to the region in which the site is located. Searches should include

- climate
- bushfire risk
- flood hazard area
- landslide hazard area
- strategic cropping land
- good quality agricultural land
- agricultural land classifications
- contaminated land register
- acid sulphate soils
- surrounding mine and extractive resources
- energy and water supply or underground facilities
- vegetation mapping
- environmentally sensitive areas
- wetlands
- cultural heritage
- national heritage places.

The type and distance to sensitive receptor sites should be confirmed on-ground.

Quick tips

- Conduct a preliminary desktop assessment of the site's suitability (e.g. about past and present land use, natural resources, geology and the surface and groundwater environment). Several sites can be evaluated in this way at minimal cost.
- Undertake a site investigation to identify and record design constraints of the site. During the site investigation, topographic limitations should be noted e.g. slope gradients, flood inundation lines, rock outcrops, vegetation coverage (shrubbery and larger trees), surface waters, groundwater and sensitive receptors.
- A site survey should establish vertical and horizontal control marks, record natural and manmade features and surface elevations.
- Check with construction contractors to ensure that survey and design data can be seamlessly integrated into machine guidance equipment.
- Obtain information on the physical properties of soils around a site to design earthworks and foundations and assess suitability of material for construction.
- Record the locations of test pits and bore holes.
- Check the suitability of nearby water supplies for cattle drinking.

Further reading

Dial Before You Dig - *www.1100.com.au*

Standards Australia (1993) AS 1726 - Geotechnical site investigation. Standards Australia, Canberra

Standards Australia 1999, AS 1289 Soil Testing for Engineering Purposes. Standards Australia, Canberra.

Standards Australia, 2005, AS 4482.1-2005, Australian Standard: Guide to the Sampling and Investigation of Potentially Contaminated Soil. Part 1: Non-volatile and Semi-volatile compounds. Standards Australia, Canberra.

Standards Australia, 1999, AS 4482.2-1999 Australian Standard: Guide to the Sampling and Investigation of Potentially Contaminated Soil. Part 2: Volatile Substances. Standards Australia, Canberra

EPA Victoria, publication IWRG701, June 2009, Sampling and analysis of waters, wastewaters, soils and wastes.