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Report on
Geotechnical Assessment – Urban Capability

Proposed Subdivision
Blocks 1605 – 1607, West Belconnen, ACT

Prepared for
The Riverview Group

Project 77356
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Report on Geotechnical Assessment – Urban Capability
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1. Introduction

This report presents the results of a geotechnical assessment for urban capability undertaken for the proposed subdivision located within Blocks 1605 – 1607, West Belconnen, ACT. The work was requested by The Riverview Group, project managers for the development.

It is understood that consideration is being given to the re-zoning of existing vacant land for future residential subdivision. Assessment was carried out to provide preliminary information on geotechnical aspects of the site to assist in conceptual planning of the development and for submission to the ACT Government with the re-zoning application.

The assessment comprised a review of published information and field mapping by a senior geotechnical engineer followed by engineering analysis and reporting. Details of the work undertaken are given in the report, together with preliminary comments relating to site development, design and construction practice.

An aerial photograph and site survey plans were provided by the client for the purpose of the assessment.

It is noted that a geotechnical assessment for urban capability for neighbouring land within New South Wales is concurrently being undertaken by Douglas Partners.

This report must be read in conjunction with the notes “About this Report” which are included in Appendix A.

2. Site Description

The overall site which comprises the consolidation of Blocks 1605 – 1607 in West Belconnen, ACT is an irregular shaped area of some 690 hectares with maximum north-south and east-west dimensions of 2,100 m and 1,700 m respectively. Due to its close proximity to the Murrumbidgee River, the western part of the site has been designated as river corridor land with no development proposed.

The extent of the proposed urban development area is expected to be approximately 50 per cent of the overall site (ie: 350 hectares). The proposed urban development area and block layout are shown on Drawings 1 and 2 in Appendix B.

The urban development area is bounded by the following:

- to the west by land designated as river corridor then by the Murrumbidgee River;
- to the south and south east by Stockdill Drive;
- to the east by a landfill facility, golf course and electrical substation; and
- to the north by the NSW state border there beyond by grazing land.

The majority of the site was undeveloped and being used for grazing purposes. It was moderately to heavily grassed with a variable tree density primarily along gully lines and in the southern half of the site where large stands were observed. Extensive rock outcropping and/or cobbles/boulders sub cropping were noted across the entire site. Uncontrolled filling was limited to farm dam wall construction and in some limited gully lines.

Site levels fall in variable directions away from a number of ridgelines and hill tops at grades ranging from near-vertical to 1 in 40 but overall fall is to the west. An overall difference in level from the highest part of the urban development site to the lowest has been estimated to be about 110 – 120 m.

3. Assessment Methods

3.1 Information Review

A review of existing geological, soil landscape and hydrogeological maps was undertaken as part of the assessment. The relevant maps reviewed were as follows:

- 1:100 000 Geological Series Sheet for Brindabella (Ref 1),
- 1:100 000 Soil Landscape Sheet for Brindabella (Ref 2),
- 1:100 000 Soil Landscape Sheet for Canberra (Ref 3),
- 1:100 000 Hydrogeology of the Australian Capital Territory (Ref 4).

3.2 Site Inspection

A site inspection was undertaken by a senior geotechnical engineer on 23 and 28 October 2013, which included qualitative assessment of site stability considerations and mapping of site features. A series of photographs illustrating notable site features are presented in Appendix C with the locations of the photographs shown on Drawings 3 – 5 in Appendix B.

4. Assessment Results

4.1 Geology and Hydrogeology

Reference to the Brindabella Geology Sheet (Ref 1) indicates that the site is underlain by three igneous rock units. Figure 1 below is an extract of the geological map showing the approximate site extent and the contained geological units.

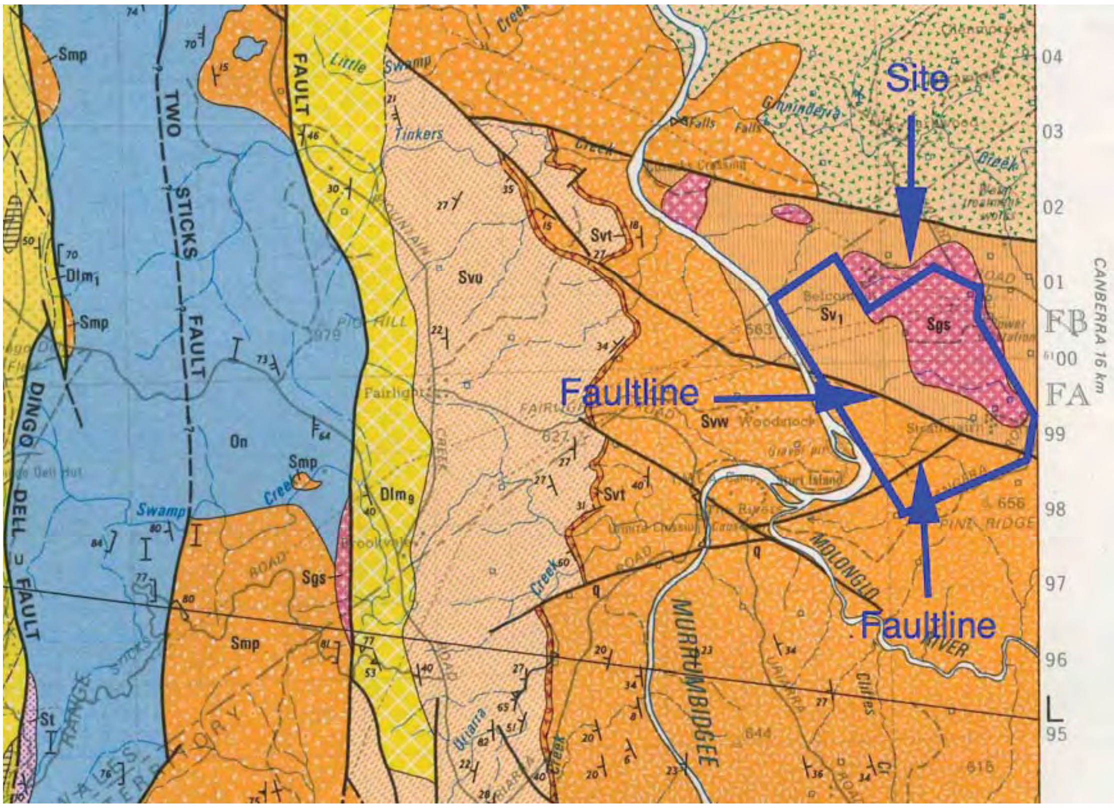


Figure 1: Extract of Geology Map.

The southern part of the site is mapped as being underlain by the Walker Volcanics of early to mid-Silurian age. The Walker Volcanics typically comprise purple and greenish grey dacitic ignimbrite.

The middle and north western parts of the site are mapped as being underlain by an unnamed mid Silurian aged extrusive unit. It typically comprises interbedded volcaniclastic sediment, dark grey ignimbrite, agglomerate and air-fall tuff.

The north eastern and a portion of the eastern side of the site are mapped as being underlain by an unnamed late Silurian aged intrusive unit. It typically comprises quartz feldspar porphyry, adamellite and granodiorite.

Three fault lines are mapped within or adjacent to the site, two in a north west to south east direction (north and in middle of the site) and one in a north east to south west direction (south of the site).

Reference to the Hydrogeology of the Australian Capital Territory and Environs Map (Ref 4) indicates that the site is located on fractured aquifers of late Middle Silurian age and fractured to massive aquifers of late Silurian age. Expected geological units referred on the map include granite, granodiorite, adamellite, leucogranite, quartz porphyry, tonalite and/or andesitic, dacitic, rhyodacitic ignimbrite, minor ashstone, shale, sandstone, limestone and disseminated sulphides.

Based on the hydrogeology map, the yield of aquifers increases from the west to the east from less than 0.5 l/s to greater than 1 l/s generally around the electrical substation and golf course. Total dissolved solids (TDS) are mapped as increasing in a westerly to easterly direction from less than 500mg/L (west) increasing to in excess of 1000mg/L (east).

Surface water was not observed during the site inspection with the exception of farm dams located across the site. Other than the dams, the site is traversed by numerous intermittently flowing water courses and gully lines which run in variable directions but ultimately water flows are from the east to west direction.

4.2 Soil Landscape

Reference to the Brindabella Soil Landscape Sheet (Ref 2) indicates that the site is beyond the extent of mapping with information only provided for land within NSW. Similarly, reference to the Canberra Soil Landscape Sheet (Ref 3) indicated the site is beyond the extent of mapping.

Given the locality of the site adjacent to the Murrumbidgee River and its similar topography and landscape to areas of land adjacent to this river it is inferred that the proposed development area would likely be underlain by the Williamsdale and Burra Soil Groups.

The Williamsdale soil group is characterised by undulating rises, alluvial fans and valley flats on Silurian Volcanics of Canberra Lowlands. Generally, little or no rock outcrops occur, within this soil group although rock outcrops are present on the site. Soils are moderately deep, well drained podzolic soils, red and brown earths on upper rises and fan elements and moderately to very deep, poorly to imperfectly drained solodic soils on lower rises and fan elements. Based pm the Brindabella soil Landscape Sheet, this soil group is characterised by its erodible and dispersible nature, its acidity, potential for seasonal waterlogging and localised flooding hazard.

The Burra soil group is characterised by undulating to rolling low hills and alluvial fans on Silurian Volcanics of Canberra Lowlands. Generally, waning and gently to moderately inclined hill slopes, foot slopes and fans. Soils are shallow, well drained earthy sands on crests and upper slopes; moderately deep, moderately well drained red podzolic soils on mid slopes and most lower slopes; and moderately deep slowly to moderately well drained yellow podzolic soils along minor drainage lines and on some lower slopes. The Landscape Sheet lists this soil group as characterised by its strong acidity and low water holding capacity, its low permeability, sheet erosion risk, run-on and localised shallow soil.

4.3 Site Inspection

The distribution of features noted during the field mapping are shown on Photos 1 – 86. The principal observations are as follows:

- The site generally comprises undulating to steeply undulating grazing land which is moderately to heavily grassed,
- Semi-mature to mature trees are scattered across the site with a higher density along gully lines and in the southern parts of the site,
- Numerous farm dams have been constructed across the site generally with one or more in each major gully line,
- The farm dam storage areas range in size from 400 m^2 to 2500 m^2,
- Surface cobbles and boulders were observed across the entire site with rock outcropping on the flanks and top of ridgelines and hilltops,
- Pillars of bedrock in the form of boulders and blocks have been created on some hilltops as a function of weathering of the surrounding soil and more weathered rock,
- The site is segmented into a series of small to large paddocks separated by fences and gates,
- Most of the site could be traversed on existing unsealed/unformed access tracks,
- Two properties (including Strathnairn Homestead) were located at the southern extent of the site which are excluded from development,
- Several high voltage power lines with associated transmission towers were observed dispersing from the western side of the adjacent electrical substation across the northern half of the site,
- Existing structures (dwelling and sheds) are limited to the northern part of the site immediately adjacent to the landfill facility,
- Extensive erosion in gully lines where the natural grass and/vegetation cover has been removed,
- Minimal erosion in areas where the grass/vegetation is infact,
- With the exception of farm dams areas, isolated uncontrolled filling, some filling/modification to drainage lines, and of the existing structures mentioned above, the remainder of the site is generally undisturbed,
- The flanks of the ridgelines and hills are generally moderately to steeply sloping with the foot slopes and gullies gently to moderately sloping in parts,
- Some gully lines have near-vertical slopes caused by erosion of the soils or where bedrock is exposed,
- No obvious signs of creep movements within near-surface soils were noted (including the steeper north eastern part of the site), nor any signs or deep-seated instability;
- No obvious signs of salinity (such as salt deposits and tree die back) or deep-seated instability within the site,
- Some stability concerns would be associated with the pillars of bedrock and the near-vertical to steep gully line banks.

5. Proposed Development

It is understood that the proposed development of the site is for residential and related purposes. Of the total area, approximately 50 per cent of the land is expected to be zoned for river corridor or conservation purposes. The balance of the land is anticipated to yield approximately 4,500 dwellings.

Detailed resolution of the site design, number and sizes of blocks, provision for schools, other community facilities and open space will be subject to the outcomes of a structure planning process and subsequent detailed design of each stage.

6. Comments

6.1 General

The following comments are based on the results of site reconnaissance, review of existing information and our involvement in similar projects.

It is understood that a future residential subdivision is proposed and that further investigations will be undertaken at the appropriate time as the planning and design of the subdivision proceeds. Accordingly, this report and the comments given within must be considered as being preliminary in nature.

6.2 Development Considerations

6.2.1 Site Classification

Classification of residential blocks within the site should comply with the requirements of AS 2870 – 2011 "Residential Slabs and Footings" (Ref 5). Likely block classifications would range from Class A (sand/rock sites), Class S (slightly reactive) to Class M (moderately reactive) or Class H1 (highly reactive), with the final classification dependent on soil reactivity, the presence of filling and rock depth. The topographic slope in various parts of the site ranges from intermediate to steep (refer Drawings 6 – 8) and accordingly, it is anticipated that some of the blocks will need to consider design and construction techniques that take account of the ground slope and possible Class P conditions. It must be noted that some areas within blocks with steep terrain may not be considered suitable for development. Classifications within these areas would also be dependent on the extent of bulk earthworks proposed.

6.2.2 Stability Assessment

The site has been assessed with reference to the Australian Geomechanics Society Sub-Committee on Landslide Risk Management: *"Landslide Risk Management Concepts and Guidelines"* (Ref 6). Based on the observations made during the inspection, an assessment of risk to property has been undertaken for each of four distinct zones as follows:

Zone 1: areas of gently sloping land ie: flatter than 1V:10H (vertical:horizontal) or 5 – 6° (referred to as *"very low risk"* as shown on Drawings 6 – 8);

Zone 2: areas of moderately sloping land ie: generally between 1V:10H and 1V:5H or 6 – 12° (referred to as *"low risk"* on Drawings 6 – 8);

Zone 3: areas of moderately to steeply sloping land ie: generally between 1V:5H and 1V:3.3H or 12 – 17° (referred to as *"moderate risk"),*

Zone 4: areas of steeply sloping land ie: steeper than 1V:3.3H or 17° (referred to as high risk).

