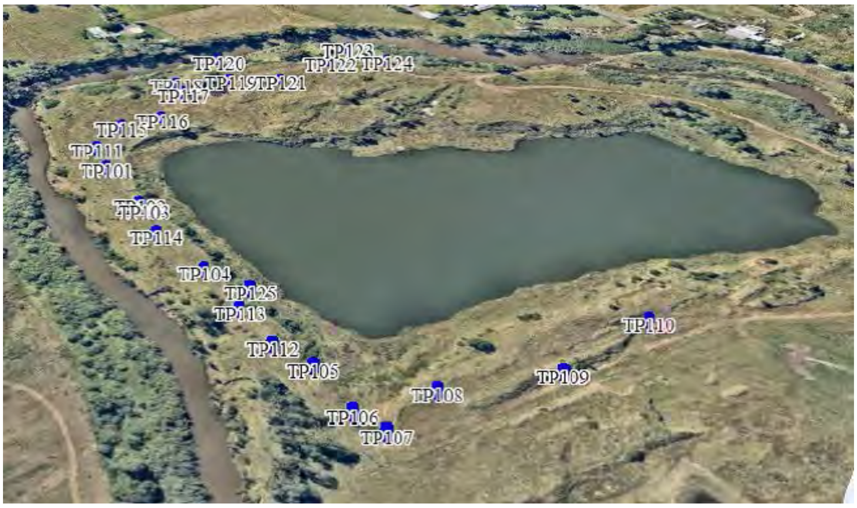
28 August 2015
Revised version of 28 July 2015 report

GRANTHAM QUARRY - GEOTECHNICAL INVESTIGATIONS & EXPERT OPINION ON FORMATION OF EARTHWORKS

Grantham Floods Commission of Inquiry

Submitted to:
Grantham Floods Commission of Inquiry
Level 3 Annexe
100 George Street
BRISBANE QLD 4000



REPORT

Report Number. 1532696-001-R-Rev2

Distribution:

Ms Joanne Paterson
Director Flood Commission of Inquiry

Golder Associates

Table of Contents

TABLES

FIGURES

TEXT PLATES

APPENDICES

EXECUTIVE SUMMARY

1. My Name is David Starr, and I am a geotechnical engineer with 44 years' experience. I have been engaged to establish the method of formation of the embankments surrounding the Grantham quarry that, at the time of the 2011 flood event, effectively served as a flood levee – including:

    a. whether natural or anthropogenic, and if a mixture of the two, the location and extent of each.
    b. for anthropogenic portions, the probable nature and method of construction.

2. The results of the investigations will provide an input to the hydrological investigations in determining reasonable assumptions for the performance of the embankment under the flood conditions.

3. The Quarry site is formed of Quaternary Flood Plain material comprising alluvial sands, gravel and silt, and is underlain by Marburg Formation sandstone and siltstone of Lower to Middle Jurassic age.

4. I describe at Section 8.1 the methodology and results of test pit investigations undertaken to delineate the interface between natural alluvium and fill material along the west, north and southern levees of the Quarry Lake.

5. The results of test pit investigations and 1982 air photo data have allowed me to derive a pre-quarry natural model surface, which has been combined with LiDAR surface contour data for pre-flood and post-flood conditions to visualise the locations and heights of man-made bunds and stockpiles present on the site in 2010 before the January 2011 flood event.

6. These visualisations have been generated for pre-flood and post-flood conditions which I present in plans and oblique views, and these have allowed me to deduce that there were two narrow fill bunds on both sides of the access track along the western levee.

7. I present below an annotated cross section through the western levee showing Lockyer Creek, the river terraces, the natural ground surface, the access track and the man-made bunds either side of the track, and the Quarry Lake. The section shows the relative heights of the features in AHD (Australian Height Datum).

8. The cross section is based on contours generated from the pre-flood LiDAR, which is a remote sensing method that uses light in the form of a pulsed laser to measure distances to the earth surface.

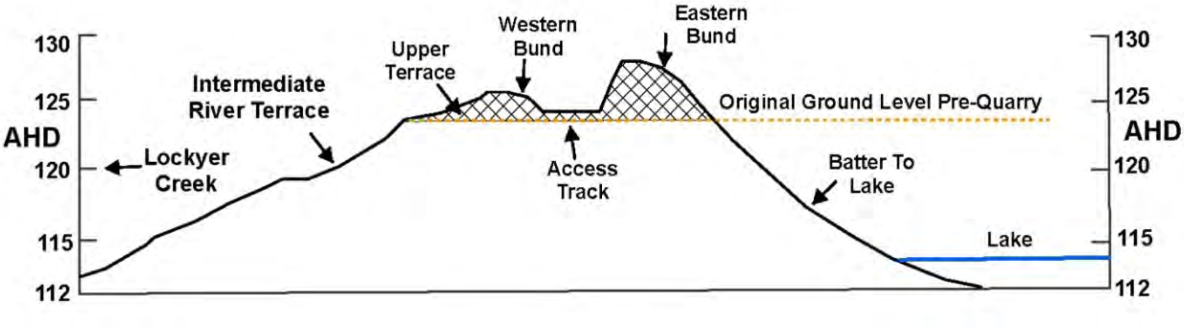


Plate1: Schematic cross-section through western levee, Grantham Quarry

9. The bund between the access track and the edge of the quarry lake (the eastern bund) was about 4 m in height above natural ground level, but varied between 2 and 6 m.

10. A narrow bund along approximately 50% of the length of the wester levee, on the western (Lockyer Creek) side of the access track, was about 2 m in height above natural ground level.

11. I have identified a low point at the northern end of the western levee, and this location is where the main breach occurred during the flood event (see Plate 2). The black solid line is the interpreted natural ground surface (designated Horizon H2).

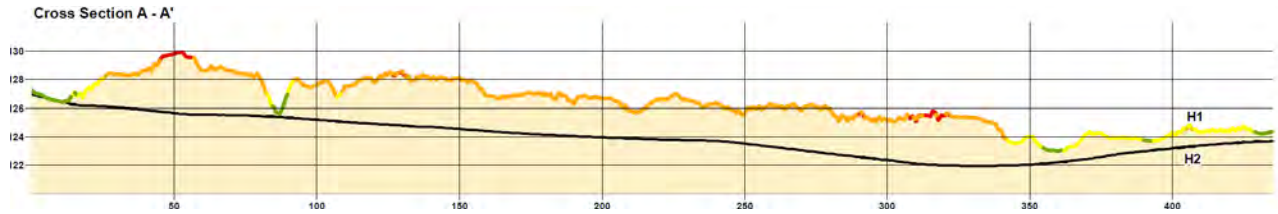


Plate 2: Section through Eastern Bund along western levee from South to North showing low point at about 300 m

12. From my examination of oblique air photos, personal photos contained in various witness statements, Wagner's survey plan of 2008, and stereo air photo examinations covering the years 1997, 2001 and 2009, it is my opinion that the construction of bunds either side of the access track along the western levee of the quarry site commenced after August 1997 and before June 2001, and the bund construction continued from 2001 until about 2005.

13. The data I particularly rely upon to make this conclusion is as follows:

    a. Witness statement J Gallagher – (which includes an oblique air photo, Plate 30a, Section 12.4 of this report), indicates that there was no wall along western side of quarry at the time of a previous flood event in 1996.

    b. Stereo air photos from 1997 showing no earthworks along the western levee (see Plate 3).

Plate 3: Annotated version of air photo from 1997 (discussed in Section 12.5 of this report)

c. Stereo air photo images for 2001 show multiple mounds of earth along the western side of the track. There is also a bund along the eastern side of the track. It is not possible to determine the exact height of these bunds from stereo viewing, but the mounds along the western side appear to be higher than along the east side (see Plate 4).

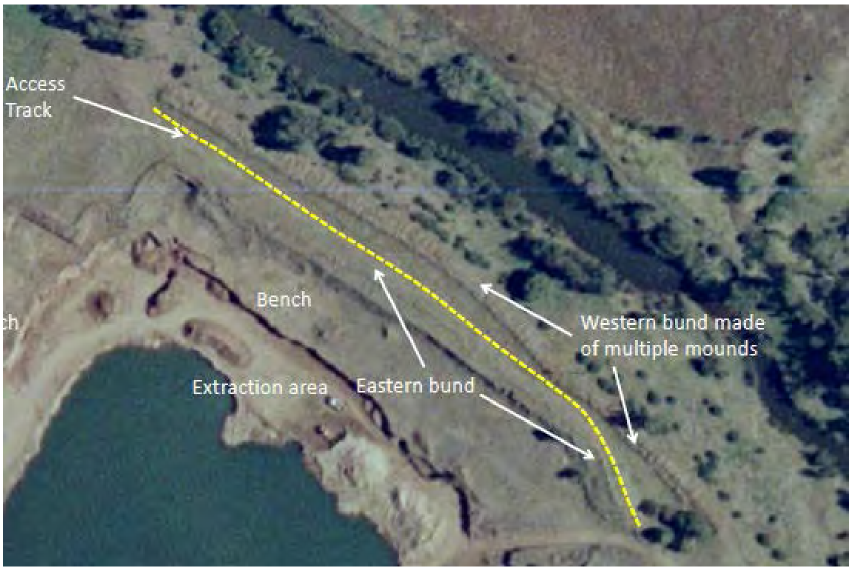


Plate 4: Annotated version of air photo from 2001 (discussed in Section 12.5 of this report)

d. Evidence from one Test Pit (TP 113) which indicates that the construction of the bunds probably developed over time in stages.

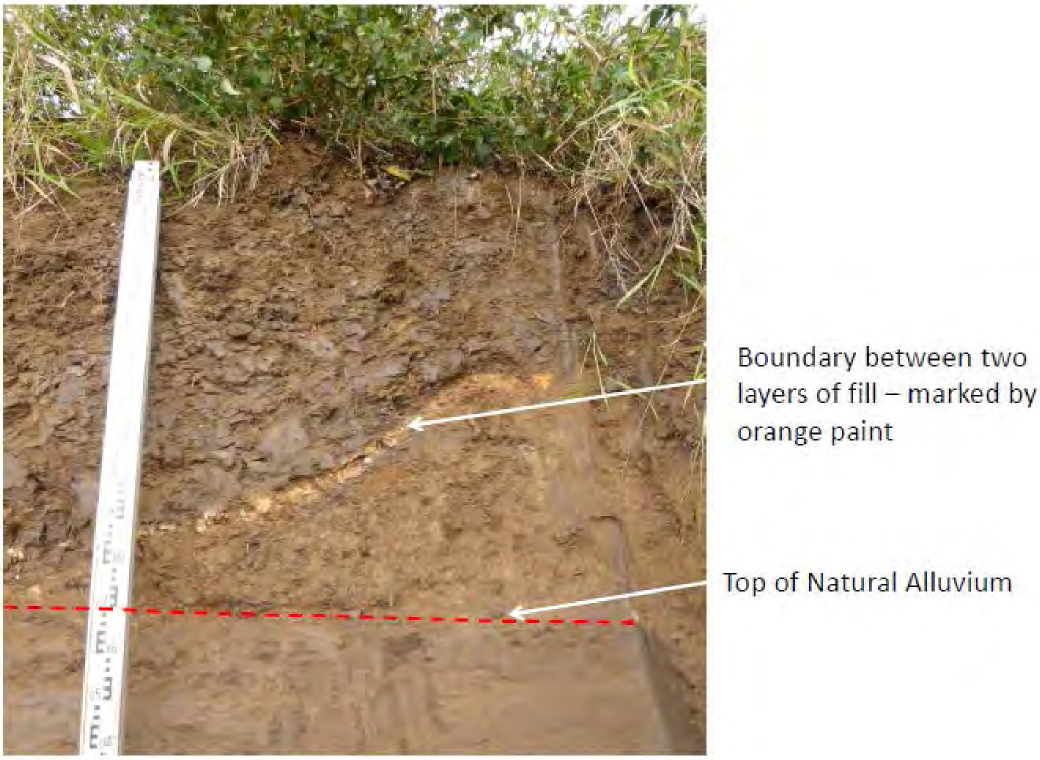


Plate 5: North face of Test pit 113 excavated in remnant portion of western bund

14. I infer that further changes in the height and location of the bunds occurred over time between 2001 and the topography shown by the 2010 pre-flood LiDAR contours. These changes are based on examination of air photos, Google Earth images and a survey plan, as well as observations in a test pit indicating staged construction of bunds.