Due to the small difference between the surface contours of moderately to steeply land i.e.: 12 - 17°, differentiating between these areas proved difficult and have been represented as a combined risk area.

The results of the assessment for each of these areas are outlined in Tables 1 – 4.

Table 1 – Slope Stability Assessment – Zone 1 (Gently Sloping Areas)

Hazard	Likelihood	Consequence to Proposed Development	Risk to Proposed Development
Creep of surface soils	Barely credible	Minor	Very Low
Near surface slumping	Barely credible	Medium	Very Low
Active / deep seated slide	Barely credible	Major	Very Low

Table 2 – Slope Stability Assessment – Zone 2 (Moderately Sloping Areas)

Hazard	Likelihood	Consequence to Proposed Development	Risk to Proposed Development
Creep of surface soils	Unlikely	Minor	Low
Near surface slumping	Unlikely	Medium	Low
Active / deep seated slide	Rare	Major	Low

Table 3 – Slope Stability Assessment – Zone 3 (Moderately to Steeply Sloping Areas)

Hazard	Likelihood	Consequence to Proposed Development	Risk to Proposed Development
Failure during construction	Possible	Medium	Moderate
Creep of surface soils	Possible	Minor	Moderate
Near surface slumping	Possible	Medium	Moderate
Active / deep seated slide	Rare	Major	Low

Table 4 – Slope Stability Assessment – Zone 4 (Steeply Sloping Areas)

Hazard	Likelihood	Consequence to Proposed Development	Risk to Proposed Development
Failure during construction	Likely	Medium	High
Creep of surface soils	Likely	Minor	Moderate
Near surface slumping	Likely	Medium	High
Active / deep seated slide	Unlikely	Major	Moderate

In summary, it is considered that most of the site is classified as very low or low risk of damage to property occurring as a result of slope instability. Several areas are considered of moderate or high risk (refer Drawings 6 – 8) of causing property damage due to the steep ground slopes and possible unsuitable design and construction practice.

Notwithstanding the various risk categories nominated, development of the site for residential purposes is considered feasible in areas of gently and moderately sloping land (very low and low instability risk) with erosion control measures and suitable dwelling design to be addressed. In areas of moderately sloping land, standard practices for hillside development must be incorporated into designs.

Areas designated as moderately to steeply sloping land (moderate risk), could be developed for residential purposes however would have to the subject of site and development specific geotechnical investigations to establish a site model and provide geotechnical limitations and design parameters.

Areas of steeply sloping land (moderately and high risk) are not recommended for residential development at this stage. A detailed site stability assessment including subsurface investigations must be undertaken in these areas to establish an appropriate site model for analysis purposes to assess whether development is feasible in the high risk zones.

It is noted that revisions to the above risk classifications may be necessary following completion of bulk earthworks. It is recommended that if development is proposed within the moderate and high risk areas, further delineation and assessment be undertaken.

6.2.3 Soil Erosion

It is considered that the erosion hazard within the areas proposed for development would be within usually accepted limits and could be managed by good engineering and land management practices which will also be required to address flood hazard and localised waterlogging limitations of soils along gully lines and low lying flat areas. These hazards are considered to impose only a minor constraint to development.

It is anticipated that the treatment of the existing erosion gullies as part of an overall site development would include:

- filling using select materials (i.e. non – dispersive or erodible) placed under controlled conditions;
- provision of temporary surface cover (e.g. pegged matting) during the period of valley floor revegetation;
- channel lining in sections of rapid change in gully floor grade;
- piping of flow where appropriate;
- the re-establishment of a zone of tree cover along gully banks.

6.2.4 Footings

All footing systems for standard residential dwellings should be designed and constructed in accordance with AS 2870 – 2011 (Ref 5) for the appropriate classification. For hillside block construction (low risk or greater), reference should be made to the publication by AGS (Ref 6), relevant extracts of which are included in Appendix D.

For preliminary sizing of footings, allowable base bearing pressures for the various strata likely to be encountered including controlled filling are given below:

- Stiff or loose to medium dense natural soils: 100 kPa
- Controlled Filling: 150 kPa
- Very stiff or medium dense natural soils: 150 kPa
- Extremely low and very low strength bedrock: 500 kPa
- Low strength bedrock: 1000 kPa

6.3 Site Preparation and Earthworks

6.3.1 Stripping

Site preparation for the construction of roadways and structures should include the removal of vegetation, topsoils, silty sandy soils, existing filling and other deleterious materials from the proposed building areas. Deep excavations (such as in gullies) could occur should localised deeper topsoils or unsuitable materials/filling be encountered, if inclement weather precedes construction or if the contractor adopts inappropriate stripping methods.

It is expected that the site is underlain at least in parts by silty sands/sandy silts (beneath the topsoils). This material is usually difficult to handle and compact and would require extremely careful moisture control. It is recommended that allowance be made for at least partial stripping of this material (say 0.3 m following topsoil stripping), with inspection undertaken by a suitably qualified geotechnical engineer to assess the depth of removal. Where possible (ie: in deep fill areas) this material could be designated to remain insitu, however if considered unsuitable would be required to be removed. Also, if stripping of the silty material is needed, it be limited to 0.4 m only as it is unlikely to improve with depth. The excavated material should be replaced with a granular bridging layer.

Depending on prior weather conditions it may also be necessary to use a geofabric separation layer.

6.3.2 Excavation Conditions

Whilst no subsurface investigation has been undertaken as part of this assessment, based on Douglas Partners involvement on nearby projects and from the site inspections it is expected that the subsurface profile will comprise a variable soil profile underlain by bedrock which in parts may be of very high to extremely high strength.

The site soils and weathered bedrock up to low strength could be expected to be removed using conventional large earthmoving plant. The presence of outcropping rock or boulders at the surface may preclude effective use of scrapers in some areas.

Excavation of the bedrock will largely be dependent on the degree of fracturing/jointing and the strike and dip of bedding within the rock relative to the excavation. Depending on excavation depths, heavy ripping or heavy rock hammering may be required but would have low production rates; blasting would be recommended to further fracture the bedrock to expedite ripping activities.

The extent of groundwater inflow would be dependent on prior weather conditions. Given the extent of gully lines and relatively flat topography over some parts of the site, groundwater seepages should be anticipated, which would increase following rainfall.

6.3.3 Filling Placement

In areas that require filling, the stripped around surfaces must be test rolled in the presence of a geotechnical engineer. Any areas exhibiting significant deflections under test rolling must be appropriately treated by over-excavation and replacement with suitable non-reactive filling. All filling material must be placed in horizontal layers of maximum 250 mm loose thickness. The material must have a moisture content within the range of ±2% of modified optimum at the time of placement.

All permanent fill batters must be constructed no steeper than 1:3 (vertical:horizontal), appropriately protected against erosion with toe and spoon drains constructed as a means of controlling surface flows on the batters and vegetation of the batter.

6.3.4 Filling Compaction

All filling placed within construction platforms must be compacted to a minimum 90% modified maximum dry density, except for the upper 1.0 m within pavement areas, which must be compacted to a minimum of 95% modified maximum dry density.

To validate future site classifications, field inspections and in-situ testing of future earthworks must be undertaken on any controlled filling placed in residential blocks in order to satisfy the requirements of a Level 1 inspection and testing service as defined in AS 3798 – 2007 (Ref 7).

6.3.5 Existing Farm Dams

It is understood that the several farm dams located onsite may be required to be filled to facilitate development. The general procedures outlined above should be adopted for the backfilling of these dams. Prior to bulk earthworks, the dams will require draining, removal of the embankment and desilting wet sediment from the base of the reservoir.

6.4 Drainage

Parts of the site have poor natural subsurface drainage. Infiltrated rainwater can become contained in the upper semi-pervious silty/sandy stratum and deeper sandy/gravelly layers. Seepage water may also enter fractures in the bedrock at locations where the bedrock outcrops or is at shallow depth. Seepage water in the subsurface profile may rise to the ground surface further downslope as springs.

In order to reduce the downslope seepage flow volume into residential areas, it is recommended that:

- An open unlined, contour drain be constructed along the upslope boundary of the estate extending to at least 0.5 m depth below the bedrock surface.
- Floodways be constructed along natural drainage lines;
- Deep subsurface gravel drains to installed along the invert of major gullies to be infilled and through any spring areas;
- Subsurface drains be installed at both sides of roads constructed in cut and/or at about natural grade. Some sections of road subgrades may need to be provided with cross-drains or a drainage blanket to control upward seepages.

6.5 House Site Maintenance

The developed blocks should be maintained in accordance with the CSIRO publication "Guide to Home Owners on Foundation Maintenance and Footing Performance", a copy of which is included in Appendix E. Whilst it must be accepted that minor cracking in most structures is inevitable, the guide describes suggested site maintenance practices aimed at minimising foundation movement to keep cracking within acceptable limits. Surface drainage should be installed and maintained at the site. All collected stormwater, groundwater and roof runoff should be discharged into the stormwater disposal system.

6.6 Pavements

Whilst subsurface investigations and design of pavements have yet to be undertaken, based on the results of the site inspection and previous experience in the nearby area, Table 4 gives indicative design CBR values for the various likely subgrade conditions.

Table 4 – Design CBR Values

Subgrade Material	Design CBR (%)
Clay (high plasticity)	1.0 – 2.0
Sandy/Gravelly Soils	3.0 – 4.0
Recompacted (Igneous) Weathered Rock	5.0 – 7.0
Insitu (Igneous) Weathered Rock	7.0 – 10.0

There may be construction advantages in undertaking subgrade replacement in those areas where any high plasticity clay subgrades occur. Detailed investigations will be required following finalisation of subdivision layout to confirm and delineate, if possible the variation in subgrade conditions.

Surface and subsurface drainage must be installed and maintained to protect the pavement and subgrade. The subsurface drains should extend a minimum of 0.5 m depth below the subgrade level.

6.7 Salinity

No visual signs of salinity were observed during the site inspection. It is recommended as part of further investigative studies that samples be collected of site soils for laboratory testing of electrical conductivity and pH values to enable further comment to be made on salinity.

6.8 Development Constraints

The assessment has identified a number of constraints on the development, which are:

- Potential for waterlogging in several areas;
- Potential for erosion in areas once vegetation cover is removed;
- Areas of moderate and high risk of damage to property with respect to slope instability;
- Uncontrolled filling around existing dams and some gully lines.
- Outcropping & shallow very high strength bedrock

Waterlogging: There is evidence of previous wet, soft and/or boggy conditions within several areas identified as potential for waterlogging. These areas are characterised by slightly greener grass and contain grass species which from Douglas Partners experience indicates previous or current presence of elevated soil/ground water levels. Drawing 9 illustrates areas which possibly could be of risk of waterlogging.

Erosion: Where the previous vegetation cover has been removed, which is mostly in gully lines, evidence of erosion ranging from slight to severe was observed.

Stability: Several areas (refer Drawings 6 – 8) have been assessed as having a potential moderate to high risk of damage to property.

Uncontrolled Filling: Removal of uncontrolled fill which was placed as stockpiles or part of dam construction and gully line modification works can be included as part of the site regrading or site clean-up during construction of the development and would only pose a minor constraint to development.

High Strength Bedrock: The presence of outcrops and shallow very high strength bedrock would prove difficult to excavate should design levels require cutting.

After the above constraints are addressed, the site will be considered suitable for the proposed development.

6.9 Remedial Measures/Site Controls

The main activities or methods to enable effective development of the site, from a geotechnical perspective, would be:

- planning/layout of development areas,
- extensive drainage measures,
- erosion management,
- timing of works,
- development restrictions from a slope instability perspective;
- minimising cut-fill on hillside.

6.9.1 Planning/Layout of Development

Gully lines and possibly low lying areas should be avoided for standard residential construction without engineering modification as these areas would require extensive drainage works and/or bulk earthworks. Roads should be positioned over the top of gully lines to enable the construction of subsurface drainage lines. If development of the low lying areas is being considered, controlled filling would be required to raise surface levels to assist in drainage design. Should residential areas be proposed over drainage areas, Class P site classifications would be warranted with special advice required on foundation design and construction as not to interfere with the drainage measures.

6.9.2 Drainage Measures

Engineered drainage both to divert overland flow and intercept subsurface flow combined with bulk earthworks to raise surface levels and or contour the surface level to improve drainage will be required if permanent structures are to be constructed in gully and/or low lying areas.

A network of drainage lines would be required across the site to intercept and provide a controlled transportation pathway for groundwater flows. Main drainage lines would be located at the base of gullies and within the low lying areas with interceptor drainage lines constructed as and where required across the site feeding into the main drainage lines. The drainage lines could either be subsurface or surface (floodway) type structures depending on surface levels.

6.9.3 Erosion Management

One of the existing limitations to development of the site is considered to be areas of gully erosion. Soil and water management is an integral part of the development process and should adopt a preventative rather than a reactive approach to the site limitations, such that the work can proceed without undue pollution of receiving streams.

Once consent is given, a detailed soil and water management plan (SWMP) will be required and should be incorporated into the engineering design of the development methods for:

- minimising water pollution due to erosion of soils or the development of saline conditions;
- reducing or managing salinity to provide acceptable conditions for building and revegetation works;
- minimisation of soil erosion during and after construction;
- maximising the re-use of materials on site.

6.9.4 Timing of Works

Timing of the site works could also be a critical aspect that will require careful consideration. Bulk earthworks activities is suggested to be undertaken in the warmer months of the year and not the winter months when ground moisture is higher due to the negative evapotranspiration effect experienced in winter. If moist soils are encountered and require drying to enable reuse in controlled filling areas, the warmer months would allow more expedited processing negating the potential for several weeks of drying time expected during winter.

6.9.5 Development Restrictions

Development within areas of medium risk of instability is technically feasible though would be required to be undertaken with geotechnical guidance. Site specific and development specific geotechnical investigation and advice would be required for individual structures.

At this stage without subsurface investigations, development within the high risk areas are not recommended. A comprehensive site stability assessment will be required if development in those areas are proposed.

6.9.6 Cut & Fill Minimisation on Hillside

It is standard hillside development practice to minimise the depths of cutting and filling. All proposed modification of the ground slop in hillside areas must be subject to geotechnical review and comment.

6.10 Subsurface Investigations

Further investigation will be required as conceptual design/planning progresses together with additional work during the construction phase. Specific investigation would include but not necessarily be limited to:

- Preliminary geotechnical investigations across the areas of gently to moderately sloping land and the areas of moderately to steeply sloping land to determine the subsurface profiles and the properties of the site soils including dispersion/erosion properties and/or acidity/aggressiveness,
- Detailed geotechnical investigation and assessment of areas of steeply sloping land should development be desired in these areas, and

- Detailed geotechnical investigation on a stage by stage basis as development proceeds to determine excavation conditions, road subgrade CBR values and confirm site classifications for each block.

6.11 Summary

The site assessment undertaken as described above has indicated that the majority of the site is suitable from a geotechnical perspective for residential development. Comments have been given on the various geotechnical aspects of the proposed development and the identified development constraints and subsequent remedial and control measures.

Conceptual comments on design and construction aspects are also given in the report. Further testing and assessment will be required as the design of the subdivision proceeds and as such, this report must be considered as being preliminary in nature.

7. References

1. Geology of Brindabella 1:100 000 Geological Series Sheet 8627, Bureau of Mineral Resources, (1979).

2. Soil Landscape of Brindabella 1:100 000 Soil Landscape Series Sheet 8627, Soil conservation Service of NSW, (1984).

3. Soil Landscape of Canberra 1:100 000 Soil Landscape Series Sheet 8727, NSW Dept of Land and Water Conservation, (2000).

4. Bureau of Mineral Resources, Geology and Geophysics (1984): 'Hydrogeology of the Australian Capital Territory and Environs' 1:100,000 scale map.

5. Australian Standard AS 2870 – 2011 Residential Slabs and Footings.

6. AGS – Landslide Risk Management Concepts and Guidelines, Australian Geomechanics Society, Sub-committee on Landslide Risk Management, 2007.

7. Australian Standard AS 3798 – 2007 Guidelines on Earthworks for Commercial and Residential Developments.

8. Limitations

Douglas Partners (DP) has prepared this report for the proposed subdivision at West Belconnen as described within this report in accordance with DP's proposal dated 3 September 2013. This report is provided for the exclusive use of The Riverview Group for this project only and for the purposes as described in the report. It should not be used by or relied upon for other projects or purposes on the same or other site or by a third party. Any party so relying upon this report beyond its exclusive use and purpose as stated above, and without the express written consent of DP, does so entirely at its own risk and without recourse to DP for any loss or damage. In preparing this report DP has necessarily relied upon information provided by the client and/or their agents.

The results provided in the report are indicative of the sub-surface conditions only at the specific sampling or testing locations, and then only to the depths investigated and at the time the work was carried out. Sub-surface conditions can change abruptly due to variable geological processes and also as a result of anthropogenic influences. Such changes may occur after DP's field testing has been completed.

DP's advice is based upon the conditions encountered during this investigation. The accuracy of the advice provided by DP in this report may be limited by undetected variations in ground conditions between sampling locations. The advice may also be limited by budget constraints imposed by others or by site accessibility.

This report must be read in conjunction with all of the attached notes and should be kept in its entirety without separation of individual pages or sections. DP cannot be held responsible for interpretations or conclusions made by others unless they are supported by an expressed statement, interpretation, outcome or conclusion given in this report.

This report, or sections from this report, should not be used as part of a specification for a project, without review and agreement by DP. This is because this report has been written as advice and opinion rather than instructions for construction.

The contents of this report do not constitute formal design components such as are required, by the Health and Safety Legislation and Regulations, to be included in a Safety Report specifying the hazards likely to be encountered during construction and the controls required to mitigate risk. This design process requires risk assessment to be undertaken, with such assessment being dependent upon factors relating to likelihood of occurrence and consequences of damage to property and to life. This, in turn, requires project data and analysis presently beyond the knowledge and project role respectively of DP. DP may be able, however, to assist the client in carrying out a risk assessment of potential hazards contained in the Comments section of this report, as an extension to the current scope of works, if so requested, and provided that suitable additional information is made available to DP. Any such risk assessment would, however, be necessarily restricted to the geotechnical and groundwater components set out in this report and to their application by the project designers to project design, construction, maintenance and demolition.

Douglas Partners Pty Ltd

Appendix A

About this Report

About this Report

Introduction

These notes have been provided to amplify DP's report in regard to classification methods, field procedures and the comments section. Not all are necessarily relevant to all reports.

DP's reports are based on information gained from limited subsurface excavations and sampling, supplemented by knowledge of local geology and experience. For this reason, they must be regarded as interpretive rather than factual documents, limited to some extent by the scope of information on which they rely.

Copyright

Borehole and Test Pit Logs

The borehole and test pit logs presented in this report are an engineering and/or geological interpretation of the subsurface conditions, and their reliability will depend to some extent on frequency of sampling and the method of drilling or excavation. Ideally, continuous undisturbed sampling or core drilling will provide the most reliable assessment, but this is not always practicable or possible to justify on economic grounds. In any case the boreholes and test pits represent only a very small sample of the total subsurface profile.

Interpretation of the information and its application to design and construction should therefore take into account the spacing of boreholes or pits, the frequency of sampling, and the possibility of other than 'straight line' variations between the test locations.

Groundwater

Where groundwater levels are measured in boreholes there are several potential problems, namely:

- In low permeability soils groundwater may enter the hole very slowly or perhaps not at all during the time the hole is left open;
- A localised, perched water table may lead to an erroneous indication of the true water table;
- Water table levels will vary from time to time with seasons or recent weather changes. They may not be the same at the time of construction as are indicated in the report; and
- The use of water or mud as a drilling fluid will mask any groundwater inflow. Water has to be blown out of the hole and drilling mud must first be washed out of the hole if water measurements are to be made.

More reliable measurements can be made by installing standpipes which are read at intervals over several days, or perhaps weeks for low permeability soils. Piezometers, sealed in a particular stratum, may be advisable in low permeability soils or where there may be interference from a perched water table.

Reports

The report has been prepared by qualified personnel, is based on the information obtained from field and laboratory testing, and has been undertaken to current engineering standards of interpretation and analysis. Where the report has been prepared for a specific design proposal, the information and interpretation may not be relevant if the design proposal is changed. If this happens, DP will be pleased to review the report and the sufficiency of the investigation work.

Every care is taken with the report as it relates to interpretation of subsurface conditions, discussion of geotechnical and environmental aspects, and recommendations or suggestions for design and construction. However, DP cannot always anticipate or assume responsibility for:

- Unexpected variations in ground conditions. The potential for this will depend partly on borehole or pit spacing and sampling frequency;
- Changes in policy or interpretations of policy by statutory authorities; or
- The actions of contractors responding to commercial pressures.

If these occur, DP will be pleased to assist with investigations or advice to resolve the matter.

About this Report

Site Anomalies

In the event that conditions encountered on site during construction appear to vary from those which were expected from the information contained in the report, DP requests that it be immediately notified. Most problems are much more readily resolved when conditions are exposed rather than at some later stage, well after the event.

Information for Contractual Purposes

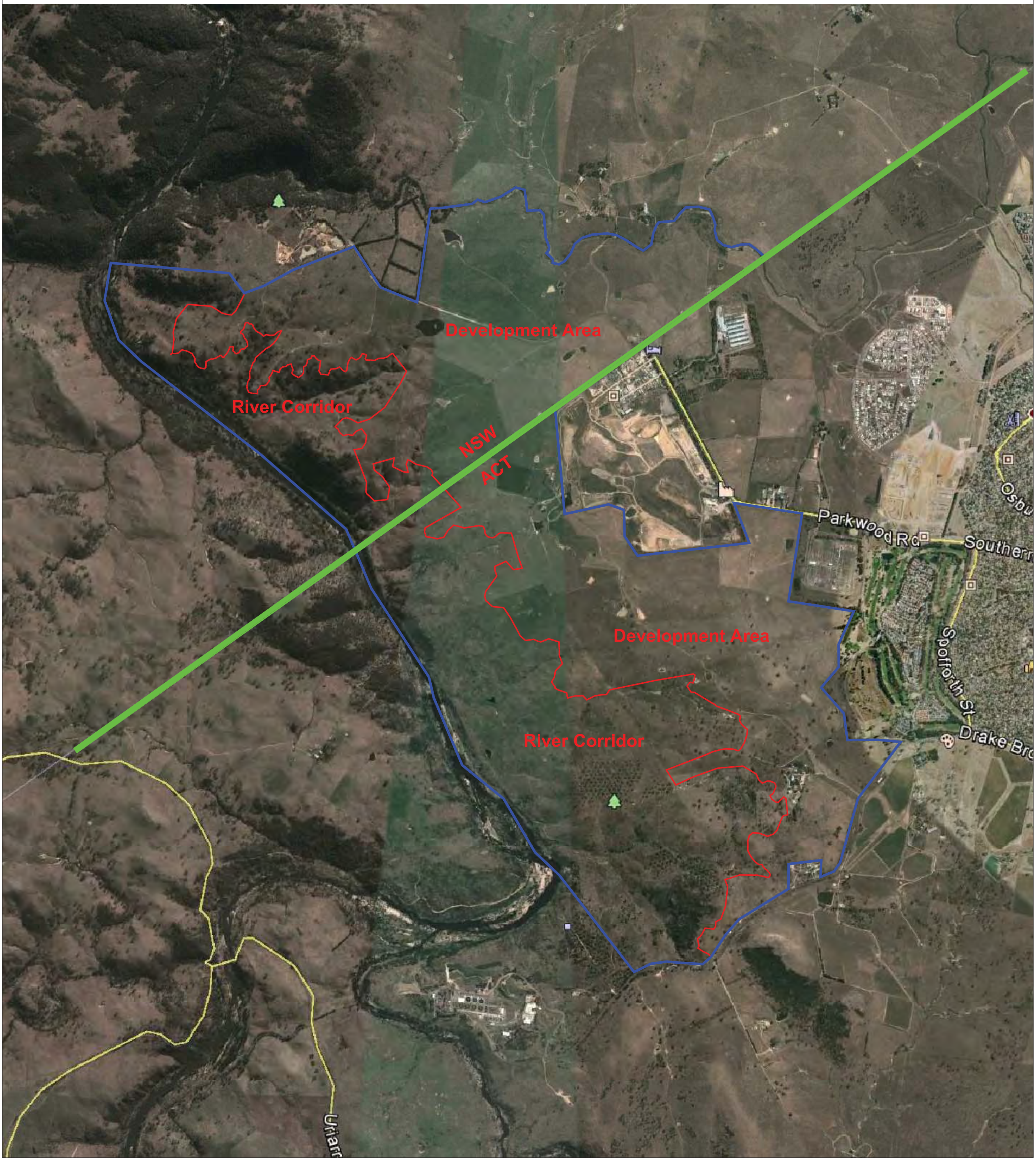
Where information obtained from this report is provided for tendering purposes, it is recommended that all information, including the written report and discussion, be made available. In circumstances where the discussion or comments section is not relevant to the contractual situation, it may be appropriate to prepare a specially edited document. DP would be pleased to assist in this regard and/or to make additional report copies available for contract purposes at a nominal charge.

Site Inspection

The company will always be pleased to provide engineering inspection services for geotechnical and environmental aspects of work to which this report is related. This could range from a site visit to confirm that conditions exposed are as expected, to full time engineering presence on site.

Appendix B

Drawings (Nos 1 – 9)



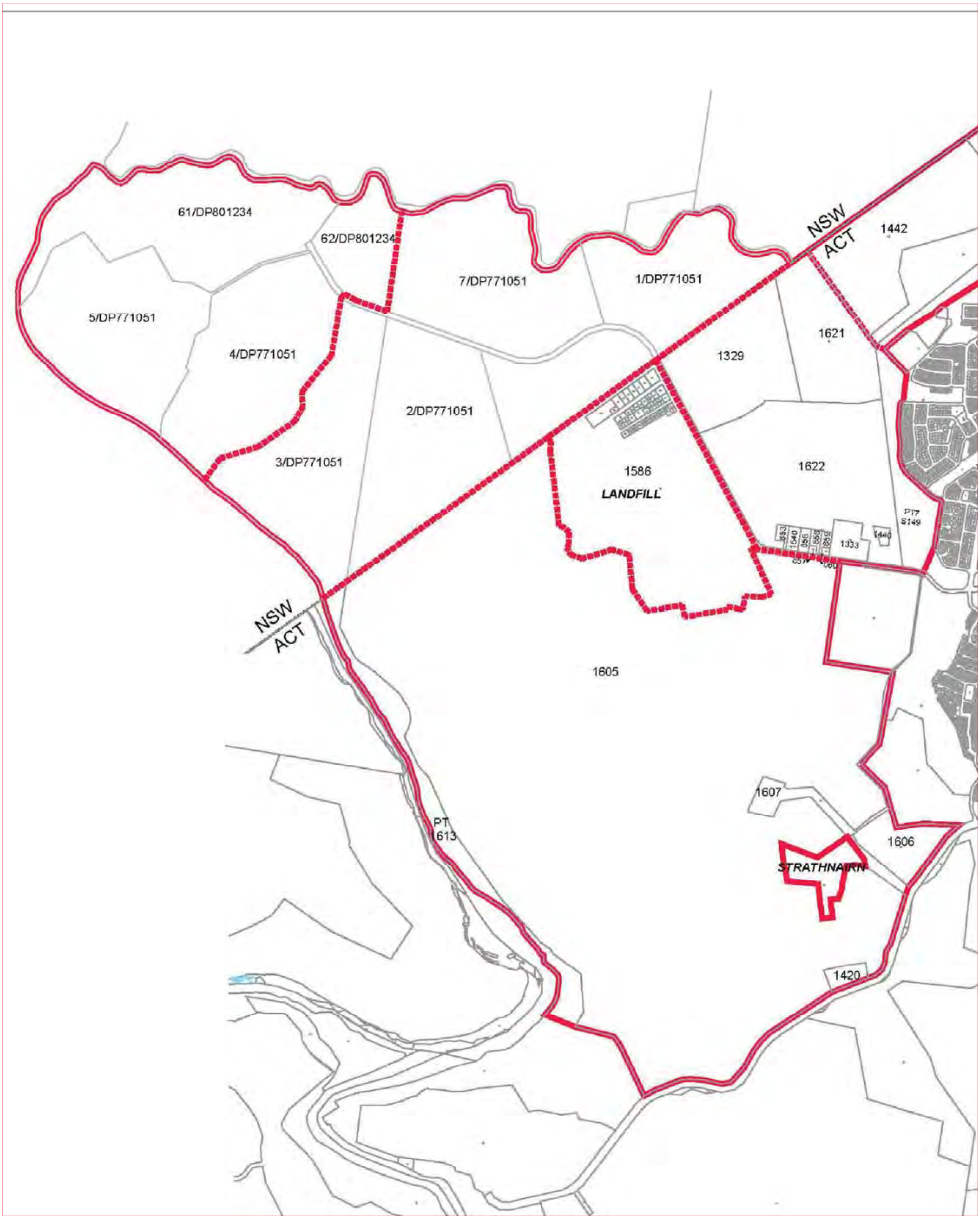
Douglas Partners
Geotechnics / Environment / Groundwater