15. A Google Earth Image dated 30 December 2005 appears to indicate the presence of the bunds either side of the access track along the western levee. It is not possible to determine the height of these bunds from the Google Earth image.

16. A contoured survey plan made for Wagner in January 2008 shows essentially the same locations and height of bunds as indicated by 2010 pre-flood LiDAR data.

17. Stereo air photos from 2009 show the western levee with the access track and bunds as indicated by the 2008 survey plan and the 2010 pre-flood LiDAR (and associated air photo overlay).

18. Plate 6 shows an annotated view of a June 2009 air photo. For comparison, the 2010 air photo is shown below in Plate 7.

19. The 2005, 2008 and 2009 photos indicate similar conditions of the bunds, and when compared with the pre-flood LiDAR data, in my opinion this indicates that the bunds had possibly reached their pre-flood condition by 2005. The topography of the bunds is confirmed by the 2008 survey plan.

Plate 6: Annotated view of air photo from 2009 (discussed in Section 12.5 of this report)

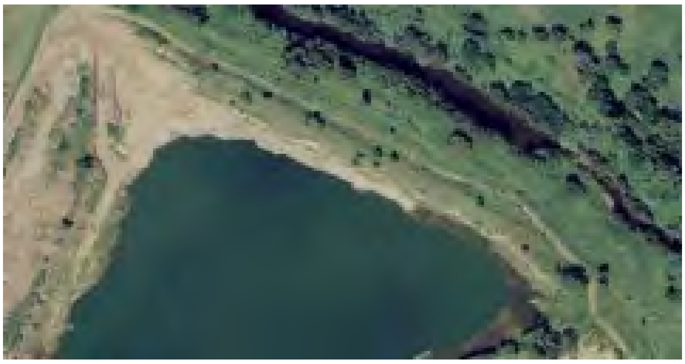


Plate 7: .2010 Photo image QAP 2091-252

1.0 THE COMMISSION

1.1 Background

20. The Grantham Floods Commission of Inquiry (The Commission) has been established under the Commissions of Inquiry Act 1950 to make full and careful inquiry into the flooding of the Lockyer Creek between Helidon and Grantham on 10 January 2011, with specific reference to any natural or man-made features of the landscape which could have altered or contributed to the flooding.

1.2 My Instructions

21. A copy of my letter of instruction is attached in Appendix A.

22. I have been engaged by The Commission to provide an expert opinion on the method of formation of the embankments surrounding the quarry to assist it in determining whether those embankments acted as a levee during the 10 January 2011 flood event.

23. The Commission has not limited the scope of the matters to be considered for my opinion, but has requested that I specifically consider the Quarry area to the east and south of the Lockyer Creek including the pit, levees and other disturbances to the natural surface so as to:

    a. identify whether the embankments are natural or anthropogenic, and, if a mixture of the two, the location and extent of each;

    b. determine, to the extent it is possible to do so, the probable nature and method of construction of any anthropogenic portions of the embankments;

    c. define the following:

        i. the extent of the likely natural pre-quarry surface;

        ii. the extent of the anthropogenic fill material surrounding the quarry which could reasonably have been expected to have:

            1. behaved as a flood protection levee at the time of the flood;

            2. been placed over flooded eroded areas (for example, eroded levee banks or where the quarry has been breached) and that over other areas (such as material which has been dumped or stockpiled);

    d. classify the extents with respect to natural, pre-flood general fill, pre-flood levee material, post-flood erosion fill, post-flood levee fill and post-flood general fill;

    e. consider the path of the corridor running parallel to the southern side of the quarry and determine whether anthropogenic fill had been placed within the subject corridor prior to the 2011 flood event and if it had, specify:

        1. the extent and specific location/s of that fill; and

        2. the extent of that fill that has since been removed and whether it was removed by the flood or by later mechanical means.

24. In order to form an opinion, I have been requested to undertake investigations I consider necessary including, but not limited to:

    a. undertaking site inspections of the quarry to confirm the physical scope of the site;

    b. undertaking test pitting at the quarry for the purpose of differentiating between natural and anthropogenic fill;

c. obtaining LiDAR photographs of the quarry and its surrounding areas for the purpose of identifying pre-quarry conditions and post quarry conditions;

d. laboratory testing of any fill material gathered from the quarry site; and

e. liaising with the Commission's expert hydrologist.

2.0 QUALIFICATIONS & EXPERIENCE

25. I am a Principal Geotechnical Engineer with Golder Associates Pty Ltd (Golder Associates) with 44 years' experience in consulting in geotechnical engineering and engineering geology.

26. I have practiced as a geotechnical engineer in the UK, Washington State (USA), The Middle East, Hong Kong, SE Asia including Indonesia, PNG, Fiji, and have been based in Australia since 1986.

27. I have published more than 20 technical papers covering topics such as case histories for infrastructure projects, and on professional practice and legal issues. I am the Australian representative on the International Society of Soil Mechanics and Geotechnical Engineers (ISSMGE) committee TC302 Forensic Engineering, and JTC4, Professional Practice.

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28. In 2006, I was awarded Queensland Professional Engineer of the Year by Engineers Australia.

29. My areas of expertise are in geotechnical investigations, geotechnical design, construction monitoring, engineering geology, rock properties, and soft soil engineering.

30. My qualifications are further described in my professional resume which is attached as Appendix E.

3.0 DOCUMENTATION & DATA PROVIDED

31. The documentation and data files provided by the Grantham Floods Commission of Inquiry, and on which I have relied in providing my opinion are listed in Appendix A.

4.0 SCOPE OF REPORT

32. I have responded to the brief outlined in Section 1.2 by undertaking the following scope of work:

a. A description of the geological setting of the quarry site. This assists in addressing Item c) i of the brief – *determine the extent of the likely natural pre-quarry surface.*

b. An assessment of the topography and morphology of the quarry site. This assists in addressing Items c) and d) of the brief – *determine the extent of the anthropogenic fill material surrounding the quarry, and classify the extents with respect to natural, pre-flood general fill, pre-flood levee material, post-flood erosion fill, post-flood levee fill and post-flood general fill*.

c. A site inspection of the quarry site. This assists in addressing Items Items c) and d) of the brief (see b above).

d. Excavator test pitting undertaken in June 2015. This work was undertaken to address Items a), c) and d) of the brief.

e. Interpretation of the pre-existing natural ground surface before quarry operations commenced in about 1982. This addresses Item c) i of the brief.

f. An assessment of the nature and extent of man-made levees, embankments and stockpiles on the site prior to the 2011 flood event. Present the results in the form of figures, sections, photographs, 3D views and mark ups of figures. This addresses Item d) of the brief - *classify the extents with respect to natural, pre-flood general fill, pre-flood levee material, post-flood erosion fill, post-flood levee fill and post-flood general fill.*

g. An assessment of the extent to which fill was removed by (1) the flood event, or (2) was modified by earthmoving operations after the flood. Present the results in the form of figures, sections, photographs, 3D views and mark ups of figures. This addresses Item d) of the brief - *classify the extents with respect to natural, pre-flood general fill, pre-flood levee material, post-flood erosion fill, post-flood levee fill and post-flood general fill.*

h. Assess the probable nature and method of construction of any anthropogenic portions of the embankments. This addresses Item b) of the brief - *determine, to the extent it is possible to do so, the probable nature and method of construction of any anthropogenic portions of the embankments.*

5.0 THE QUARRY SITE & GEOLOGICAL SETTING

33. The quarry site is located approximately 4 km west of the town of Grantham, Queensland. It is enclosed within an oxbow bend in the Lockyer River, creating a ”U” shaped parcel of land bounded on three sides by the creek.

34. According to the 1:250 000 Ipswich Geological Map (Sheet SG 56-14), published by the Geological Survey of Queensland, I note that the site is formed of Quaternary Flood Plain material comprising alluvial sands, gravel and silt, and is underlain by Marburg Formation sandstone and siltstone of Lower to Middle Jurassic age.

35. The Marburg Formation is shown to outcrop immediately south of the quarry site, as shown on my mark-up of a 1982 air photo by the Symbol Jm (see Plate 8).

36. From my general knowledge of the geology of SE Queensland, the Quaternary Alluvium has been deposited by Lockyer Creek over at least the last 12,000 years. The Symbol Qa applied to alluvial deposits on the geological map refers to terraces which are recognisable as present day river flats. These flats are generally considered to be of Holocene Age (11,700 years before present), but the highest terrace in some areas may be of late Pleistocene age (1.8million to 11,700 ybp), an epoch associated with glacial events (ref Land Resources Bulletin QNRM 01215).

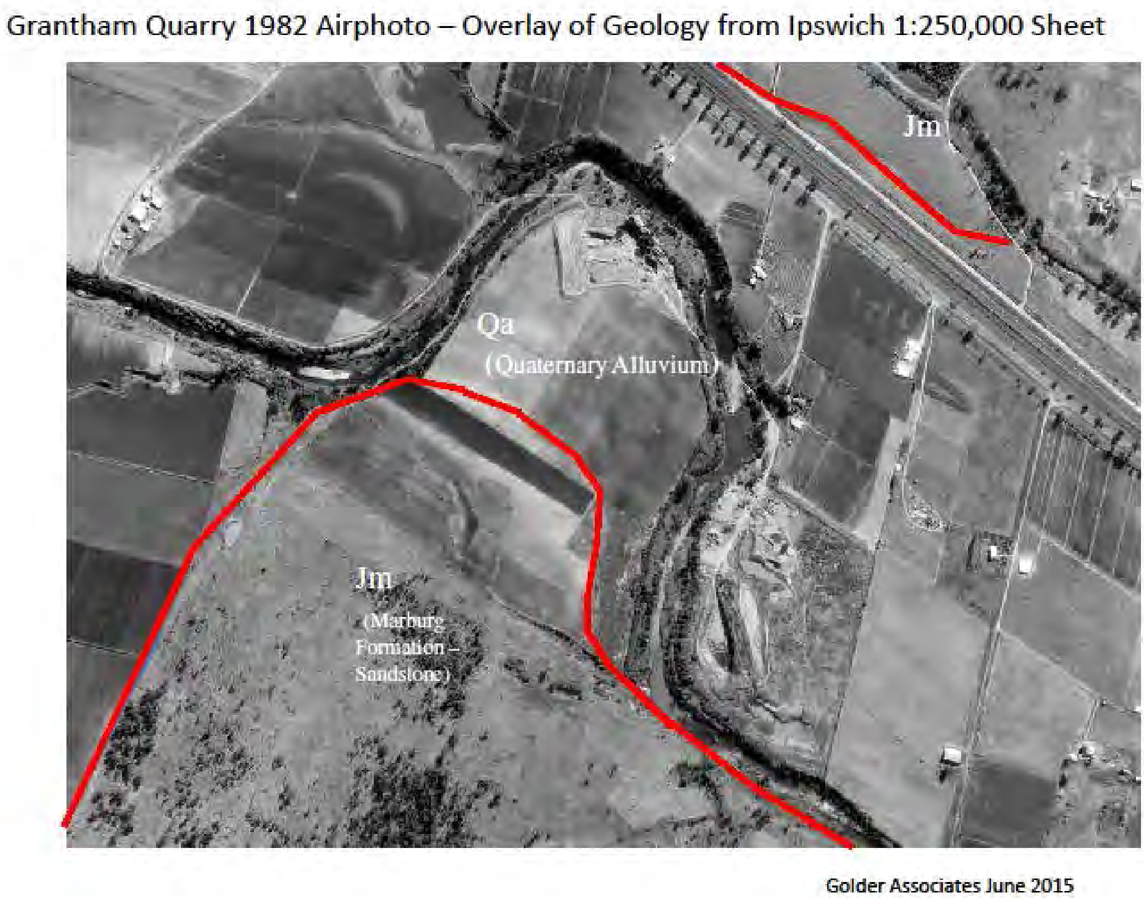


Plate 8: Overlay of 1982 Air Photo Showing Interpreted Geology (Photo Ref QAP4014-13, source DERM)

37. The lowest terrace generally has the coarser cobbles and sand bar deposits, compared with finer deposits in the second terrace (silt and sand), and clay with silt in the third terrace (if present).

38. A maximum thickness of 33 m has been indicated for the Holocene/Pleistocene unit in the Lockyer Creek Alluvium (Zahawi 1975).

6.0 TOPOGRAPHY & MORPHOLOGY OF THE QUARRY SITE

39. I have made use of topographic data available for the area of the quarry both pre-flood and post-flood in the form of contours generated from LiDAR surveys. The first survey was undertaken between 1st to 22nd August 2010 before the flood and from 10th February to 9th March 2011 after the flood.

40. LIDAR, which stands for Light Detection and Ranging, is a remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the earth surface. These light pulses - combined with other data recorded by the airborne system - generate precise, three-dimensional information about the surface characteristics of the area being surveyed.

41. Advice received from the DNRM who are responsible for the LiDAR data collected for the Lockyer Valley in 2010, 2011 (and a further set in 2013), indicates that accuracy of AHD heights derived from LiDAR data along roadways is better than plus or minus 200 mm. However, the errors in height may increase slightly due to the presence of vegetation such as grass cover.

42. I note that based on the topographic data generated by the LiDAR surveys, in normal flow conditions, Lockyer creek is about 10 m below the general level of the quarry levee banks.

43. The LiDAR data has been plotted by a Golder GIS expert under my direction on Figures presented with this report (Figures 1 to 3, 4 to 6, and 7 & 8). I provide my interpretation of the LiDAR contours in Sections 10 and 11 of this report.

44. Stereographic air photo images have been obtained from Department of Environment and Natural Resources covering the Grantham area. Air photography flown on 13 May 1982 at a height of 4300 m ASL shows the future quarry site, and I have examined three images – Run 9342 Q4014 Number 11, 12 and 13.

45. The mirror stereoscope allows height information to be assessed by means of viewing overlapping stereo pairs. The height information is exaggerated (depending on the interval between adjacent photographs).

46. My interpretation of the 1982 air photo is discussed in detail under Section 9.1 of this report.

47. I have made a search of imagery available on the web by using Google Earth and photomaps by Nearmap (Golder has a Nearmap license). Nearmap Ltd is an international provider of high resolution aerial imagery, and currently operates a web portal which serves up its imagery and terrain models.

48. I have summarised my findings in terms of the following recent history of the site (see imagery reproduced in Appendix C) :

    1) **Google Earth – 30 December 2005.** This is the earliest Google imagery for this area**.** There is a large stockpile on the northern side of the Quarry. The extent of the lake is less than shown in later images – this is probably due to more material being removed in quarrying at later stages. There is a strip of land east of the western levee which has been lowered, and there is a haul road going down to the lake at the north end of the western levee. It is not possible to determine height information (i.e. the imagery is not stereographic), however there is some evidence from shadows that there are bunds with vegetation either side of the access track along the western levee. The area south of the quarry lake has been utilised for stockpiling material, although there appears to be a strip of original agricultural land south of the lake still virtually undisturbed.

    2) **Google Earth – 11 August 2009.** Material stockpiles can be seen in the northern portion of the site. There is a clear space between two stockpile areas. A haul road can be seen adjacent to the SW corner of the quarry lake. Earthmoving equipment can be seen on this track and to the south. The haul road at the northern end of the western levee appears to have been removed.

Various stockpiles can be seen to the south of the quarry lake. There is evidence from shadows (the sun is to the north east of the field of view), that there are bunds with vegetation either side of the access track along the western levee. The 2008 survey plan discussed under Section 12 of this report, and shown in Plate 28 indicates that by 2009, the bunds along the western levee were of similar height to that which existed immediately before the flood event.

3) **Nearmap – 17 July 2010 (pre-flood).** There is one large stockpile on the northern side of the quarry lake, with a smaller area of stockpiled material to the northwest. There is a portable screening plant between the two stockpiles. Part of the haul road seen in the 2009 Google Earth image adjacent to the SW corner of the quarry lake, is being filled – a number of soil dumps can be observed. Shadows clearly indicate the presence of bunds either side of the access track along the western levee (the sun is to the north west of the area of view).

4) **Google Earth – 12 August 2011 (post flood).** Earthworks have been undertaken in the northern portion of the site – a level platform has been created to fill the breach caused by the flooding. The platform has a steep side adjacent to the quarry lake. The haul road previously adjacent to the south west corner of the quarry lake has disappeared. Grass has re-grown on areas along the western levee which were eroded by the flood event (compared with the post-flood LiDAR imagery and accompanying air photo dated February/March 2011).

5) **Google Earth –** A number of images post flood dated 5 January 2012, 11 January 2013, 28 April 2013, 3 June 2013, and 16 March 2014. No evidence of any significant earthmoving since the first few months of 2011.

6) **Nearmap – 10 May 2015.** Stockpiles and levees are grass covered. The extent of stockpiles to the south of the quarry lake appears similar to pre-flood. Some material has been taken from the eastern end of a stockpile south of the track.

49. Changes in height are difficult to interpret from single images obtained by air photography or satellites. Shadows can give some impression of height, and although large stockpiles can be interpreted, the height and extent of narrow linear features such as levee bunds are not easy to infer. In my opinion, LiDAR contours, stereo air photography and survey plans provide the best means of determining height information, as discussed in Sections 9.1, 10.0 and 12.0 of this report.

7.0 SITE INSPECTION

50. I undertook a walkover site inspection in the presence of John Macintosh (Water Solutions) and Tim Slack (Boral) on 1 June 2015, and my selected photographs are presented as Appendix B.

51. In the following descriptions, levee bank is used to mean a bank raised above water level adjacent to a river course. Lockyer Creek is incised by about 10m resulting in a water level 10m below the crest of the natural bank. One objective of my report is to determine the extent to which the heights of levee banks have been raised further by the placement of fill bunds. In this report my use of the word levee does not necessarily imply a man-made feature.

52. I undertook an inspection by walking along the access track in an anticlockwise direction around the quarry. A Google Earth kmz/kml file was recorded by John Macintosh on a gps device to show the path taken. The path file was subsequently provided to me.

53. I have numbered the photo images approximately in the order taken, and these are designated B1 to B15 in Appendix B.

54. Photo B1 shows the north bank of the quarry lake, viewed from the in-filled main breach. A platform can be seen which approximates to the interpreted natural ground level, above which there is stockpile.

Photo B1

Photo B2

55. Photo B2 shows an original fence post on the western side of the western levee. In my opinion, the fence line was close to the crest of the upper terrace which existed before quarrying operations. (Test Pit 101 was subsequently excavated close to this location).

56. Photo B3 shows a terrace along the western side of the quarry. I infer that there is at least one terrace below the top of the pre-existing natural river bank.

Photo B3

Photo B4

57. Photo B4 shows the track along the western side of the quarry flanked by remnants of bunds erected either side of this track. The height of these bunds prior to the flood event is considered in Section 10 of my report.

58. Photo B5 shows the northern end of the remnant bund on the west side of the path depicted in Image B4. The fill used for construction of the bund is exposed. I infer that the portion of the bund north of this point was eroded by the flood event.

Photo B5

Photo B6

59. Photo B6 shows an original fence post on the lower river terrace towards the southern end of the western levee. The terrace appears to be widest at the southern end of western levee bank.

60. Photo B7 depicts an erosion scar on the western levee bank, which I believe to be a result of the 2011 flood, based on post-flood imagery discussed in Section 6.0 of this report.

Photo B7

Photo B8

61. Photo B8 shows layered bands of clayey silt and sand within the alluvial deposits exposed in an erosion scar on the western side of the levee bank.

62. Photo B10 shows a fence post believed to have been present before commencement of quarrying operations in about 1982. The fence line ran approximately north south along this section of the Lockyer Creek bank. I infer that the higher land to the left of the fence post is part of the remnants of a man-made bund situated to the west of the access track at the top of the levee.

Photo B10

Photo B11

63. Photo B11 depicts the lower terrace at the southern end of the western levee bank. I believe that the trees pre-date the creation of the quarry (the trees can be seen in the 1982 air photo I discuss in Section 9.1 of this report).

64. Photo B12 shows the access track along the southern side of the quarry. Stockpiles can be seen in the middle distance either side of the southern track.

Photo B12

Photo B13

65. Photo B13 shows the track along the western side of the quarry, viewed from the south. A remnant of the bund on the eastern side of this track can be seen (I estimate that its maximum height is about 4 m).

66. Photo B14 shows the track on the southern side of the quarry viewed from the west. A stockpile to the south of the track reveals two faces where material has been removed. I note that these faces appear fresh on the Google Earth image of 5 January 2012.

Photo B14

Photo B15

67. Photo B15 shows the southern side of the quarry lake viewed from the south eastern corner of the track.

8.0 EXCAVATION OF TEST PITS & TEST TRENCHES

8.1 Methodology

68. The fieldwork methodology described below was agreed with Boral (the current owner of the Grantham quarry), in order to ensure that health and safety requirements were met.

69. The objective of the test pit investigations was to delineate as well as possible the interface between natural alluvium and fill material along the west, north and southern levees of the Quarry Lake.

70. For simplicity, I have designated the natural alluvial material as Horizon H2, and all Fill Material Horizon H1. The test pitting was directed at establishing the top of Horizon H2, and determining the nature of the materials within Horizons H1 and H2.

71. I decided on the location of test pits from my initial inspection of the site, and they are located along the western levee, either side of the existing access track, to investigate the interface between natural alluvium and remnant fill bunds built above the track level.

72. The test pit investigations also included the area to the south of the quarry lake, where the access track runs immediately adjacent to stockpiled material.

73. Test pitting was also undertaken on the north side of the quarry, including an area adjacent to the flood breach.

74. The test pitting was undertaken under my fulltime supervision, using a 20 tonne excavator with a 1200 mmm wide batter bucket, operated by Aussie Enviro Excavations.

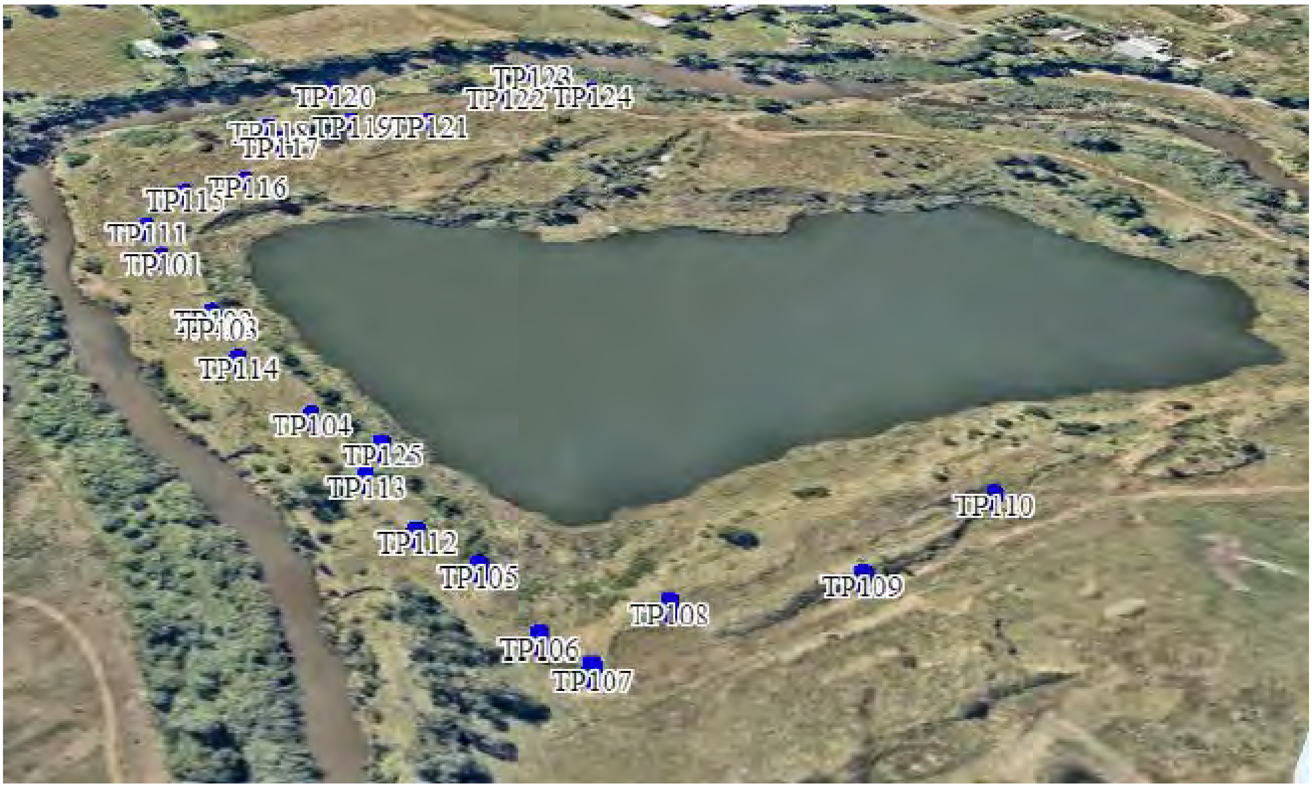


Plate 9: Test pit locations shown on 2015 Nearmap Image

75. I was assisted by Nick Coulson, a hydrogeologist from Golder's Brisbane office, who acted as a scribe to record soil descriptions assigned by me. A representative from Boral was present at all times during the investigation works.