TITLE: **Site Boundary**
Proposed Subdivision
Blocks 1605 - 1607, West Belconnen, ACT

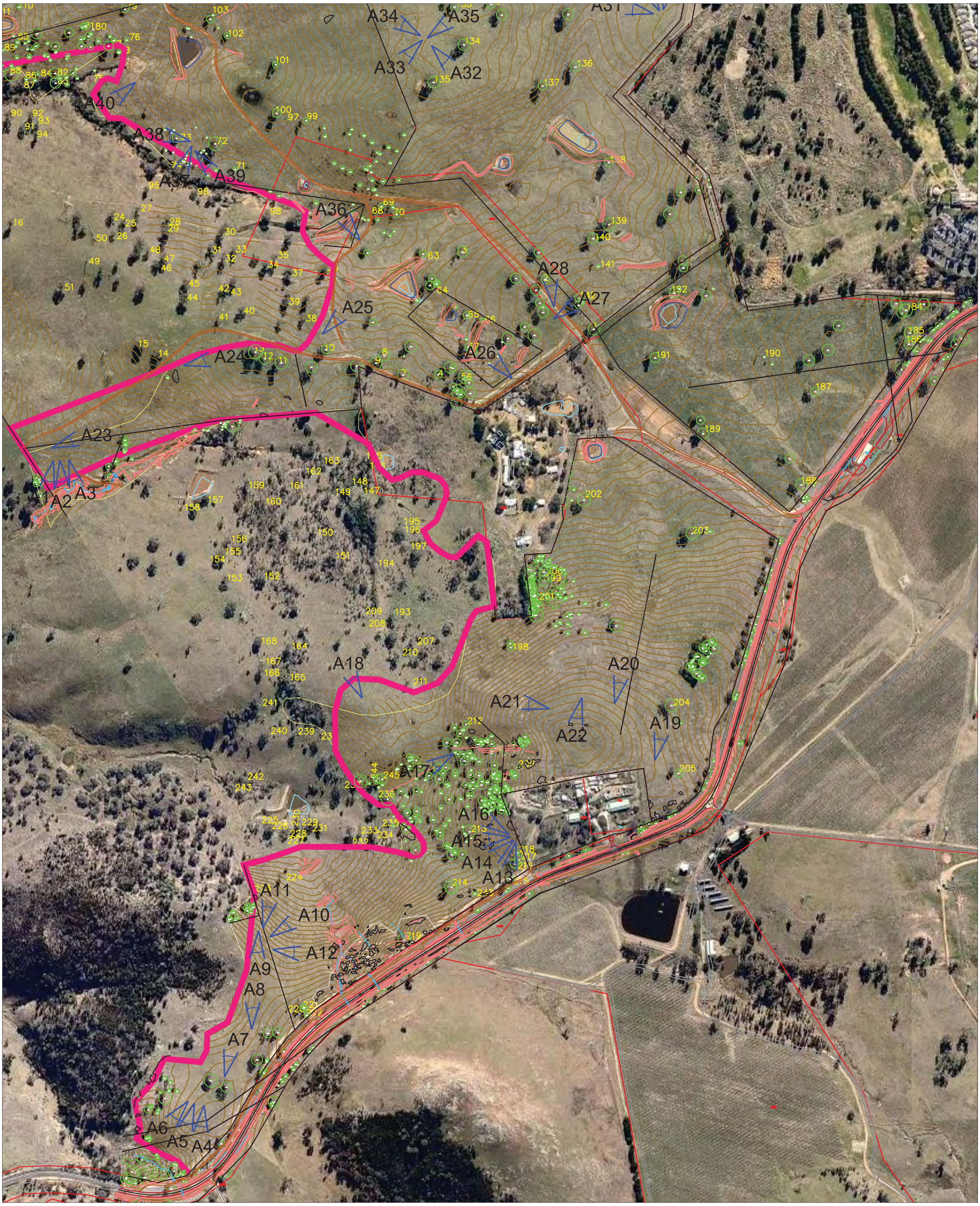
MAG ISG MGA N

OFFICE: Canberra
DRAWN BY: MJJ
DATE: 5.11.2013

CLIENT: The Riverview Group	PROJECT No: 77356	DRAWING No: 1	REVISION: 0	SCALE: NTS



Douglas Partners Geotechnics / Environment / Groundwater	TITLE: **Structure Plan** **Proposed Subdivision** **Blocks 1605 - 1607, West Belconnen, ACT**		N MAG ISG MGA	OFFICE: Canberra DRAWN BY: MJJ DATE: 5.11.2013
CLIENT: The Riverview Group	PROJECT No: 77356	DRAWING No: 2	REVISION: 0	SCALE: NTS



LEGEND

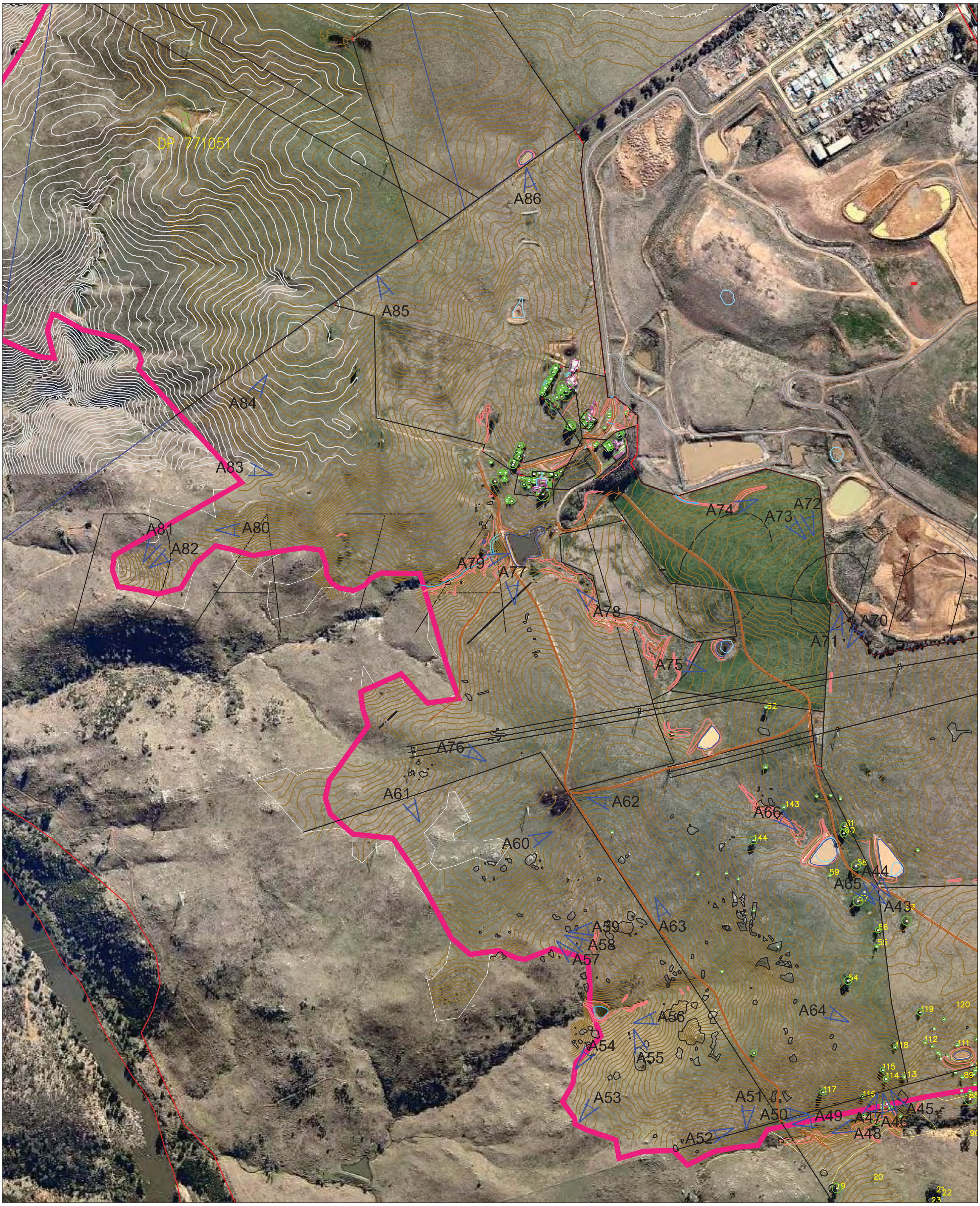
A12 Site Photograph Number and Direction

Douglas Partners — Geotechnics / Environment / Groundwater	TITLE: **Location of Site Photographs** **Proposed Subdivision** **Blocks 1605 - 1607, West Belconnen, ACT**		OFFICE: Canberra DRAWN BY: MJJ DATE: 5.11.2013
CLIENT: The Riverview Group	PROJECT No: 77356	DRAWING No: 3	REVISION: 0	SCALE: NTS

LEGEND

A12 Site Photograph Number and Direction

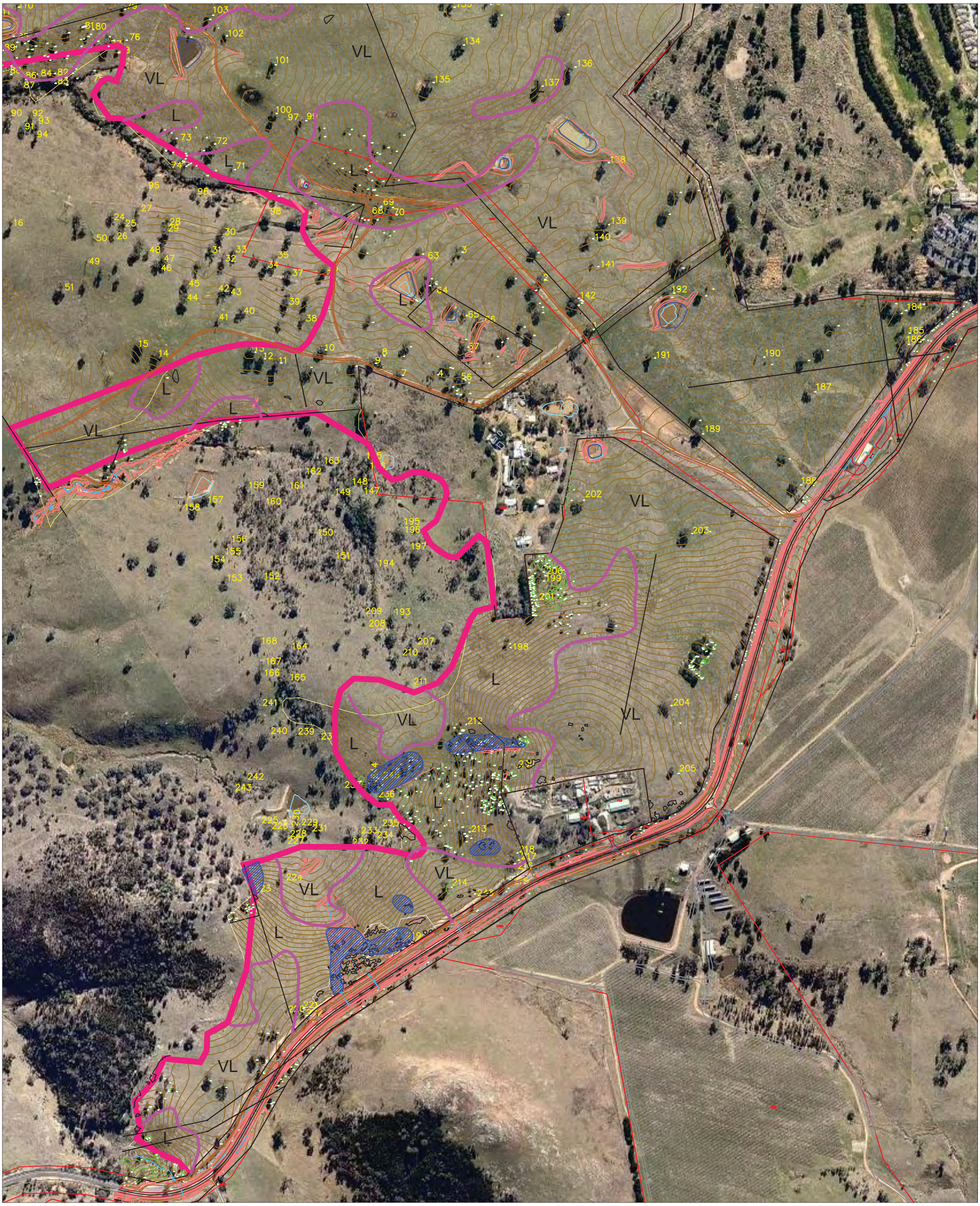
Douglas Partners Geotechnics / Environment / Groundwater	TITLE: **Location of Site Photographs** **Proposed Subdivision** **Blocks 1605 - 1607, West Belconnen, ACT**	OFFICE: Canberra DRAWN BY: MJJ DATE: 5.11.2013
CLIENT: The Riverview Group	PROJECT No: 77356 DRAWING No: 4 REVISION: 0	SCALE: NTS