76. For safety reasons, the excavator was not permitted to work within 10 m of the steep banks either side of the western levee. This did not result in the investigation being compromised.

77. Test pits were excavated to a maximum depth of 1.5 m initially, after which I examined the conditions revealed and took photographs. Nick Coulson took samples of materials under my direction to represent the range of materials encountered within fill and alluvium.

78. It was necessary to extend two pits to depths greater than 1.5m in order to determine the nature of ground conditions encountered (TP108 and TP118). Pits deeper than 1.5 m were not entered.

79. Test pits were backfilled after completion and marked with survey pegs for pickup by a licensed surveyor (North Surveys). The pegs were labelled with test pit number, and were also annotated to indicate depths to specific horizons.

80. Pits were backfilled with excavated material, tamped down with the bucket, and track rolled to produce a smooth surface.

81. A total of 25 pits were excavated, and are designated TP101 to TP125.

82. I described the conditions revealed in test pits using terminology defined on Page 2 of the Golder Associates Field Guide (included in Appendix D).

83. The field guide includes the following system for describing soil properties:

    a. Soil Name; e.g. Sandy CLAY - with the primary soil type in block letters.
    b. Plasticity for cohesive soils, or particle size and shape for sands and gravels.
    c. Colour
    d. Secondary soil components; with an estimate of their percentage, (optional), and giving their plasticity or particle size.
    e. Other minor soil components, such as gravel.
    f. Moisture condition.
    g. Strength or degree of compaction. (Applies to soils in their in situ state)
    h. Structure; i.e. fissuring , layering, cementation, ped structure.
    i. Additional observations on origin i.e. "FILL" or "ALLUVIUM".

84. The descriptions made by me were recorded by Nick Coulson on field logs.

85. Test Pit locations were recorded in terms of coordinates and surface RLs by a licensed surveyor from North Surveys, and the results are tabulated on a plan of the site entitled "Test Pit Location – Grantham Quarry". The plan is presented in the front of Appendix D – Test Pit Logs and Photographs. The survey datum is GDA 94, Projection MGA Zone 56, and levels were referenced to a Permanent Survey Marker on the Helidon-Grantham Road to Australian Height Datum (AHD).

86. Two columns are presented on the tabulated Test Pit Location Plan listing RLs. The first column is the surface RL of the test pit, and the second column is the level of the interpreted surface of pre-existing natural ground, designated Horizon H2.

87. In addition to recording coordinates and RLs at test pit and trench locations, surface levels were taken at points on the adjacent track, as designated below:

- TP101-1 and TP101-4
- TP111-1, TP111-2, TP111-3
- TP114-1, TP114-2, TP114-3

88. In Test Pit 125, three levels were taken at different points along an interface between Horizon H1 fill and Horizon H2 alluvium, designated TP125-1, TP125-2 and TP125-3.

89. Surface levels were also taken at three locations on the access track adjacent to test pits. These locations are designated Track Level TLTP101, TLTP102, and TLTP111.

90. The test pit logs are presented in the form of vertical profiles representing the materials encountered in each pit or at different locations in a trench, supported by photographs of each pit. The logs and photographs are presented separately in numerical order in Appendix D.

91. The locations of samples recovered from test pits are shown on the respective logs. A summary of the samples recovered is presented as Table 1.

Table 1: Disturbed samples recovered from Test Pits and Trenches

Site ID	Depth (mm bgl)	Unit	Comments
TP101-1	0 to 350	Fill (H1)	
TP101-2	350 to 500	Natural (H2)	
TP102-1	400 to 800	Natural (H2)	
TP104-1	0 to 400	Natural (H2)	
TP104-2	(+)1200 to 0	Fill (H1)	Above ground surface
TP105-1	(+)300 to (-)300	Fill (H1)	300 above to 300 below natural ground surface
TP105-2	300 to 900	Natural (H2)	
TP108-1	100 to 450	cemented sand (H1B)	
TP108-2	450 to 650	clay (H2)	
TP108-3	Aprox 2000	clayey sand (H2)	
TP108-4	2400 to 2800	sand (H2)	
TP110-1	0 to 150	Topsoil (H2)	
TP110-2	150 to 900	silty sand (H2)	
TP112-1	0 to 700	Fill (H1)	
TP112-2	1000 to 1600	cemented sand (H2)	
TP113-1	300 to 1100	silty clay (H1)	
TP114-1	500 to 600	gravel (old haul road?/H1)	
TP117-1	300 to 1000	fine to coarse sand (H2)	
TP122-1	0 to 650	Fill (H1)	
TP122-2	1000 to 1400	fine to coarse sand (H2)	
TP125-1	(+)500 to (-)100	Fill (H1)	500 above natural ground surface to 100 below ground surface
TP125-2	100 to 900	Natural cemented sand (H2)	

8.2 Conditions Revealed

8.2.1 Fill Material - Horizon H1

92. I have summarised the types of fill materials encountered in the test pits and trenches under six categories as set out below under items a to g, together with typical photographic examples:

   a. A thin layer of sandy fill with thicknesses of up to about 500 mm along the access track on the western levee bank. This is sometimes mixed with gravel. This layer may not represent a deliberate attempt at placing fill – it could have accumulated as spillage from truck movements or be a result of local filling of pot holes. *This layer was encountered in or inferred from TPs 101-4, 102-4, 103, 104, and 111-3 (see Plate 10).*

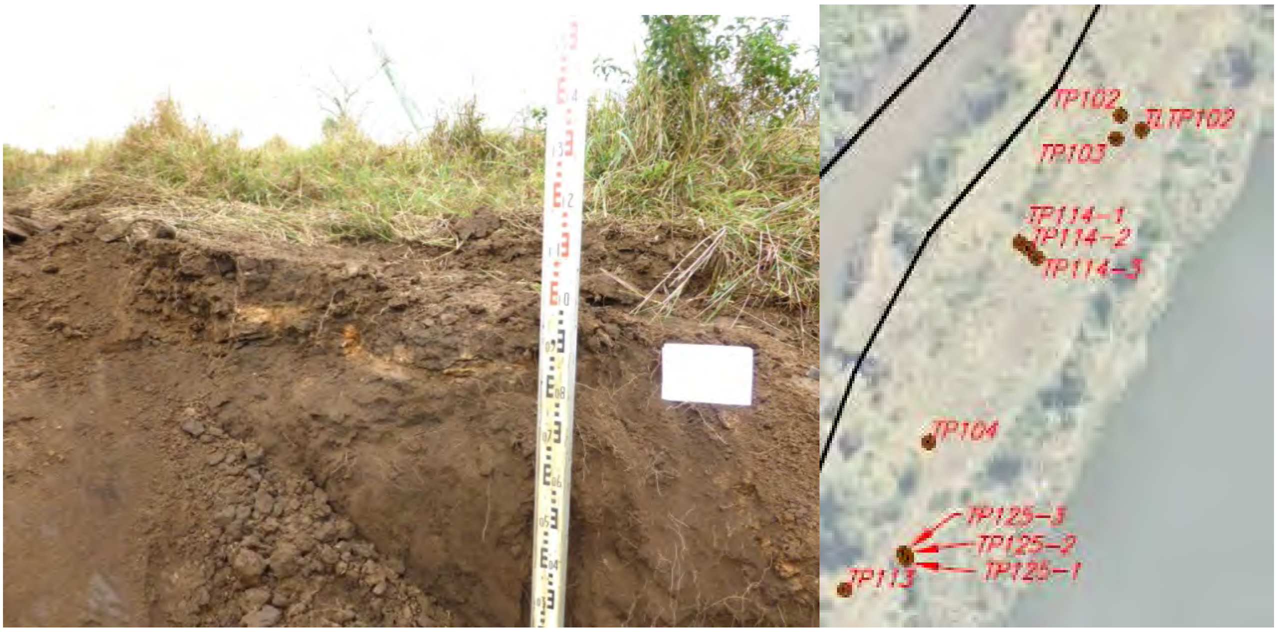


Plate 10: Thin layer of fill and topsoil adjacent to access track, TP101

   b. Fill material within remnant bunds along both sides of the access track southern portion of the western levee bank. I consider that the bund fill material on the western side of the access track to be a sandy CLAY, of stiff to very stiff consistency, showing random structure and inclusions of gravel and organic material. I do not know how this material was placed and compacted although air photo evidence suggests that it was dumped by a front-end loader. It is possible that the basal fill layers were track rolled, although the bunds are generally too narrow to allow safe access for large compaction equipment.

c. The fill/natural interface is illustrated in Plate 11 below (TP104). *Test pits TP104, 105, 106, 107, 112, 113, and 125 were excavated at the toe of remnant bunds.*

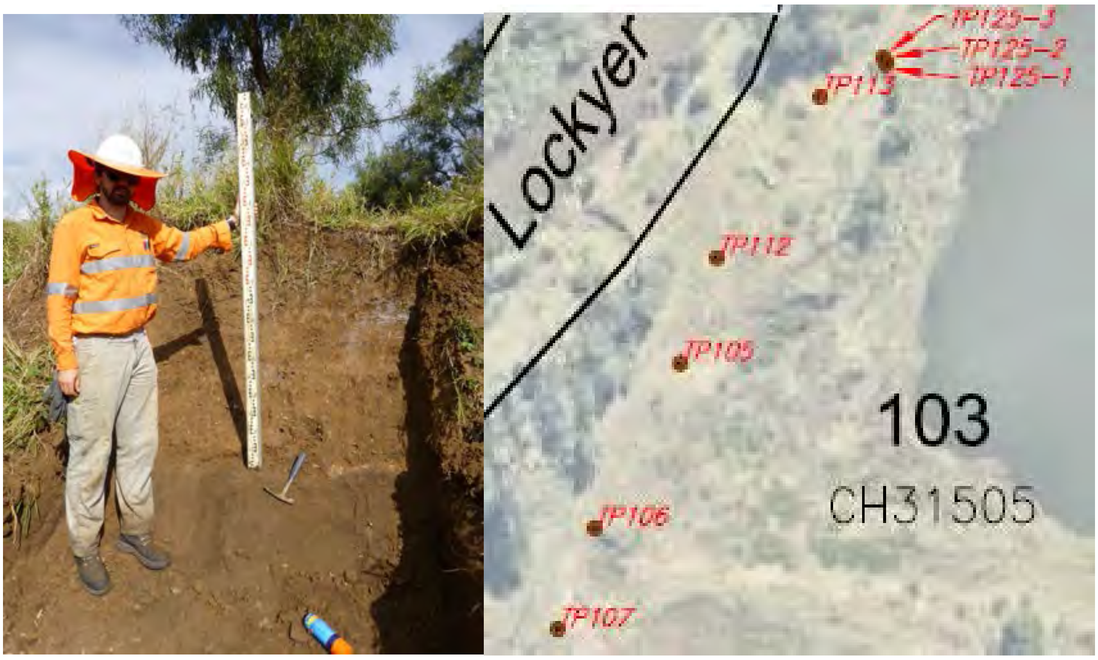


Plate11: Interface between remnant bund fill and natural alluvium, TP104 (base of staff is on interface)

d. A layer of fill in the northern west portion of the quarry site which I observed to vary between about 300 mm and 1.0 m thick, and is probably a result of past quarrying activities (stockpiles and processing operations), and more recently from earthmoving operations after the 2011 flood. The fill platform can be observed in this part of the site on Google Earth image dated 12 August 2011 (see Plate 12, TP 117 and Plate 13 TP 115). *This layer was encountered or inferred from TPs 115, 117, 118, 119 and 120.*

Plate 12: Interface between coarse sand – (possibly reworked material) and alluvium, TP117

Plate 13: Interface between general fill and natural alluvium, TP115

e. Stockpiles in the north east portion of the site, now with grass cover. I do not know whether these were topsoil mounds, waste from processing, or product stockpiles. *The interface between the stockpile material and "natural" ground was investigated by TPs 119, 121, 122, and 124, all excavated at the toe of stockpiles (see Plate 14).*

Plate 14: Interface between stockpile fill and natural alluvium, TP119

f. Stockpiles in the southern side of the quarry lake, now with grass cover. Again I do not know whether these were topsoil mounds, waste from processing, or product stockpiles. The former operators of the quarry would be able to confirm the origin of these and similar fill mounds on the quarry site. The 2008 Survey Plan discussed under Section 11.0 of this report labels them as “dirt mounds”. *The interface between the stockpile material and “natural” ground was investigated by TPs 107, 109 and 110, all excavated at the toe (see Plate 15).*

Plate15: Interface between stockpile fill and natural alluvium, TP109

g. Fill material used to backfill the main breach at the northern end of the western bund. I infer that this operation included levelling and infilling of a low spot immediately north east of the breach, as TP116 encountered at least 1.6 m of fill containing concrete waste, boulders and plastic (see Plate 16). I note that there was formerly a haul road to the quarry lake at this location (see Sections 10.0 and 12.0 of this report).

Plate 16: Fill material adjacent to main breach backfill area, TP116

8.2.2 Quaternary Alluvium – Horizon H2

93. The Quaternary Alluvial soils adjacent to the incised bed of the Lockyer Creek are terrace and flood plain deposits, which have probably developed over the last 30,000 years. A characteristic of the Lockyer Valley is the series of extensive, deeply incised valleys (*Land Resources Bulletin QNRM 01215, Queensland Natural Resources & Mines, 2002).*

94. A detailed analysis of the alluvial soils is beyond the scope of this report, but the natural surface profile within the Lockyer Creek flood plains is described to be generally 0.3−0.7 m thick, dark coloured, moderately structured and comprising loam to clay texture range, i.e. a mixture of sand, silt and a small amount of clay. (*Ref QNRM 01215, Op Cit).*

95. The top soil is underlain by buried soil layers, comprising of gravel, cobble, overlain by sand or finer sedimentary layers (Quaternary Alluvium).

96. The Quaternary Alluvium was encountered in all test pits with the exception of TP116, (which contained backfill associated with the breach filling operation undertaken after the flood during 2011).

97. I assess that the alluvium encountered in the test pits was generally a mixture of silt, fine sand with some clay. The grading of the material is consistent with origin as an intermediate terrace deposit, which would have been deposited as a result of intermittent flood events.

98. I observed that the silty fine sand is generally compact and partially cemented (probably due to carbonate content). Structural features observed within the sand were limited to occasional faint layering, and thin sand lenses and organic inclusions (see Plate 17).

Plate 17: Faint layering within alluvial silty SAND, TP109

99. In almost all cases, the interface between fill material and underlying natural alluvial deposits could be clearly recognised. It is acknowledged however, that in the north of the quarry site, there is a possibility that material between test pit locations inferred to be in situ natural alluvium is re-worked alluvium or spoil material, as a result of backfilling of the first stage of workings, or the earthworks undertaken post flood in 2011. This is discussed further in Section 8.2.4 and Section 11.

8.2.3 Residual Sandstone

100. I infer that the material encountered below a near surface layer of compacted sand in TP108 may be residual soil derived from weathering of the underlying Marburg Formation sandstone. The pit was extended to a depth of 2.8 m in an attempt to reveal relict bedrock structures or rock fragments.

101. The overlay of geological boundaries onto the 1982 air photo as depicted in Plate 9 (Section 6 of this report), indicates that TP108 is located on an area where sandstone is expected to be present beneath superficial deposits.

8.2.4 Previous backfilling of early stage of workings

102. I have superimposed test pit locations onto a 1982 Air Photo – see Plate 18 (Photo Ref QAP4014-13, source DERM)

103. It can be seen that three of the test pits are close to what I interpret to be an early stage of quarry workings

Plate 18: Test pit locations in relation to 1982 landscape

104. I assume that the early workings were eventually backfilled, and subsequently covered by stockpiles visible in the Google Earth imagery of 30 December 2005

9.0 MODEL OF PRE-EXISTING NATURAL GROUND SURFACE AT SITE OF QUARRY

9.1 Air photography 1982

105. As discussed in Section 6, stereographic air photo images have been obtained from Department of Environment and Natural Resources covering the Grantham area. The 1982 air photography was flown on 13 May at a height of 4300 m ASL, and three images – Run 9342 Q4014 Number 11, 12 and 13 were found to be relevant to the current assessment. I have examined these images using a mirror stereoscope.

106. The stereoscope allows height information to be assessed by means of viewing overlapping stereo pairs. The height information is exaggerated (depending on the interval between adjacent photographs), which allows landforms to be identified and relative heights to be gauged.

Plate 19: Oblique view generated from 1982 air photo showing relief interpreted from stereoscope

107. I have generated Plate 19 from one of the air photos to provide a visualisation of the relief which can be seen when viewing the air photos with a stereoscope.

108. It can be seen from Plates 20a and 20b, which show the test pit locations in relation to (a) the 1982 air photo and (b) a recent Nearmap image, that the test pits in the southern end of the site are located on the northern crest of the strip of land labelled on Plate 11 as “higher relief in this area”.

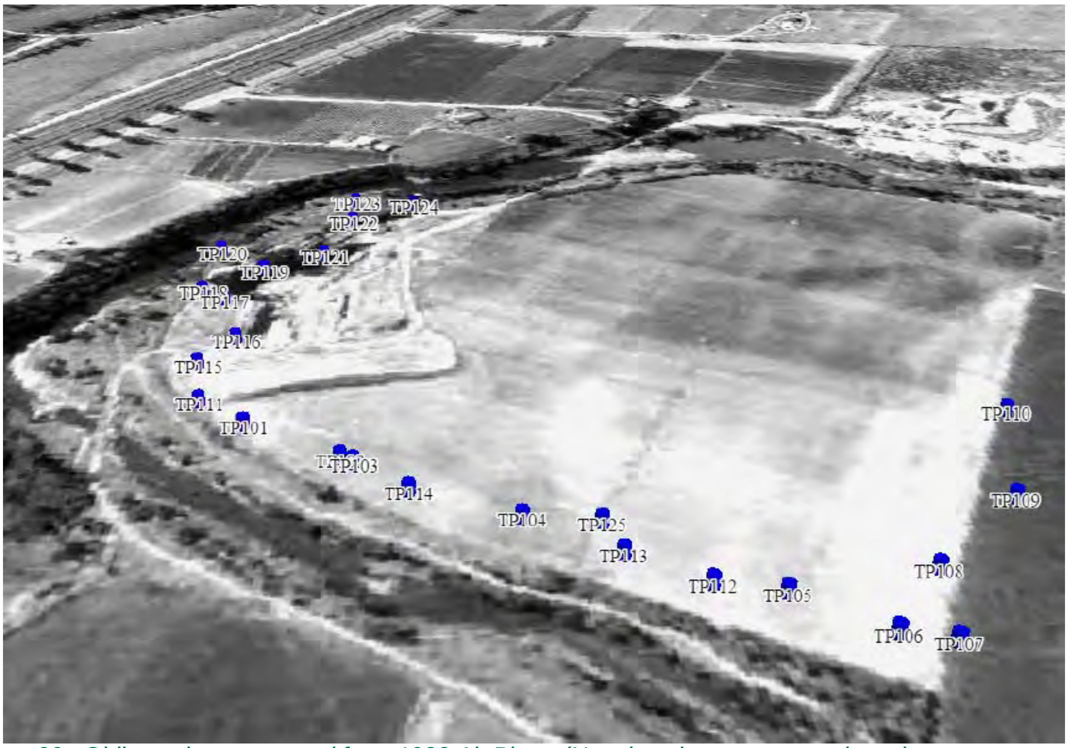
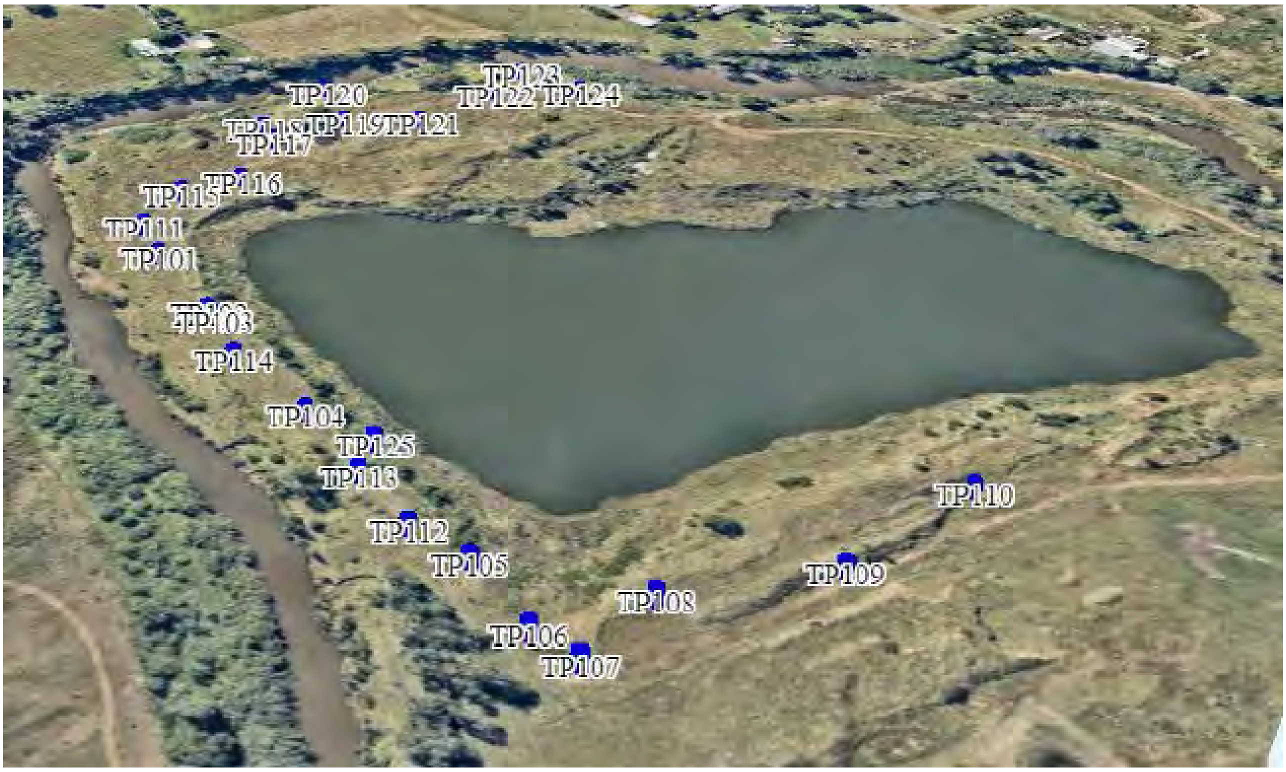


Plate 20a Oblique view generated from 1982 Air Photo (Note locations are approximate).