LEGEND

A12 Site Photograph Number and Direction

Douglas Partners Geotechnics / Environment / Groundwater	TITLE: **Location of Site Photographs** **Proposed Subdivision** **Blocks 1605 - 1607, West Belconnen, ACT**		OFFICE: Canberra DRAWN BY: MJJ DATE: 5.11.2013
CLIENT: The Riverview Group	PROJECT No: 77356	DRAWING No: 5	REVISION: 0
			SCALE: NTS



LEGEND

VL Very Low Instability Risk

L Low Instability Risk

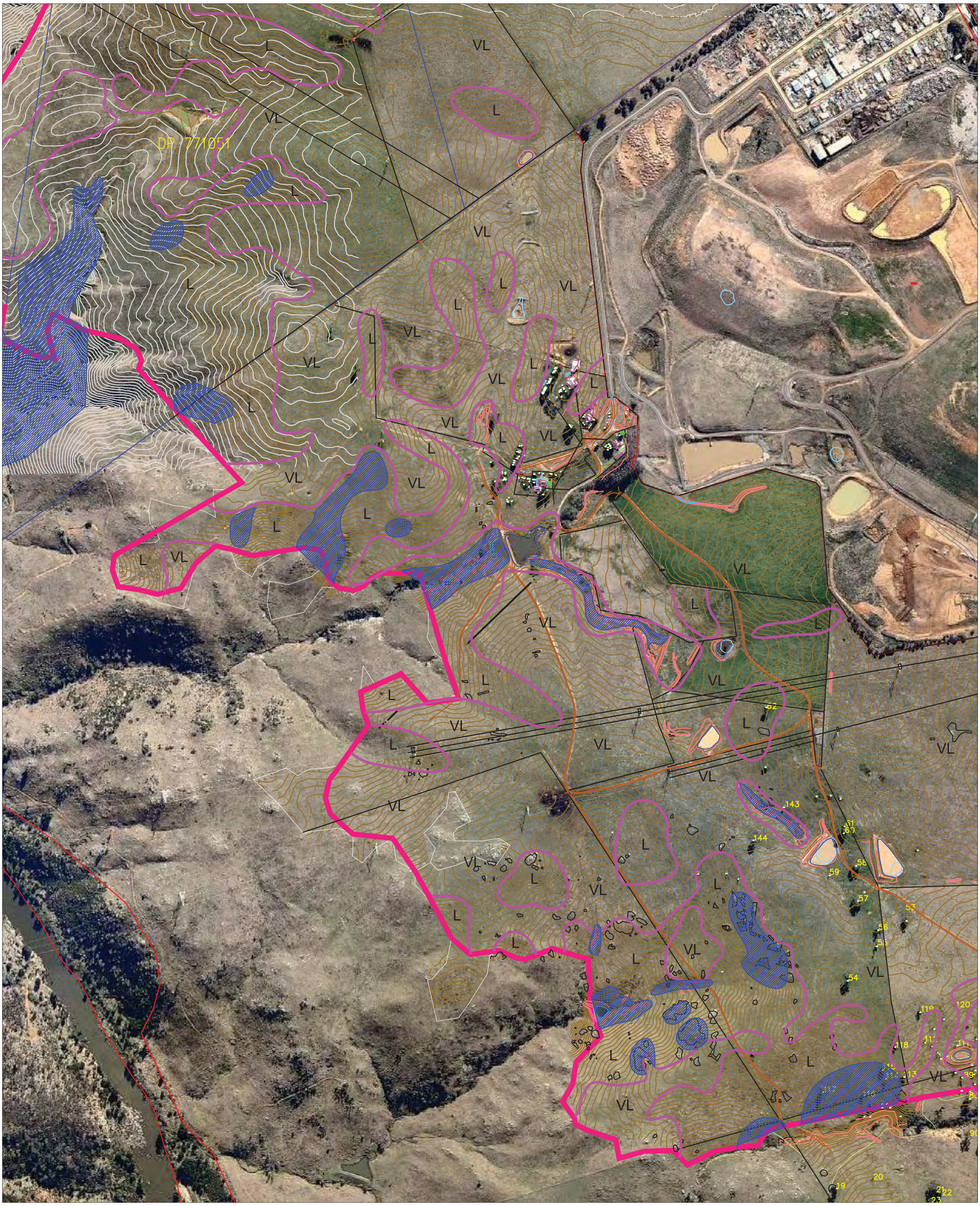
Medium & High Instability Risk - Undifferentiated

Douglas Partners Geotechnics / Environment / Groundwater	TITLE: Approximate Locations of Potential Instability Risk Proposed Subdivision ACT Blocks 1605 - 1607, West Belconnen	OFFICE: Canberra DRAWN BY: MJJ DATE: 5.11.2013
CLIENT: The Riverview Group	PROJECT No: 77356 · DRAWING No: 6 · REVISION: 0	SCALE: NTS

LEGEND

VL	Very Low Instability Risk
L	Low Instability Risk
	Medium & High Instability Risk - Undifferentiated

Douglas Partners Geotechnics / Environment / Groundwater	TITLE: **Approximate Locations of Potential Instability Risk** **Proposed Subdivision** **ACT Blocks 1605 - 1607, West Belconnen**			OFFICE: Canberra / DRAWN BY: MJJ / DATE: 5.11.2013
CLIENT: The Riverview Group	PROJECT No: 77356	DRAWING No: 7	REVISION: 0	SCALE: NTS



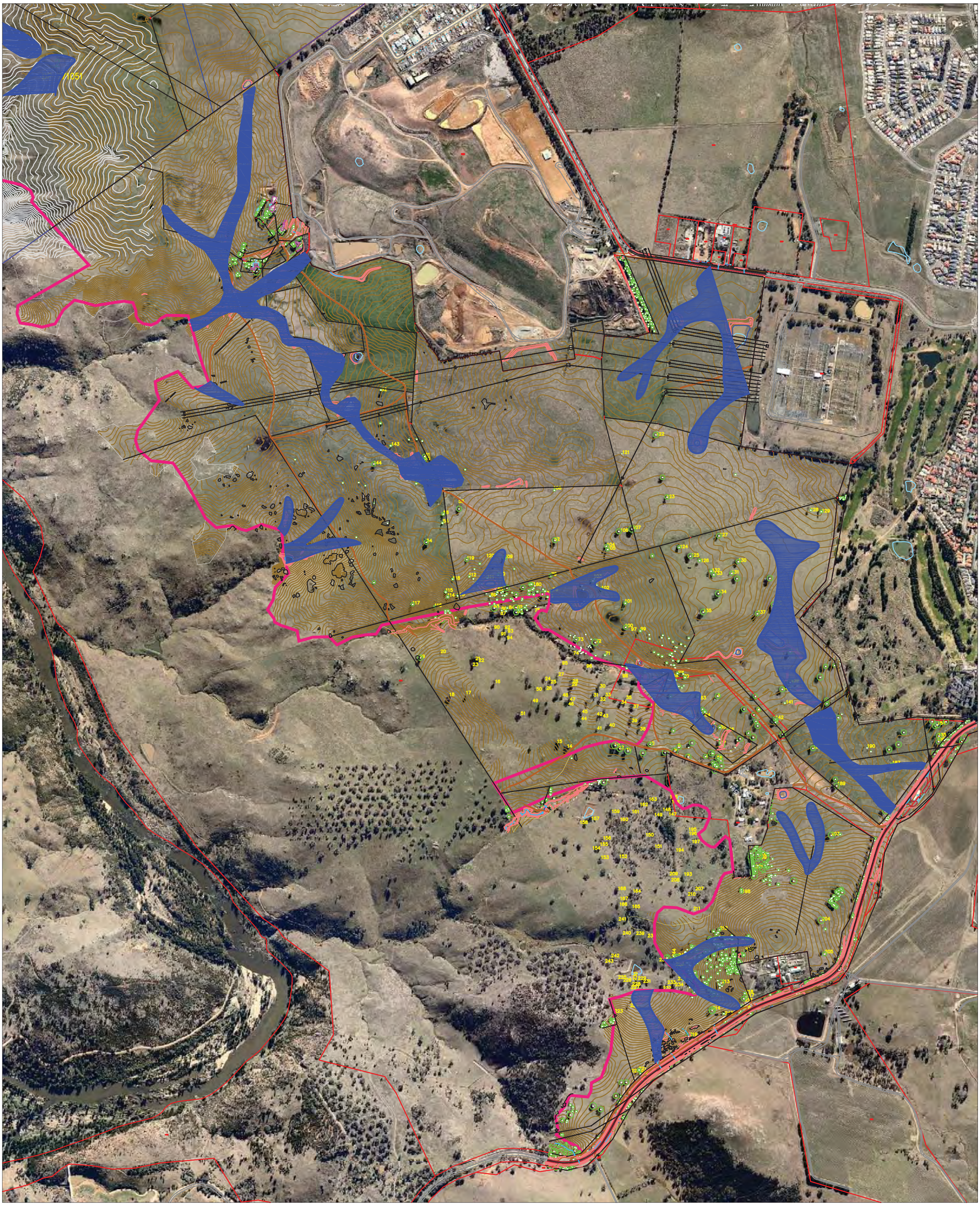
LEGEND

VL Very Low Instability Risk

L Low Instability Risk

Medium & High Instability Risk - Undifferentiated

Douglas Partners Geotechnics / Environment / Groundwater	TITLE: Approximate Locations of Potential Instability Risk Proposed Subdivision ACT Blocks 1605 - 1607, West Belconnen		OFFICE: Canberra DRAWN BY: MJJ DATE: 5.11.2013
CLIENT: The Riverview Group	PROJECT No: 77356	DRAWING No: 8	REVISION: 0
			SCALE: NTS



LEGEND

Areas of Potential Waterlogging Risk

Douglas Partners — Geotechnics / Environment / Groundwater	TITLE: **Areas of Potential Waterlogging Risk** **Proposed Subdivision** **Blocks 1605 - 1607, West Belconnen, ACT**			OFFICE: Canberra DRAWN BY: MJJ DATE: 5.11.2013
CLIENT: The Riverview Group	PROJECT No: 77356	DRAWING No: 9	REVISION: 0	SCALE: NTS

Appendix C

Site Photographs (Photo Plates 1 – 43)

Photo A3 – Refer Drawing 3 for locality and direction

Photo A4 – Refer Drawing 3 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs** **Urban Capability Study** **West Belconnen, ACT**	PROJECT: 77356.00 PLATE No: A2 REV: 0
	CLIENT: The Riverview Group	DATE: 4/11/13

Photo A1 – Refer Drawing 3 for locality and direction

Photo A2 – Erosion in creek line. Refer Drawing 3 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs**	PROJECT:	77356.00
	Urban Capability Study	PLATE No:	A1
	West Belconnen, ACT	REV:	0
	CLIENT: The Riverview Group	DATE:	4/11/13

Photo A5 – Refer Drawing 3 for locality and direction

Photo A6 – Refer Drawing 3 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs** **Urban Capability Study** **West Belconnen, ACT**	PROJECT: 77356.00 PLATE No: A3 REV: 0
	CLIENT: The Riverview Group	DATE: 4/11/13

Photo A7 – Refer Drawing 3 for locality and direction

Photo A8 – Refer Drawing 3 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs**	PROJECT:	77356.00
	Urban Capability Study	PLATE No:	A4
	West Belconnen, ACT	REV:	0
	CLIENT: The Riverview Group	DATE:	4/11/13

Photo A9 – Refer Drawing 3 for locality and direction

Photo A10 – Refer Drawing 3 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs**	PROJECT:	77356.00
	Urban Capability Study	PLATE No:	A5
	West Belconnen, ACT	REV:	0
	CLIENT: The Riverview Group	DATE:	4/11/13

Photo A11 – Refer Drawing 3 for locality and direction

Photo A12 – Refer Drawing 3 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs**	PROJECT:	77356.00
	Urban Capability Study	PLATE No:	A6
	West Belconnen, ACT	REV:	0
	CLIENT: The Riverview Group	DATE:	4/11/13

Photo A13 – Refer Drawing 3 for locality and direction

Photo A14 – Refer Drawing 3 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs**	PROJECT:	77356.00
	Urban Capability Study	PLATE No:	A7
	West Belconnen, ACT	REV:	0
	CLIENT: The Riverview Group	DATE:	4/11/13

Photo A15 – Refer Drawing 3 for locality and direction

Photo A16 – Refer Drawing 3 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs**	PROJECT:	77356.00
	Urban Capability Study	PLATE No:	A8
	West Belconnen, ACT	REV:	0
	CLIENT: The Riverview Group	DATE:	4/11/13

Photo A17 – Refer Drawing 3 for locality and direction

Photo A18 – Refer Drawing 3 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs** **Urban Capability Study** **West Belconnen, ACT**	PROJECT:	77356.00
		PLATE No:	A9
		REV:	0
	CLIENT: The Riverview Group	DATE:	4/11/13

Photo A19 – Refer Drawing 3 for locality and direction

Photo A20– Refer Drawing 3 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs** **Urban Capability Study** **West Belconnen, ACT**	PROJECT: 77356.00 PLATE No: A10 REV: 0
	CLIENT: The Riverview Group	DATE: 4/11/13

Photo A21 – Refer Drawing 3 for locality and direction

Photo A22 – Rock outcropping. Refer Drawing 3 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs**	PROJECT:	77356.00
	Urban Capability Study	PLATE No:	A11
	West Belconnen, ACT	REV:	0
	CLIENT: The Riverview Group	DATE:	4/11/13