Plates 20b: Oblique view generated from Nearmap Image May 2015 showing test pit locations.

109. Based on the features shown in Plate 19, I infer that the topography prior to development of the quarry comprises an alluvial flood plain bounded on three sides by the incised course of the Lockyer Creek. The land use prior to quarrying was for agriculture.

110. There is a slight fall to the north over the majority of the area now occupied by the quarry lake. There is a ridge of higher elevation running approximately east-west (labelled "higher relief in this area" on Plate 19, Page 25). The land falls to the north and south of this ridge. To the south of the ridge, there appears to be a depression which may have been a former course of Lockyer Creek.

111. I believe that the area of higher relief in the south to be underlain by weathered Marburg Sandstone. The quarry lake appears to have been extended to the boundary between alluvium and weathered sandstone (I presume to the limit of workable alluvial deposits).

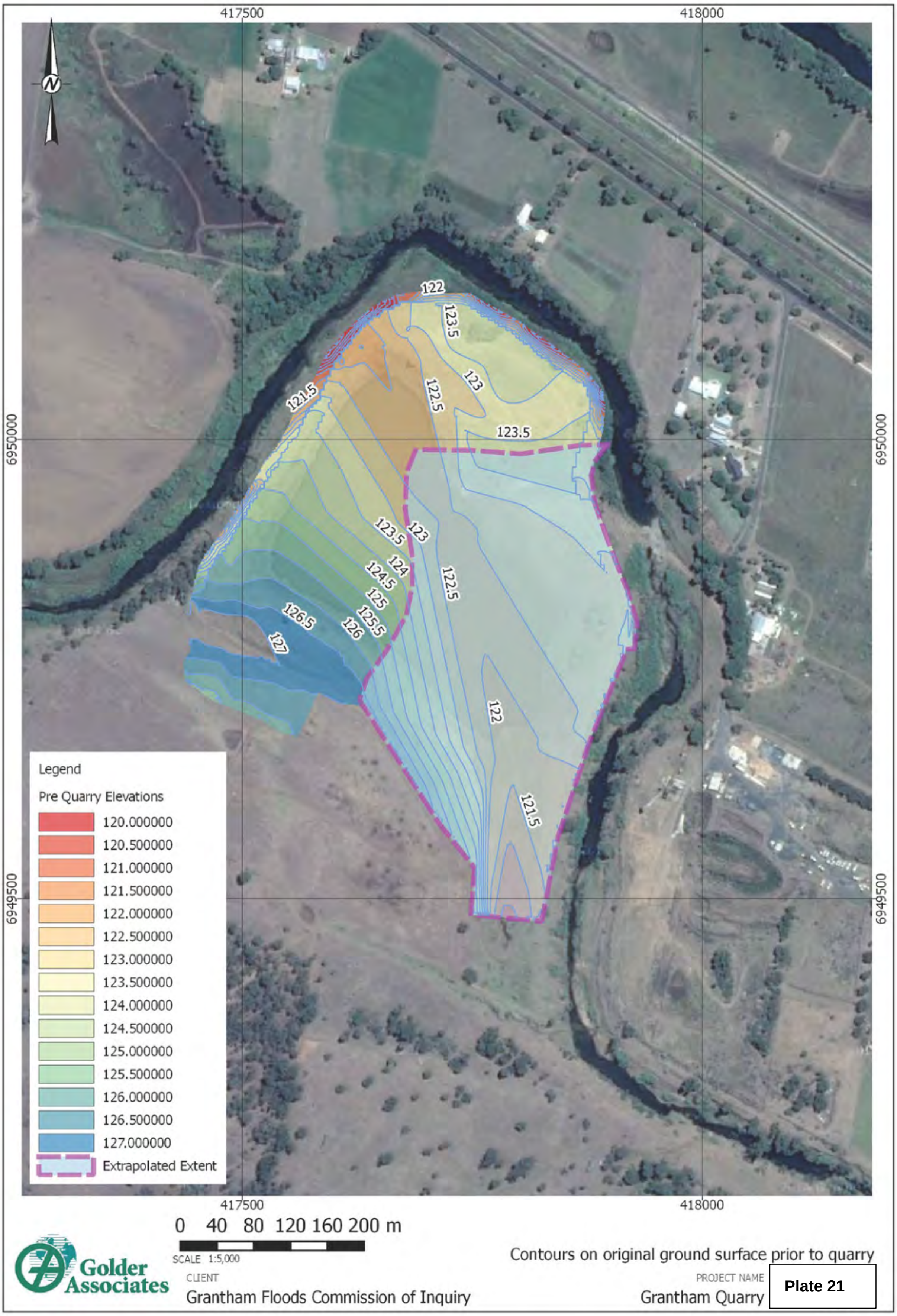
112. I infer that Test Pits 108, 109 and 110 are probably located on the weathered sandstone outcrop. TP108 was taken to a depth of 2.6m, and in my opinion may have encountered residual sandstone. TP 109 and 110 were shallow, and proved only the interface between a fill stockpile and interpreted top of natural ground.

9.2 Data from observations in test pits and trenches

113. AHD levels recorded for the H2 horizon (Quaternary Alluvium) in each of the test pits are tabulated in the plan generated by North Surveys (included in Appendix D). My interpretation of the data points indicates that the natural ground surface falls from approximately 128 AHD in the south to about 124 AHD in the north, with a low point of about 122 AHD towards the northern end of the western levee (see Figures 1 to 3 presented after the report text).

114. The contoured surface of the interpreted pre-existing natural ground is shown below in Plate 21. This surface has been plotted based on the top of H2 data points, and I believe it to be consistent with the inferences made from the 1982 air photo, at least for the southwest, western and northern portions of the quarry.

115. The contours in the southeast of the quarry area (shown contained within light blue shading), have been extrapolated beyond available data points. Other interpretations are possible, and the contours in this area could be further refined if detailed pre-quarry contour data were available.


417500
418000
6950000
6949500
122
123.5
123
122.5
121.5
123.5
123.5
123
124
124.5
125
125.5
126
126.5
127
122.5
122
121.5
Legend
Pre Quarry Elevations
120.000000
120.500000
121.000000
121.500000
122.000000
122.500000
123.000000
123.500000
124.000000
124.500000
125.000000
125.500000
126.000000
126.500000
127.000000
Extrapolated Extent
0 40 80 120 160 200 m
SCALE 1:5,000
CLIENT
Grantham Floods Commission of Inquiry
Contours on original ground surface prior to quarry
PROJECT NAME
Grantham Quarry
Plate 21

10.0 NATURE & EXTENT OF THE EMBANKMENTS SURROUNDING THE QUARRY PRE 2011 FLOOD

116. Pre-flood heights of fill have been modelled under my supervision by a Golder GIS specialist, by adding the natural surface shown in Plate 21 to the pre-flood contour data, and showing the difference between two surfaces as colour coded fill heights. Figure 21 shows my interpretation of the pre-quarry ground surface derived the test pit data points, overlain on a recent Nearmap image of the site. The resulting model is shown as heights of fill above natural surface in Figures 1 to 3 (colour coded only) and Figures 1A to 3A (colour coded and surface level contour data added).

117. The interpreted heights of fill are illustrated in ranges of 0.1 to 1.0 m, 1 to 2 m, 2 to 4 m, 4 to 6 m and 6 to 8.7 m. Sections along the western bunds are presented as A - A' and B - B' on Figures 2 and 2A.

118. An oblique 3D view of the western levee has also been generated under my supervision to show height information, and these visualisations are shown as Figures 7 (with colour coded heights) and 7A (without colour coding). I have labelled features of interest on the bunds either side of the access track, in order to illustrate the conclusions drawn below.

119. I can draw the following conclusions from these figures:

   a. There was a narrow fill bund along the western levee between the access track and the edge of the quarry lake. This bund was about 4 m in height (the colour coding suggests between 2 and 6 m, and a study of the contours indicates a mean value of about 3 to 4 m). See Figures 2 and 2A, Section A – A', and Figures 7 and 7A (oblique views).

   b. A low point at the northern end of the western levee is labelled, together with low points in the eastern bund. At the southern end of the bund, the ground level is close to pre-existing natural ground level (see Figures 7 and 7A).

   c. There was a narrow bund along approximately 50% of the length of the western levee, on the western side of the access track (i.e. Lockyer Creek side). This bund was about 2 m in height (the colour coding indicates between 1 and 2 m). See Figures 2 and 2A and cross section B – B'.

   d. Fill heights of less than 1 m (coloured green 0.1 to 1.0 m) are interpreted along access tracks and in other areas around the perimeter of stockpiles.

   e. The bund along the western side of the access track is also shown on Figures 7 and 7A.

   f. Stockpiles up to 6 m in height were located to the south of the quarry lake, and up to about 8 m on the eastern side of the north lake area (see Figures 2 and 2A and 1 and 1A respectively).

   g. Fill heights of about 1 to 4 m are indicated within and around a smaller stockpile at the northern end of the western levee. See Figures 1 and 1A.

   h. There was a low point in the topography at the northern end of the western levee, where fill heights were less than about 1 m. This is where the main breach occurred during the flood event (see Section Line A – A' on Figures 2 and 2A). I note that from about 2000 to 2005, there was a haul road going from the access track to the quarry lake at this point (based on an oblique air photo included in a witness statement by Mallon, and Google Earth Imagery dated December 2005). I discuss this further in Section 12.2.. The low point is labelled on Figures 7 and 7A.

   i. There was also a haul road in 2005 near the southern end of the eastern bund where labelled "Apparent Gap in Eastern Bund" on Figures 7 and 7A.

j. Figures 3 and 3A show stockpile heights on the eastern end of the southern side of the quarry. The available data has not been extrapolated further east to show height above pre-existing natural surface in the eastern side of the quarry lake.

11.0 OPINION ON MATERIAL REMOVED DURING AND AFTER THE 2011 FLOOD

120. A further set of figures has been generated to show differences in heights between the pre-flood and post-flood LiDAR contours. The comparison is presented as Figures 4 to 6, on which the decrease in surface levels (i.e. material eroded by the flood) is colour coded with values ranging from 0 to 1 m, 1 to 2m, 2 to 4 m, 4 to 6 m and 6 to 8.9 m. The western levee is also shown as oblique views in Figures 8 and 8A.

121. It can be seen from Figures 4 and 5 that at least 6 m of material was eroded within the main breach at the northern end of the western levee. The breach is about 50 m at its widest point.

122. Figures 4 and 5 indicate that erosion occurred along the eastern bank of Lockyer Creek (on the western side of the levee bank). Similarly, erosion occurred along the western and southern shores of the quarry lake (Figure 5).

123. Substantial portions of the artificial bund along the eastern side of the access track described under Section 10 above, were eroded/removed by the flood event. Two remnants remain, one in the south approximately 40 m in length and another further north about 10 m in length.

124. These remnants are labelled on Figures 8 and 8A.

125. Similarly, I infer that portions of the artificial bund along the western side of the access track described above were also eroded/removed by the flood event (see Figures 4 and 5). Three remnants remain along the western bund and these are labelled on Figures 8 and 8A.

126. The remnants are shown on the extract from an air photo taken immediately after the flood between 18 and 22 January 2011, presented as Plate 22.

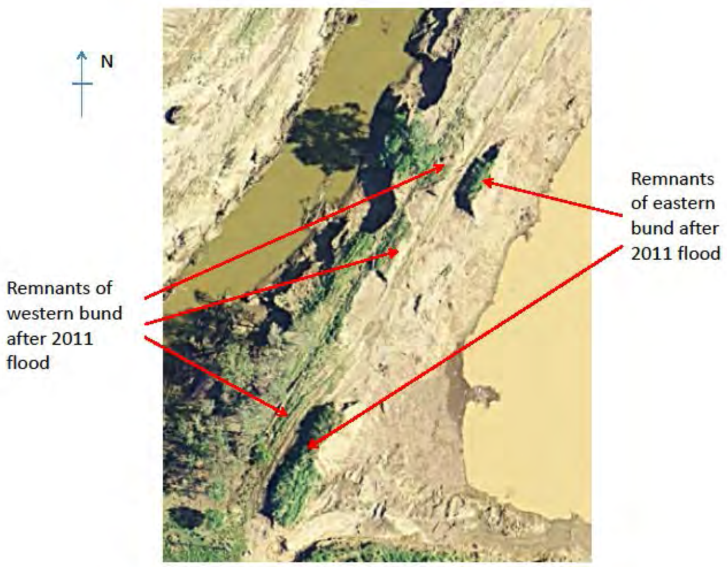


Plate 22: Extract from 2011 Air photo showing remnant sections of bunds after flood event

127. Portions of the stockpile in the northern part of the site immediately east of the breach were eroded by the flood, with height reductions in the range 2 to 4 m (see Fig 4). The main stockpile in the northern area referred to above under Paragraph 113 (f) above was eroded along the western fringes, with height reductions of up to about 6 m (see Figure 4).

128. Portions of the banks of the quarry lake on the eastern portion of the site were also eroded by the flood event (see Figure 4).

129. At the southwest end of the western levee, where there was a natural break compared with fill heights to the north, approximately 1 to 2 m of material was eroded (see Fig 5).

130. In the period following the flood, I understand from a submission to the Queensland Floods Commission of Inquiry prepared by Amanda Gearing (dated 7 November 2011), that earthworks were undertaken in the north west portion of the quarry (see photograph below reproduced as Plate 23).

Aerial photo 2011 post-flood, looking east from the quarry and showing the remains of the northern wall around the quarry being demolished. Grantham town is in the top left of the photo.

Plate 23: Oblique air photo included in submission prepared by Amanda Gearing taken in 2011 (exact date and source unknown).

131. I infer from examining this photograph that material forming a stockpile in the NW corner of the site and visible on Figure 4 (differences in heights between the pre-flood and post-flood LiDAR contours – Plan North), was used to fill the breach in the western levee. I can see that the breach has been partially filled at the time the photo was taken.

132. A further photo included in the submission by Amanda Gearing shows earthmoving equipment (see photo below reproduced as Plate 24).

Heavy equipment demolishing part of the remaining earthen wall on the northern side of the Grantham quarry.

Plate 24: Photo of earthmoving equipment included in submission prepared by Amanda Gearing (exact date unknown).

133. The lack of grass cover on a stockpile visible on the south side of the quarry in Figure 23 (oblique air photo), indicates to me that some material was moved from this area after the flood.

134. From my inspections and evidence available at the time of preparing my report, I believe that the material removed from the parallel bunds along the western levee was a result of erosion during the 2011 flood event (i.e. not removed by earthworks in early 2011).

12.0 OPINION ON THE METHOD OF FORMATION AND SOIL PROPERTIES OF THE EMBANKMENTS SURROUNDING THE QUARRY PRE - 2011 FLOOD

12.1 Introduction

135. In the time available to prepare this report, it has not been possible to research a complete history of the construction of the quarry lake and associated earthworks.

136. Stereographic air photos have been sourced from *the Queensland Government Business and Industry Portal Air Photo Library*, and are discussed in Section 12.4.

137. The Google Earth and Nearmap images described in Section 6.0 of this report assist in forming my opinion on the development of the quarry from 2005. However, these images do not provide calibrated data on topography or heights of stockpiles and bunds.

138. It has been possible to identify plans, photos and oblique air photographs from witness statements which provide some information at particular points in time.

139. My examination of material in test pits either side of the access track along the western levee indicates that clayey sand material was probably sourced from quarrying operations to construct the bunds.

140. The lower portions of the bunds may have been compacted or track rolled. However, I did not observe layering in exposed sections of the remnant bunds to indicate construction in layers.

141. There is evidence in Test Pit 119 of at least two phases of construction of the bunds. I discuss this in further detail in Section 12.6.

142. The following sections are directed at examining the history of earthworks along the western levee.

12.2 Oblique air photos

143. An oblique air photo included in the submission by Amanda Gearing referred to above, is dated 1985 (i.e. approximately 3 years after quarrying operations commenced).

Grantham quarry and surrounding farmland taken in approximately 1985.

Plate 25: Oblique air photo included in submission prepared by Amanda Gearing 1985 (source and exact date unknown).

144. The photo appears to have been taken viewing the quarry from the NE, and shows that a substantial strip of land to the west of the quarry lake had not been removed by quarrying operations. The colour of the exposed surface suggests that topsoil has been removed, but I infer that ground levels are close to the pre-existing level of the agricultural land between the eastern side of Lockyer Creek and the quarry lake (see Plate 25).

145. An oblique air photo included in a witness statement by Jonathan Sippel labelled JS-1 is shown below as Plate 26 (dated July 97). It appears to depict the north end of the quarry site in the middle distance (no apparent grass cover but some small trees). The northern end of the lake can just be seen. There appears to be some vegetation along the north-eastern levee (behind the lake). I cannot determine with certainty whether there are bunds above the natural ground level.

Plate 26: Oblique air photo included in statement prepared by Jonathan Sippel (date shown as July 1997 and supported by stereo air-photos dated August 1997).

146. An oblique air photo included in a witness statement by Charmaine Mallon labelled CDM-4 is shown below as Plate 27a (dated April 2000 and verified by a receipt). The photo is taken from the north of the quarry (the Helidon to Gatton Road and the railway can be seen in the foreground). I can identify the northern end of the western levee, and a haul road going down to the edge of the quarry lake. I can see some stockpiles of material along the west side of the lake, and possibly some earthmoving machinery. Based on Plate 27b which is an enlargement of a cropped section of Plate 27a, there may be a cutting alongside the haul road. Because the field of view is cut-off at the right side (western end), I cannot see the access track along the western levee, and am not able to comment on the presence of any bunds either side of the track.

Plates 27a and 27b. Oblique air photo and detail, April 2000 (witness statement C Mallon, CDM-4)

12.3 Survey Plans

147. A source made available by the Commission of Inquiry entitled “Wagner’s Supplementary Documents” includes a survey plan dated 21 January 2008 entitled “Detail Survey – Wagner Grantham Concrete Plant”. This plan was prepared by OWR surveyors and was signed 6 June 2008. Sheet 4 of the plan (page 93 of the documents) is reproduced below as Plate 28.

148. Plate 28 (Sheet 4 – Survey Plan), indicates that bunds had been formed either side of the access track on the western side of the quarry lake, with maximum heights of about 128.5 AHD on the eastern side of the track, and 126.4 AHD on the western side. The spot height values can be deciphered on an enlargement of the survey plan covering the western bund, presented as Plate 29.

149. The access track along the western levee falls from about 125.3 in the south to 124 half way along, to a low point of 122.05 at the northern end of the track and 123.3 immediately east of the track (close to where the breach occurred in the 2011 flood).

150. The height data contained on the 2008 survey plan appears to be essentially the same as that shown on the 2010 pre-flood LiDAR contour plans. A CAD drawing file provided for the 2008 survey plans indicates that the contours were derived by interpolation between individual points spaced at between a few metres and 10 to 20 metres. Hence the survey plan shows contours between points as straight lines. The LiDAR survey provides better resolution and an accuracy of about 250 mm in height, and hence a direct comparison is not appropriate.

Plate 28: Survey plan of Grantham Quarry prepared for Wagner in January, 2008.

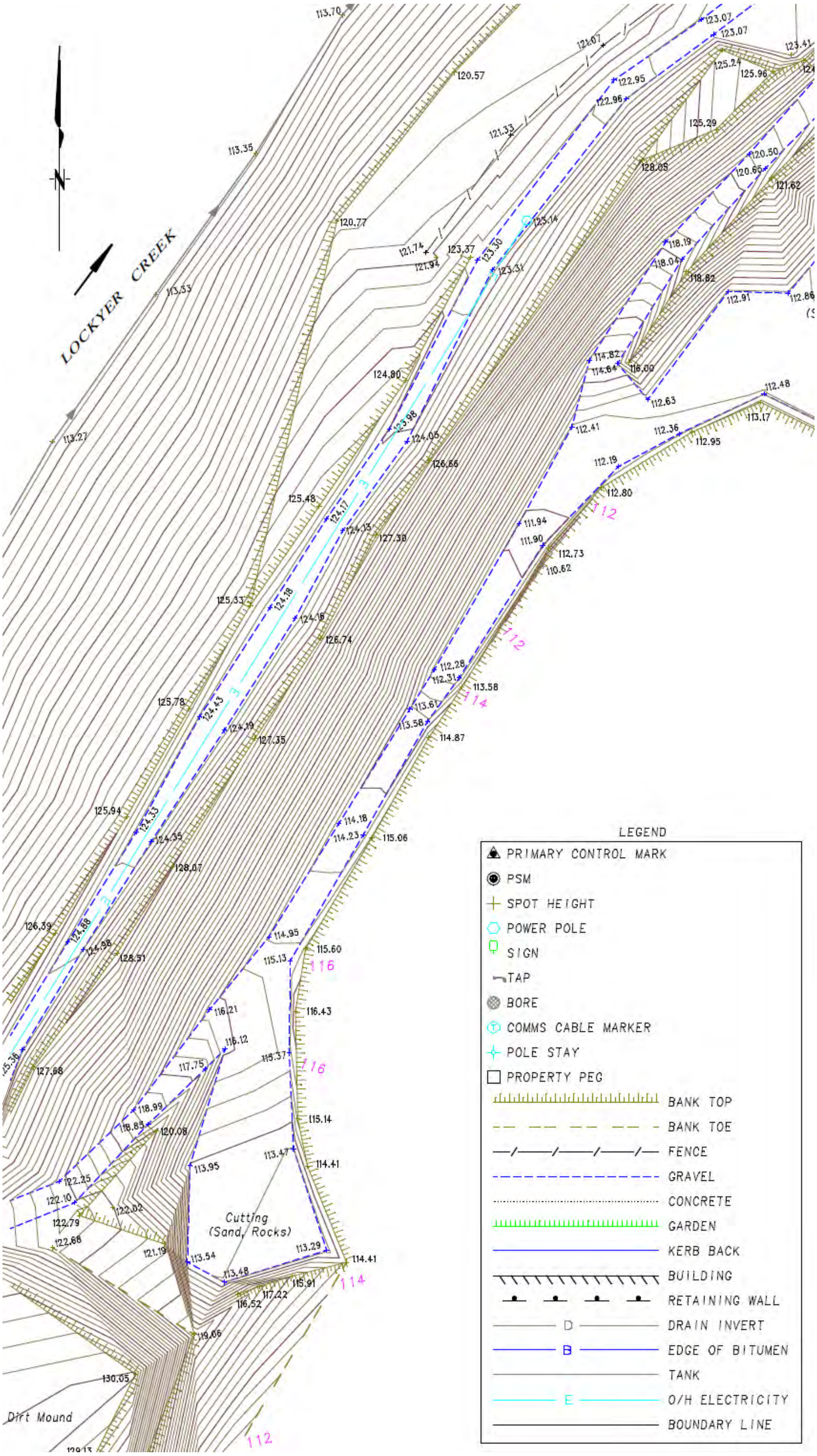


Plate 29: Detail from Survey plan of Grantham Quarry prepared for Wagner in January, 2008.

12.4 Photos taken during the 1996 Floods

151. OMITTED

Plate 30a Photo taken during 1996 floods by J Gallager (witness statement PJG-1)

Plate 30b (cropped section) of Plate 30 taken during 1996 floods by J Gallager (witness statement PJG-1)

152. OMITTED

12.5 Examination of Air Photographs covering the period 1997 to 2009

153. I have been provided with a series of stereo images of air photos covering the Helidon/Grantham area for the years 1982, 1988, 1992, 1997, 2001, 2009, 2010 and 2011. I have previously examined the 1982 photos, as discussed in Section 9.1 of this report. The 2011 photos are those used for the post-flood LiDAR imagery.