Photo A23 – Refer Drawing 3 for locality and direction

Photo A24– Refer Drawing 3 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs**	PROJECT:	77356.00
	Urban Capability Study	PLATE No:	A12
	West Belconnen, ACT	REV:	0
	CLIENT: The Riverview Group	DATE:	4/11/13

Photo A25 – Refer Drawing 3 for locality and direction

Photo A26– Refer Drawing 3 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs**	PROJECT:	77356.00
	Urban Capability Study	PLATE No:	A13
	West Belconnen, ACT	REV:	0
	CLIENT: The Riverview Group	DATE:	4/11/13

Photo A27 – Refer Drawing 3 for locality and direction

Photo A28– Refer Drawing 3 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs**	PROJECT:	77356.00
	Urban Capability Study	PLATE No:	A14
	West Belconnen, ACT	REV:	0
	CLIENT: The Riverview Group	DATE:	4/11/13

Photo A29 – Refer Drawing 4 for locality and direction

Photo A30– Refer Drawing 4 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs**	PROJECT:	77356.00
	Urban Capability Study	PLATE No:	A15
	West Belconnen, ACT	REV:	0
	CLIENT: The Riverview Group	DATE:	4/11/13

Photo A31 – Refer Drawing 4 for locality and direction

Photo A32– Refer Drawing 4 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs**	PROJECT:	77356.00
	Urban Capability Study	PLATE No:	A16
	West Belconnen, ACT	REV:	0
	CLIENT: The Riverview Group	DATE:	4/11/13

Photo A33 – Refer Drawing 4 for locality and direction

Photo A34– Refer Drawing 4 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs**	PROJECT:	77356.00
	Urban Capability Study	PLATE No:	A17
	West Belconnen, ACT	REV:	0
	CLIENT: The Riverview	DATE:	4/11/13

Photo A35 – Refer Drawing 4 for locality and direction

Photo A36– Refer Drawing 4 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs** **Urban Capability Study** **West Belconnen, ACT**	PROJECT: 77356.00 PLATE No: A18 REV: 0
	CLIENT: The Riverview	DATE: 4/11/13

Photo A37 – Placed cobbles and modification of creek line. Refer Drawing 4 for locality and direction

Photo A38– Placed cobbles and modification of creek line. Refer Drawing 4 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs**	PROJECT:	77356.00
	Urban Capability Study	PLATE No:	A19
	West Belconnen, ACT	REV:	0
	CLIENT: The Riverview Group	DATE:	4/11/13

Photo A39 – Refer Drawing 4 for locality and direction

Photo A40– Erosion in gully line. Refer Drawing 4 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	Site Photographs	PROJECT:	77356.00
	Urban Capability Study	PLATE No:	A20
	West Belconnen, ACT	REV:	0
	CLIENT: The Riverview Group	DATE:	4/11/13

Photo A41 – Refer Drawing 4 for locality and direction

Photo A42– Refer Drawing 4 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs**	PROJECT:	77356.00
	Urban Capability Study	PLATE No:	A21
	West Belconnen, ACT	REV:	0
	CLIENT: The Riverview Group	DATE:	4/11/13

Photo A43 – Refer Drawing 4 for locality and direction

Photo A44– Refer Drawing 4 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs** **Urban Capability Study** **West Belconnen, ACT**	PROJECT: 77356.00 PLATE No: A22 REV: 0
	CLIENT: The Riverview Group	DATE: 4/11/13

Photo A45 – Rock outcropping. Refer Drawing 4 for locality and direction

Photo A46– Refer Drawing 4 for locality and direction

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Geotechnics / Environment / Groundwater</td><td rowspan="3">Site Photographs
Urban Capability Study
West Belconnen, ACT</td><td>PROJECT:</td><td>77356.00</td></tr>
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<tr><td>REV:</td><td>0</td></tr>
<tr><td>CLIENT: The Riverview Group</td><td>DATE:</td><td>4/11/13</td></tr>
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Photo A47 – Rock outcropping. Refer Drawing 4 for locality and direction

Photo A48–Refer Drawing 4 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	Site Photographs Urban Capability Study West Belconnen, ACT	PROJECT:	77356.00
		PLATE No:	A24
		REV:	0
	CLIENT: The Riverview Group	DATE:	4/11/13

Photo A49 – Refer Drawing 4 for locality and direction

Photo A50– Refer Drawing 5 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs**	PROJECT:	77356.00
	Urban Capability Study	PLATE No:	A25
	West Belconnen, ACT	REV:	0
	CLIENT: The Riverview Group	DATE:	4/11/13

Photo A51 – Rock pillars. Refer Drawing 5 for locality and direction

Photo A52– Refer Drawing 5 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs**	PROJECT:	77356.00
	Urban Capability Study	PLATE No:	A26
	West Belconnen, ACT	REV:	0
	CLIENT: The Riverview Group	DATE:	4/11/13

Photo A53 – Refer Drawing 5 for locality and direction

Photo A54– Refer Drawing 5 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	Site Photographs	PROJECT:	77356.00
	Urban Capability Study	PLATE No:	A27
	West Belconnen, ACT	REV:	0
	CLIENT: The Riverview Group	DATE:	4/11/13

Photo A55 – Rock pillars. Refer Drawing 5 for locality and direction

Photo A56– Rock pillars. Refer Drawing 5 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	Site Photographs	PROJECT:	77356.00
	Urban Capability Study	PLATE No:	A28
	West Belconnen, ACT	REV:	0
	CLIENT: The Riverview Group	DATE:	4/11/13

Photo A57 – Refer Drawing 5 for locality and direction

Photo A58– Refer Drawing 5 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs**	PROJECT:	77356.00
	Urban Capability Study	PLATE No:	A29
	West Belconnen, ACT	REV:	0
	CLIENT: The Riverview Group	DATE:	4/11/13

Photo A59 – Rock pillars. Refer Drawing 5 for locality and direction

Photo A60– Refer Drawing 5 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs** **Urban Capability Study** **West Belconnen, ACT**	PROJECT:	77356.00
		PLATE No:	A30
		REV:	0
	CLIENT: The Riverview Group	DATE:	4/11/13

Photo A61 – Refer Drawing 5 for locality and direction

Photo A62– Refer Drawing 5 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs**	PROJECT:	77356.00
	Urban Capability Study	PLATE No:	A31
	West Belconnen, ACT	REV:	0
	CLIENT: The Riverview Group	DATE:	4/11/13

Photo A63 – Refer Drawing 5 for locality and direction

Photo A64– Refer Drawing 5 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	Site Photographs Urban Capability Study West Belconnen, ACT	PROJECT: 77356.00 PLATE No: A32 REV: 0
	CLIENT: The Riverview Group	DATE: 4/11/13

Photo A65 – Refer Drawing 5 for locality and direction

Photo A66– Erosion and rock outcropping in gully line. Refer Drawing 5 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs** **Urban Capability Study** **West Belconnen, ACT**	PROJECT: 77356.00 PLATE No: A33 REV: 0
	CLIENT: The Riverview Group	DATE: 4/11/13

Photo A67 – Refer Drawing 4 for locality and direction

Photo A68– Refer Drawing 4 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs**	PROJECT:	77356.00
	Urban Capability Study	PLATE No:	A34
	West Belconnen, ACT	REV:	0
	CLIENT: The Riverview Group	DATE:	4/11/13

Photo A69 – Refer Drawing 4 for locality and direction

Photo A70– Rock outcropping. Refer Drawing 5 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs**	PROJECT:	77356.00
	Urban Capability Study	PLATE No:	A35
	West Belconnen, ACT	REV:	0
	CLIENT: The Riverview	DATE:	4/11/13

Photo A71 – Refer Drawing 5 for locality and direction

Photo A72– Refer Drawing 5 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs**	PROJECT:	77356.00
	Urban Capability Study	PLATE No:	A36
	West Belconnen, ACT	REV:	0
	CLIENT: The Riverview Group	DATE:	4/11/13

Photo A73 – Refer Drawing 5 for locality and direction

Photo A74– Refer Drawing 5 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs**	PROJECT:	77356.00
	Urban Capability Study	PLATE No:	A37
	West Belconnen, ACT	REV:	0
	CLIENT: The Riverview Group	DATE:	4/11/13

Photo A75 – Refer Drawing 5 for locality and direction

Photo A76– Refer Drawing 5 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs** **Urban Capability Study** **West Belconnen, ACT**	PROJECT: 77356.00 PLATE No: A38 REV: 0
	CLIENT: The Riverview Group	DATE: 4/11/13

Photo A77 – Concrete pipes. Refer Drawing 5 for locality and direction

Photo A78– Erosion in gully line. Refer Drawing 5 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs**	PROJECT:	77356.00
	Urban Capability Study	PLATE No:	A39
	West Belconnen, ACT	REV:	0
	CLIENT: The Riverview Group	DATE:	4/11/13

Photo A79 – Refer Drawing 5 for locality and direction

Photo A80– Refer Drawing 5 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs**	PROJECT:	77356.00
	Urban Capability Study	PLATE No:	A40
	West Belconnen, ACT	REV:	0
	CLIENT: The Riverview Group	DATE:	4/11/13

Photo A81 – Refer Drawing 5 for locality and direction

Photo A82– Refer Drawing 5 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs**	PROJECT:	77356.00
	Urban Capability Study	PLATE No:	A41
	West Belconnen, ACT	REV:	0
	CLIENT: The Riverview Group	DATE:	4/11/13

Photo A83 – Refer Drawing 5 for locality and direction

Photo A84 – Refer Drawing 5 for locality and direction

Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs**	PROJECT:	77356.00
	Urban Capability Study	PLATE No:	A42
	West Belconnen, ACT	REV:	0
	CLIENT: The Riverview Group	DATE:	4/11/13

Photo A85 – Refer Drawing 5 for locality and direction

Photo A86 – Refer Drawing 5 for locality and direction

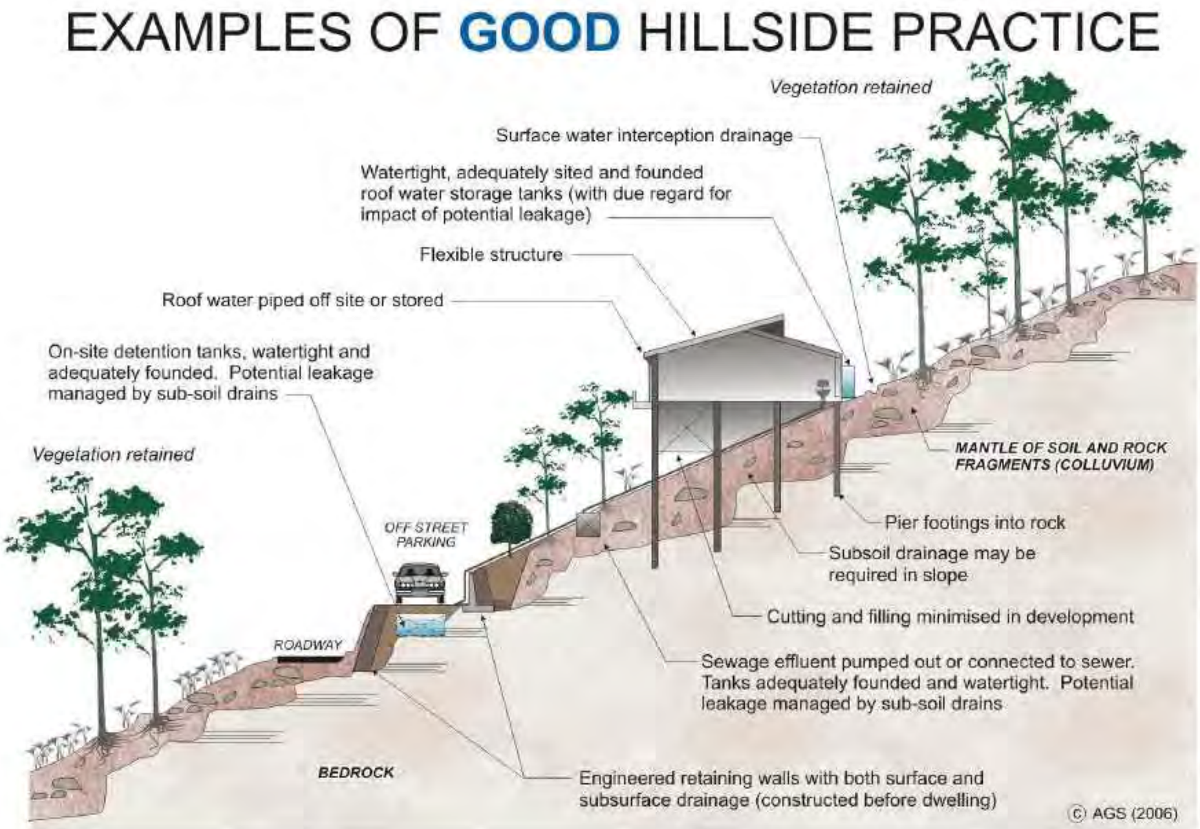
Douglas Partners Geotechnics / Environment / Groundwater	**Site Photographs**	PROJECT:	77356.00
	Urban Capability Study	PLATE No:	A43
	West Belconnen, ACT	REV:	0
	CLIENT: The Riverview Group	DATE:	4/11/13

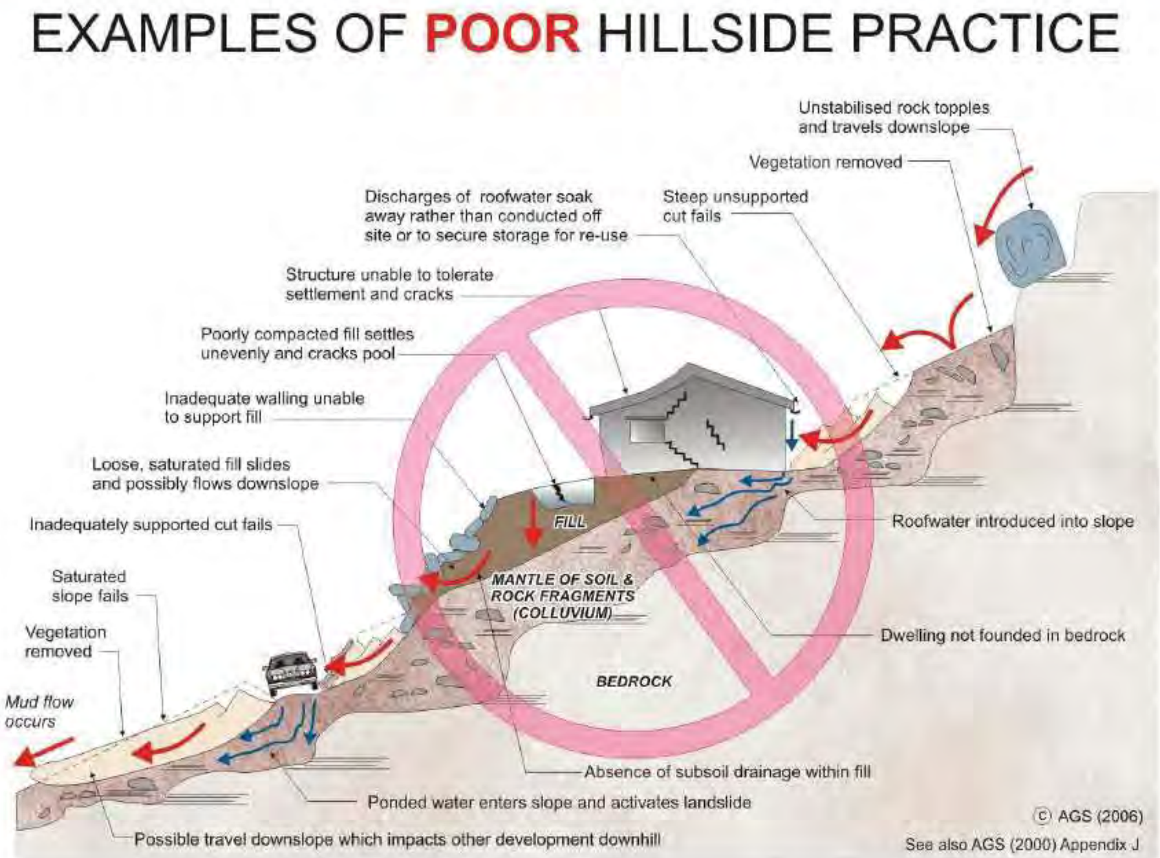
Appendix D

AGS Guidelines Extract

APPENDIX G - SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

	GOOD ENGINEERING PRACTICE	*POOR ENGINEERING PRACTICE*
ADVICE		
GEOTECHNICAL ASSESSMENT	Obtain advice from a qualified, experienced geotechnical practitioner at early stage of planning and before site works.	Prepare detailed plan and start site works before geotechnical advice.
PLANNING		
SITE PLANNING	Having obtained geotechnical advice, plan the development with the risk arising from the identified hazards and consequences in mind.	Plan development without regard for the Risk.
DESIGN AND CONSTRUCTION		
HOUSE DESIGN	Use flexible structures which incorporate properly designed brickwork, timber or steel frames, timber or panel cladding. Consider use of split levels. Use decks for recreational areas where appropriate.	Floor plans which require extensive cutting and filling. Movement intolerant structures.
SITE CLEARING	Retain natural vegetation wherever practicable.	Indiscriminately clear the site.
ACCESS & DRIVEWAYS	Satisfy requirements below for cuts, fills, retaining walls and drainage. Council specifications for grades may need to be modified. Driveways and parking areas may need to be fully supported on piers.	Excavate and fill for site access before geotechnical advice.
EARTHWORKS	Retain natural contours wherever possible.	Indiscriminatory bulk earthworks.
CUTS	Minimise depth. Support with engineered retaining walls or batter to appropriate slope. Provide drainage measures and erosion control.	Large scale cuts and benching. Unsupported cuts. Ignore drainage requirements
FILLS	Minimise height. Strip vegetation and topsoil and key into natural slopes prior to filling. Use clean fill materials and compact to engineering standards. Batter to appropriate slope or support with engineered retaining wall. Provide surface drainage and appropriate subsurface drainage.	Loose or poorly compacted fill, which if it fails, may flow a considerable distance including onto property below. Block natural drainage lines. Fill over existing vegetation and topsoil. Include stumps, trees, vegetation, topsoil, boulders, building rubble etc in fill.
ROCK OUTCROPS & BOULDERS	Remove or stabilise boulders which may have unacceptable risk. Support rock faces where necessary.	Disturb or undercut detached blocks or boulders.
RETAINING WALLS	Engineer design to resist applied soil and water forces. Found on rock where practicable. Provide subsurface drainage within wall backfill and surface drainage on slope above. Construct wall as soon as possible after cut/fill operation.	Construct a structurally inadequate wall such as sandstone flagging, brick or unreinforced blockwork. Lack of subsurface drains and weepholes.
FOOTINGS	Found within rock where practicable. Use rows of piers or strip footings oriented up and down slope. Design for lateral creep pressures if necessary. Backfill footing excavations to exclude ingress of surface water.	Found on topsoil, loose fill, detached boulders or undercut cliffs.
SWIMMING POOLS	Engineer designed. Support on piers to rock where practicable. Provide with under-drainage and gravity drain outlet where practicable. Design for high soil pressures which may develop on uphill side whilst there may be little or no lateral support on downhill side.	
DRAINAGE		
SURFACE	Provide at tops of cut and fill slopes. Discharge to street drainage or natural water courses. Provide general falls to prevent blockage by siltation and incorporate silt traps. Line to minimise infiltration and make flexible where possible. Special structures to dissipate energy at changes of slope and/or direction.	Discharge at top of fills and cuts. Allow water to pond on bench areas.
SUBSURFACE	Provide filter around subsurface drain. Provide drain behind retaining walls. Use flexible pipelines with access for maintenance. Prevent inflow of surface water.	Discharge roof runoff into absorption trenches.
SEPTIC & SULLAGE	Usually requires pump-out or mains sewer systems; absorption trenches may be possible in some areas if risk is acceptable. Storage tanks should be water-tight and adequately founded.	Discharge sullage directly onto and into slopes. Use absorption trenches without consideration of landslide risk.
EROSION CONTROL & LANDSCAPING	Control erosion as this may lead to instability. Revegetate cleared area.	Failure to observe earthworks and drainage recommendations when landscaping.
DRAWINGS AND SITE VISITS DURING CONSTRUCTION		
DRAWINGS	Building Application drawings should be viewed by geotechnical consultant	
SITE VISITS	Site Visits by consultant may be appropriate during construction/	
INSPECTION AND MAINTENANCE BY OWNER		
OWNER'S RESPONSIBILITY	Clean drainage systems; repair broken joints in drains and leaks in supply pipes. Where structural distress is evident see advice. If seepage observed, determine causes or seek advice on consequences.	


EXAMPLES OF GOOD HILLSIDE PRACTICE
Vegetation retained
Surface water interception drainage
Watertight, adequately sited and founded roof water storage tanks (with due regard for impact of potential leakage)
Flexible structure
Roof water piped off site or stored
On-site detention tanks, watertight and adequately founded. Potential leakage managed by sub-soil drains
Vegetation retained
MANTLE OF SOIL AND ROCK FRAGMENTS (COLLUVIUM)
OFF STREET PARKING
Pier footings into rock
Subsoil drainage may be required in slope
Cutting and filling minimised in development
ROADWAY
Sewage effluent pumped out or connected to sewer. Tanks adequately founded and watertight. Potential leakage managed by sub-soil drains
BEDROCK
Engineered retaining walls with both surface and subsurface drainage (constructed before dwelling)
© AGS (2006)


EXAMPLES OF POOR HILLSIDE PRACTICE
Unstabilised rock topples and travels downslope
Vegetation removed
Discharges of roofwater soak away rather than conducted off site or to secure storage for re-use
Steep unsupported cut fails
Structure unable to tolerate settlement and cracks
Poorly compacted fill settles unevenly and cracks pool
Inadequate walling unable to support fill
Loose, saturated fill slides and possibly flows downslope
FILL
Inadequately supported cut fails
Roofwater introduced into slope
Saturated slope fails
MANTLE OF SOIL & ROCK FRAGMENTS (COLLUVIUM)
Vegetation removed
Dwelling not founded in bedrock
BEDROCK
Mud flow occurs
Absence of subsoil drainage within fill
Ponded water enters slope and activates landslide
© AGS (2006)
Possible travel downslope which impacts other development downhill
See also AGS (2000) Appendix J

Appendix E

CSIRO Publication

Foundation Maintenance and Footing Performance: A Homeowner's Guide

BTF 18
replaces
Information
Sheet 10/91

Buildings can and often do move. This movement can be up, down, lateral or rotational. The fundamental cause of movement in buildings can usually be related to one or more problems in the foundation soil. It is important for the homeowner to identify the soil type in order to ascertain the measures that should be put in place in order to ensure that problems in the foundation soil can be prevented, thus protecting against building movement.

This Building Technology File is designed to identify causes of soil-related building movement, and to suggest methods of prevention of resultant cracking in buildings.

Soil Types

The types of soils usually present under the topsoil in land zoned for residential buildings can be split into two approximate groups – granular and clay. Quite often, foundation soil is a mixture of both types. The general problems associated with soils having granular content are usually caused by erosion. Clay soils are subject to saturation and swell/shrink problems.

Classifications for a given area can generally be obtained by application to the local authority, but these are sometimes unreliable and if there is doubt, a geotechnical report should be commissioned. As most buildings suffering movement problems are founded on clay soils, there is an emphasis on classification of soils according to the amount of swell and shrinkage they experience with variations of water content. The table below is Table 2.1 from AS 2870, the Residential Slab and Footing Code.

Causes of Movement

Settlement due to construction
There are two types of settlement that occur as a result of construction:

- Immediate settlement occurs when a building is first placed on its foundation soil, as a result of compaction of the soil under the weight of the structure. The cohesive quality of clay soil mitigates against this, but granular (particularly sandy) soil is susceptible.
- Consolidation settlement is a feature of clay soil and may take place because of the expulsion of moisture from the soil or because of the soil's lack of resistance to local compressive or shear stresses. This will usually take place during the first few months after construction, but has been known to take many years in exceptional cases.

These problems are the province of the builder and should be taken into consideration as part of the preparation of the site for construction. Building Technology File 19 (BTF 19) deals with these problems.

Erosion
All soils are prone to erosion, but sandy soil is particularly susceptible to being washed away. Even clay with a sand component of say 10% or more can suffer from erosion.

Saturation
This is particularly a problem in clay soils. Saturation creates a bog-like suspension of the soil that causes it to lose virtually all of its bearing capacity. To a lesser degree, sand is affected by saturation because saturated sand may undergo a reduction in volume – particularly imported sand fill for bedding and blinding layers. However, this usually occurs as immediate settlement and should normally be the province of the builder.

Seasonal swelling and shrinkage of soil
All clays react to the presence of water by slowly absorbing it, making the soil increase in volume (see table below). The degree of increase varies considerably between different clays, as does the degree of decrease during the subsequent drying out caused by fair weather periods. Because of the low absorption and expulsion rate, this phenomenon will not usually be noticeable unless there are prolonged rainy or dry periods, usually of weeks or months, depending on the land and soil characteristics.

The swelling of soil creates an upward force on the footings of the building, and shrinkage creates subsidence that takes away the support needed by the footing to retain equilibrium.

Shear failure
This phenomenon occurs when the foundation soil does not have sufficient strength to support the weight of the footing. There are two major post-construction causes:

- Significant load increase.
- Reduction of lateral support of the soil under the footing due to erosion or excavation.
- In clay soil, shear failure can be caused by saturation of the soil adjacent to or under the footing.

GENERAL DEFINITIONS OF SITE CLASSES

Class	Foundation
A	Most sand and rock sites with little or no ground movement from moisture changes
S	Slightly reactive clay sites with only slight ground movement from moisture changes
M	Moderately reactive clay or silt sites, which can experience moderate ground movement from moisture changes
H	Highly reactive clay sites, which can experience high ground movement from moisture changes
E	Extremely reactive sites, which can experience extreme ground movement from moisture changes
A to P	Filled sites
P	Sites which include soft soils, such as soft clay or silt or loose sands; landslip; mine subsidence; collapsing soils; soils subject to erosion; reactive sites subject to abnormal moisture conditions or sites which cannot be classified otherwise

Tree root growth
Trees and shrubs that are allowed to grow in the vicinity of footings can cause foundation soil movement in two ways:

- Roots that grow under footings may increase in cross-sectional size, exerting upward pressure on footings.
- Roots in the vicinity of footings will absorb much of the moisture in the foundation soil, causing shrinkage or subsidence.

Unevenness of Movement

The types of ground movement described above usually occur unevenly throughout the building's foundation soil. Settlement due to construction tends to be uneven because of:

- Differing compaction of foundation soil prior to construction.
- Differing moisture content of foundation soil prior to construction.

Movement due to non-construction causes is usually more uneven still. Erosion can undermine a footing that traverses the flow or can create the conditions for shear failure by eroding soil adjacent to a footing that runs in the same direction as the flow.

Saturation of clay foundation soil may occur where subfloor walls create a dam that makes water pond. It can also occur wherever there is a source of water near footings in clay soil. This leads to a severe reduction in the strength of the soil which may create local shear failure.

Seasonal swelling and shrinkage of clay soil affects the perimeter of the building first, then gradually spreads to the interior. The swelling process will usually begin at the uphill extreme of the building, or on the weather side where the land is flat. Swelling gradually reaches the interior soil as absorption continues. Shrinkage usually begins where the sun's heat is greatest.

Effects of Uneven Soil Movement on Structures

Erosion and saturation
Erosion removes the support from under footings, tending to create subsidence of the part of the structure under which it occurs. Brickwork walls will resist the stress created by this removal of support by bridging the gap or cantilevering until the bricks or the mortar bedding fail. Older masonry has little resistance. Evidence of failure varies according to circumstances and symptoms may include:

- Step cracking in the mortar beds in the body of the wall or above/below openings such as doors or windows.
- Vertical cracking in the bricks (usually but not necessarily in line with the vertical beds or perpends).

Isolated piers affected by erosion or saturation of foundations will eventually lose contact with the bearers they support and may tilt or fall over. The floors that have lost this support will become bouncy, sometimes rattling ornaments etc.

Seasonal swelling/shrinkage in clay
Swelling foundation soil due to rainy periods first lifts the most exposed extremities of the footing system, then the remainder of the perimeter footings while gradually permeating inside the building footprint to lift internal footings. This swelling first tends to create a dish effect, because the external footings are pushed higher than the internal ones.

The first noticeable symptom may be that the floor appears slightly dished. This is often accompanied by some doors binding on the floor or the door head, together with some cracking of cornice mitres. In buildings with timber flooring supported by bearers and joists, the floor can be bouncy. Externally there may be visible dishing of the hip or ridge lines.

As the moisture absorption process completes its journey to the innermost areas of the building, the internal footings will rise. If the spread of moisture is roughly even, it may be that the symptoms will temporarily disappear, but it is more likely that swelling will be uneven, creating a difference rather than a disappearance in symptoms. In buildings with timber flooring supported by bearers and joists, the isolated piers will rise more easily than the strip footings or piers under walls, creating noticeable doming of flooring.

Trees can cause shrinkage and damage

As the weather pattern changes and the soil begins to dry out, the external footings will be first affected, beginning with the locations where the sun's effect is strongest. This has the effect of lowering the external footings. The doming is accentuated and cracking reduces or disappears where it occurred because of dishing, but other cracks open up. The roof lines may become convex.

Doming and dishing are also affected by weather in other ways. In areas where warm, wet summers and cooler dry winters prevail, water migration tends to be toward the interior and doming will be accentuated, whereas where summers are dry and winters are cold and wet, migration tends to be toward the exterior and the underlying propensity is toward dishing.

Movement caused by tree roots
In general, growing roots will exert an upward pressure on footings, whereas soil subject to drying because of tree or shrub roots will tend to remove support from under footings by inducing shrinkage.

Complications caused by the structure itself
Most forces that the soil causes to be exerted on structures are vertical – i.e. either up or down. However, because these forces are seldom spread evenly around the footings, and because the building resists uneven movement because of its rigidity, forces are exerted from one part of the building to another. The net result of all these forces is usually rotational. This resultant force often complicates the diagnosis because the visible symptoms do not simply reflect the original cause. A common symptom is binding of doors on the vertical member of the frame.

Effects on full masonry structures
Brickwork will resist cracking where it can. It will attempt to span areas that lose support because of subsided foundations or raised points. It is therefore usual to see cracking at weak points, such as openings for windows or doors.

In the event of construction settlement, cracking will usually remain unchanged after the process of settlement has ceased.

With local shear or erosion, cracking will usually continue to develop until the original cause has been remedied, or until the subsidence has completely neutralised the affected portion of footing and the structure has stabilised on other footings that remain effective.

In the case of swell/shrink effects, the brickwork will in some cases return to its original position after completion of a cycle, however it is more likely that the rotational effect will not be exactly reversed, and it is also usual that brickwork will settle in its new position and will resist the forces trying to return it to its original position. This means that in a case where swelling takes place after construction and cracking occurs, the cracking is likely to at least partly remain after the shrink segment of the cycle is complete. Thus, each time the cycle is repeated, the likelihood is that the cracking will become wider until the sections of brickwork become virtually independent.

With repeated cycles, once the cracking is established, if there is no other complication, it is normal for the incidence of cracking to stabilise, as the building has the articulation it needs to cope with the problem. This is by no means always the case, however, and monitoring of cracks in walls and floors should always be treated seriously.

Upheaval caused by growth of tree roots under footings is not a simple vertical shear stress. There is a tendency for the root to also exert lateral forces that attempt to separate sections of brickwork after initial cracking has occurred.

The normal structural arrangement is that the inner leaf of brickwork in the external walls and at least some of the internal walls (depending on the roof type) comprise the load-bearing structure on which any upper floors, ceilings and the roof are supported. In these cases, it is internally visible cracking that should be the main focus of attention, however there are a few examples of dwellings whose external leaf of masonry plays some supporting role, so this should be checked if there is any doubt. In any case, externally visible cracking is important as a guide to stresses on the structure generally, and it should also be remembered that the external walls must be capable of supporting themselves.

Effects on framed structures
Timber or steel framed buildings are less likely to exhibit cracking due to swell/shrink than masonry buildings because of their flexibility. Also, the doming/dishing effects tend to be lower because of the lighter weight of walls. The main risks to framed buildings are encountered because of the isolated pier footings used under walls. Where erosion or saturation cause a footing to fall away, this can double the span which a wall must bridge. This additional stress can create cracking in wall linings, particularly where there is a weak point in the structure caused by a door or window opening. It is, however, unlikely that framed structures will be so stressed as to suffer serious damage without first exhibiting some or all of the above symptoms for a considerable period. The same warning period should apply in the case of upheaval. It should be noted, however, that where framed buildings are supported by strip footings there is only one leaf of brickwork and therefore the externally visible walls are the supporting structure for the building. In this case, the subfloor masonry walls can be expected to behave as full brickwork walls.

Effects on brick veneer structures
Because the load-bearing structure of a brick veneer building is the frame that makes up the interior leaf of the external walls plus perhaps the internal walls, depending on the type of roof, the building can be expected to behave as a framed structure, except that the external masonry will behave in a similar way to the external leaf of a full masonry structure.

Water Service and Drainage

Where a water service pipe, a sewer or stormwater drainage pipe is in the vicinity of a building, a water leak can cause erosion, swelling or saturation of susceptible soil. Even a minuscule leak can be enough to saturate a clay foundation. A leaking tap near a building can have the same effect. In addition, trenches containing pipes can become watercourses even though backfilled, particularly where broken rubble is used as fill. Water that runs along these trenches can be responsible for serious erosion, interstrata seepage into subfloor areas and saturation.

Pipe leakage and trench water flows also encourage tree and shrub roots to the source of water, complicating and exacerbating the problem.
Poor roof plumbing can result in large volumes of rainwater being concentrated in a small area of soil:

- Incorrect falls in roof guttering may result in overflows, as may gutters blocked with leaves etc.
- Corroded guttering or downpipes can spill water to ground.
- Downpipes not positively connected to a proper stormwater collection system will direct a concentration of water to soil that is directly adjacent to footings, sometimes causing large-scale problems such as erosion, saturation and migration of water under the building.

Seriousness of Cracking

In general, most cracking found in masonry walls is a cosmetic nuisance only and can be kept in repair or even ignored. The table below is a reproduction of Table C1 of AS 2870.

AS 2870 also publishes figures relating to cracking in concrete floors, however because wall cracking will usually reach the critical point significantly earlier than cracking in slabs, this table is not reproduced here.

Prevention/Cure

Plumbing
Where building movement is caused by water service, roof plumbing, sewer or stormwater failure, the remedy is to repair the problem. It is prudent, however, to consider also rerouting pipes away from the building where possible, and relocating taps to positions where any leakage will not direct water to the building vicinity. Even where gully traps are present, there is sometimes sufficient spill to create erosion or saturation, particularly in modern installations using smaller diameter PVC fixtures. Indeed, some gully traps are not situated directly under the taps that are installed to charge them, with the result that water from the tap may enter the backfilled trench that houses the sewer piping. If the trench has been poorly backfilled, the water will either pond or flow along the bottom of the trench. As these trenches usually run alongside the footings and can be at a similar depth, it is not hard to see how any water that is thus directed into a trench can easily affect the foundation's ability to support footings or even gain entry to the subfloor area.

Ground drainage
In all soils there is the capacity for water to travel on the surface and below it. Surface water flows can be established by inspection during and after heavy or prolonged rain. If necessary, a grated drain system connected to the stormwater collection system is usually an easy solution.

It is, however, sometimes necessary when attempting to prevent water migration that testing be carried out to establish watertable height and subsoil water flows. This subject is referred to in BTF 19 and may properly be regarded as an area for an expert consultant.

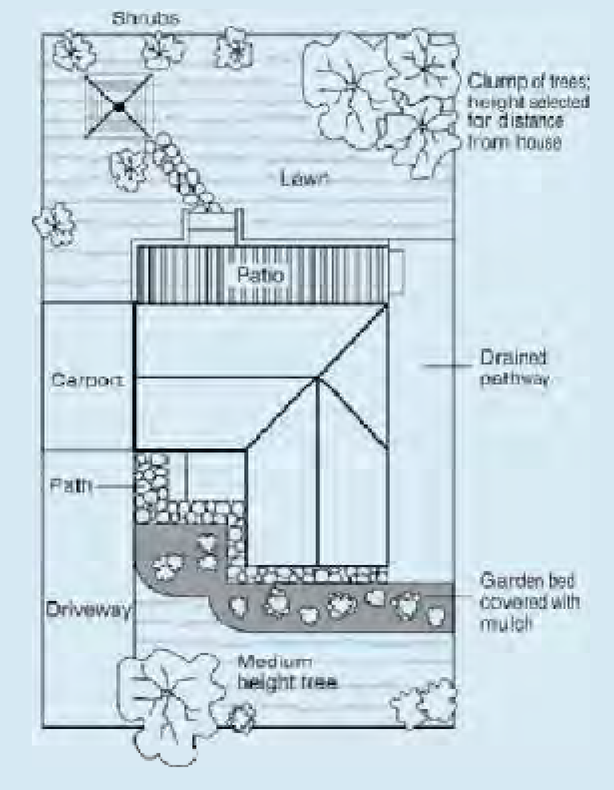
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

For this reason, particularly where problems exist or are likely to occur, it is recommended that an apron of paving be installed around as much of the building perimeter as necessary. This paving

CLASSIFICATION OF DAMAGE WITH REFERENCE TO WALLS

Description of typical damage and required repair	Approximate crack width limit (see Note 3)	Damage category
Hairline cracks	<0.1 mm	0
Fine cracks which do not need repair	<1 mm	1
Cracks noticeable but easily filled. Doors and windows stick slightly	<5 mm	2
Cracks can be repaired and possibly a small amount of wall will need to be replaced. Doors and windows stick. Service pipes can fracture. Weathertightness often impaired	5–15 mm (or a number of cracks 3 mm or more in one group)	3
Extensive repair work involving breaking-out and replacing sections of walls, especially over doors and windows. Window and door frames distort. Walls lean or bulge noticeably, some loss of bearing in beams. Service pipes disrupted	15–25 mm but also depend on number of cracks	4

Gardens for a reactive site



should extend outwards a minimum of 900 mm (more in highly reactive soil) and should have a minimum fall away from the building of 1:60. The finished paving should be no less than 100 mm below brick vent bases.

It is prudent to relocate drainage pipes away from this paving, if possible, to avoid complications from future leakage. If this is not practical, earthenware pipes should be replaced by PVC and backfilling should be of the same soil type as the surrounding soil and compacted to the same density.

Except in areas where freezing of water is an issue, it is wise to remove taps in the building area and relocate them well away from the building – preferably not uphill from it (see BTF 19).

It may be desirable to install a grated drain at the outside edge of the paving on the uphill side of the building. If subsoil drainage is needed this can be installed under the surface drain.

Condensation

In buildings with a subfloor void such as where bearers and joists support flooring, insufficient ventilation creates ideal conditions for condensation, particularly where there is little clearance between the floor and the ground. Condensation adds to the moisture already present in the subfloor and significantly slows the process of drying out. Installation of an adequate subfloor ventilation system, either natural or mechanical, is desirable.

Warning: Although this Building Technology File deals with cracking in buildings, it should be said that subfloor moisture can result in the development of other problems, notably:

- Water that is transmitted into masonry, metal or timber building elements causes damage and/or decay to those elements.
- High subfloor humidity and moisture content create an ideal environment for various pests, including termites and spiders.
- Where high moisture levels are transmitted to the flooring and walls, an increase in the dust mite count can ensue within the living areas. Dust mites, as well as dampness in general, can be a health hazard to inhabitants, particularly those who are abnormally susceptible to respiratory ailments.

The garden

The ideal vegetation layout is to have lawn or plants that require only light watering immediately adjacent to the drainage or paving edge, then more demanding plants, shrubs and trees spread out in that order.

Overwatering due to misuse of automatic watering systems is a common cause of saturation and water migration under footings. If it is necessary to use these systems, it is important to remove garden beds to a completely safe distance from buildings.

Existing trees

Where a tree is causing a problem of soil drying or there is the existence or threat of upheaval of footings, if the offending roots are subsidiary and their removal will not significantly damage the tree, they should be severed and a concrete or metal barrier placed vertically in the soil to prevent future root growth in the direction of the building. If it is not possible to remove the relevant roots without damage to the tree, an application to remove the tree should be made to the local authority. A prudent plan is to transplant likely offenders before they become a problem.

Information on trees, plants and shrubs

State departments overseeing agriculture can give information regarding root patterns, volume of water needed and safe distance from buildings of most species. Botanic gardens are also sources of information. For information on plant roots and drains, see Building Technology File 17.

Excavation

Excavation around footings must be properly engineered. Soil supporting footings can only be safely excavated at an angle that allows the soil under the footing to remain stable. This angle is called the angle of repose (or friction) and varies significantly between soil types and conditions. Removal of soil within the angle of repose will cause subsidence.

Remediation

Where erosion has occurred that has washed away soil adjacent to footings, soil of the same classification should be introduced and compacted to the same density. Where footings have been undermined, augmentation or other specialist work may be required. Remediation of footings and foundations is generally the realm of a specialist consultant.

Where isolated footings rise and fall because of swell/shrink effect, the homeowner may be tempted to alleviate floor bounce by filling the gap that has appeared between the bearer and the pier with blocking. The danger here is that when the next swell segment of the cycle occurs, the extra blocking will push the floor up into an accentuated dome and may also cause local shear failure in the soil. If it is necessary to use blocking, it should be by a pair of fine wedges and monitoring should be carried out fortnightly.

This BTF was prepared by John Lewer FAIB, MIAMA, Partner, Construction Diagnosis.

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