154. In the time available for a detailed examination under a stereoscope, I have selected the 1997, 2001, 2009 and 2010 air photos, by identifying adjacent stereo pairs covering the Grantham Quarry site.

155. It is not possible to show the detail available from viewing with a stereoscope in a printed report. However, I have attempted to annotate the main features on the relevant photos, by annoating one of each pair, and marking the location of the access track, and topography evident from the stereo view.

156. Figure 31a shows an annotated view of a section of air photo from 1997 (ref QAP 5558024) flown on 9 August 1997. I can see no evidence when viewed in stereo of relief associated with bunds either side of the western access track. This air photo shows the bare area in the north of the quarry site which I can see in the July 1997 Sippel oblique photo, hence appearing to confirm the date written on Sippel's photo.

Plate 31a: Air photo of Grantham Quarry, 1997

Plate 31b Enlargement of 1997 air photo showing western levee – note no bunds either side of access track

Plate 32a Air photo of Grantham Quarry, 2001

157. Plate 32a shows an annotated view of a section of the 2001 air photo (ref QAP 5903060) flown on 22 June 2001. When viewed in stereo, I can recognise features either side of the access track.

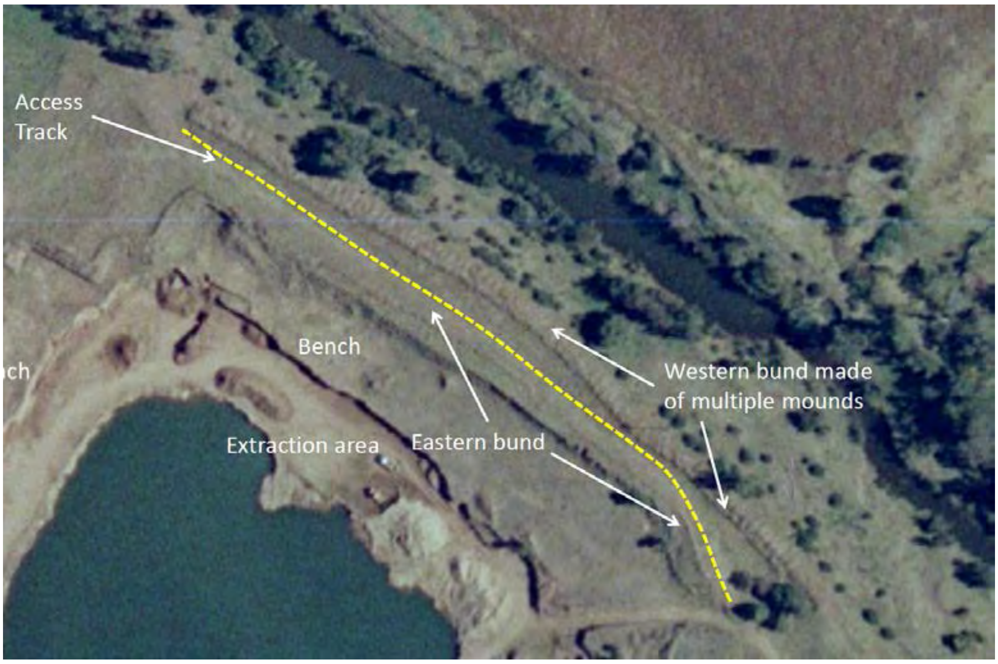


Plate 32b: Enlargement of 2001 air photo showing western levee – note multiple mounds of earth on west side of access track

158. Plate 32b shows an annotated enlargement of the 2001 air photo detailing the western levee. It is noted that the access track has migrated further west compared with 1997.

159. It appears that multiple mounds of earth along the western side of the track were formed by repeated dumping from a truck or front end loader. It is not possible to determine the exact height of these mounds from stereo viewing, but I estimate that it could be in the range of 1 to 2 m.

160. There is also evidence of a bund along the east side of the track, although it appears to be less wide and less high than the more recent western bund. The east side may also have been formed by repeated dumping from a front end loader (based on close examination of the air photo).

Plate 33 Air photo of Grantham Quarry, 2009

161. Plate 33 shows an annotated view of an enlarged section of air photo from 2009 (ref DIG70033 296), flown on 28 June 2009.

162. The bunds either side of the western access track visible under a stereo viewer are very similar to those seen in the 2010 pre-flood LiDAR imagery.

163. The available stereo air photos suggest that the bunds may have been constructed in stages between 1997 and 2009. The first evidence of their construction is from the 2001 air photos, and based on the 2008 survey plan, I infer that the form of the bunds revealed by the 2010 LiDAR data were in place before January 2008, and possibly by 2005 if account is taken of the Google Earth image for this year.

12.6 Evidence of stages of bund construction from test pitting

164. Some of the test pits along the western levee were excavated to reveal the contact between natural alluvium and remnant bunds. The face revealed in Test Pit 113 indicates that this section of bund was constructed in at least two stages, as illustrated in Plates 34 and 35.

165. I consider it likely that more extensive excavations would have found further evidence of stages of bund construction as revealed in TP 113, which was located at the northern end of a remnant bund on the western side of the track (see Plate 22, on page 31).

166. Based on the height and shape of the lower stage of bund construction revealed in Plate 34, it may be representative of the mounds observed in the 2001 air photo. I am not able to determine the time difference between the upper and lower portions.

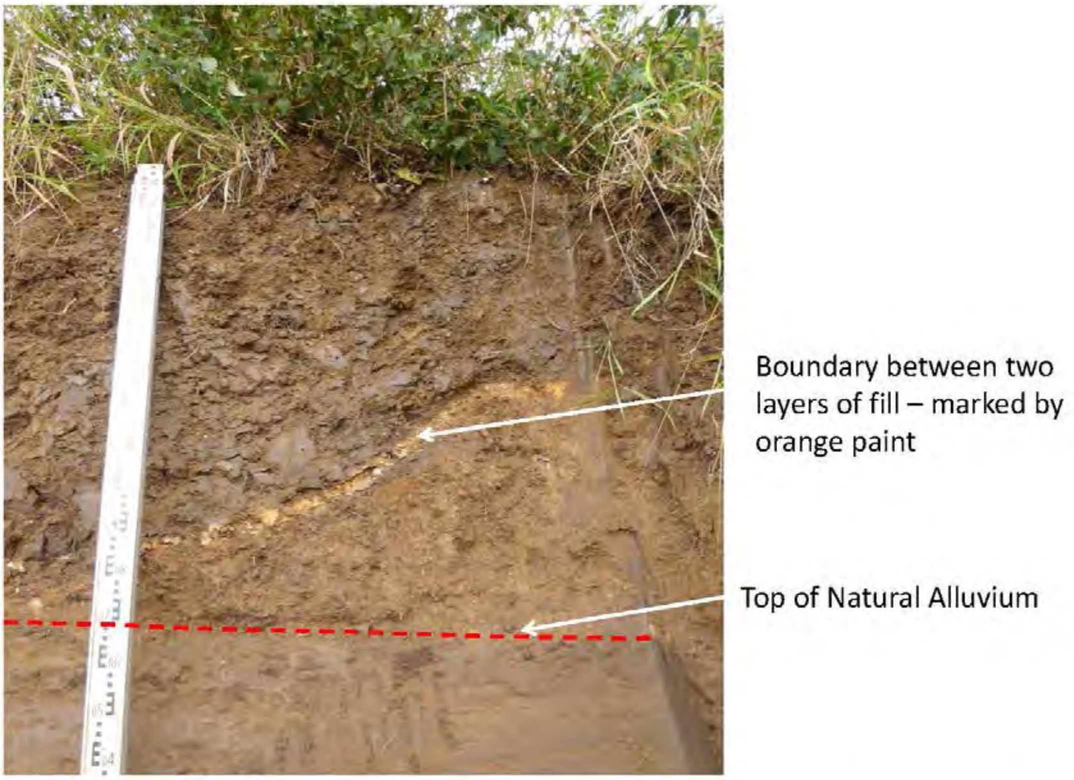


Plate 34: Test Pit 113 – Western side of access track – viewed towards south – face excavated in remnant bund

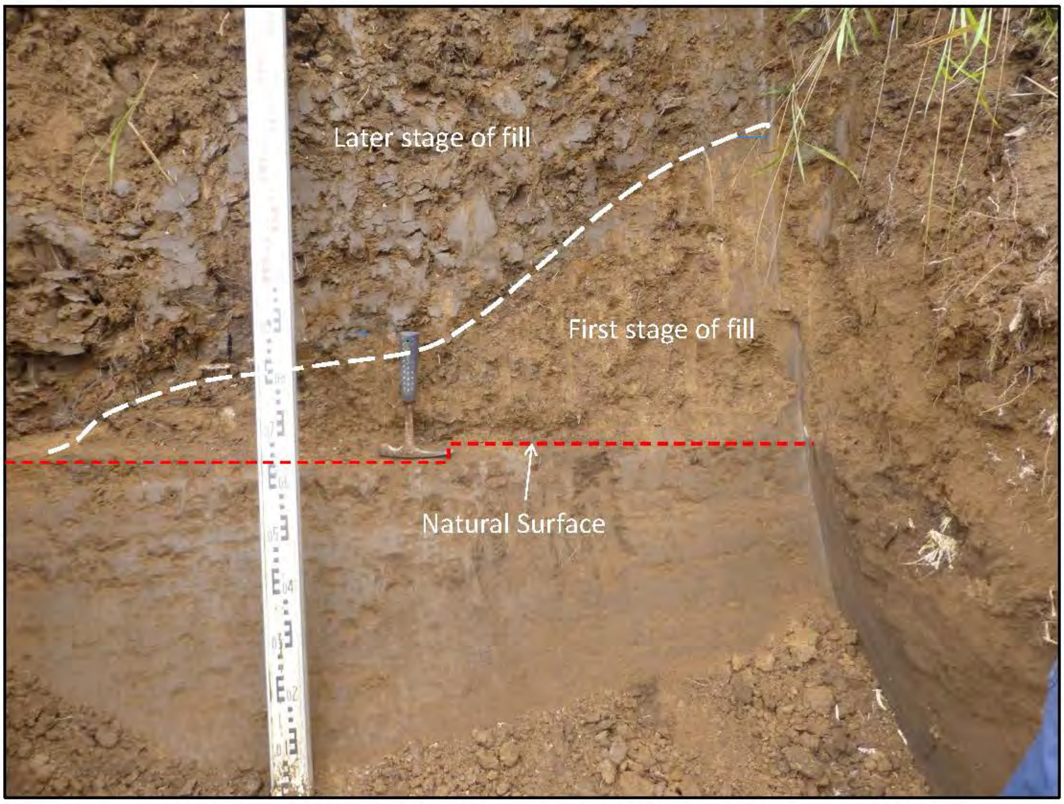


Plate 35: Test Pit 113 – Western side of access track – viewed towards south

13.0 CONCLUSIONS ON TIMING OF BUND CONSTRUCTION

167. Based on the material from witness statements, Wagner's survey plan, and the stereo air photo examinations covering the years 1997, 2001 and 2009 discussed in the sections 12.2 to 12.6 above, it is my opinion that the construction of bunds either side of the access track along the western levee of the quarry site commenced after August 1997 and before June 2001.

168. Stereo air photo images for 2001 show a multiple mounds of earth along the western side of the track. It is not possible to determine the exact height of these bunds from stereo viewing, but I estimate heights in the range of 1 to 2 m for the western bund.

169. The eastern bund appears to be slightly lower that the western bund as viewed in the 2001 air photo. If constructed in the same manner as inferred for the western bund (multiple mounds of earth dumped by a front end loader), the eastern bund material may have settled.

170. Evidence from Test Pit 113 and the air photo examination indicates that the bunds on both sides of the access track were probably developed over time in stages.

171. The Google Earth Image dated 30 December 2005 appears to indicate the presence of the bunds either side of the access track along the western levee in a similar form to shown by the 2008 survey plan, although it is not possible to determine the height of these bunds in 2005 from the Google Earth image.

172. It is evident, in my opinion, that by 2008, the location and height of the bunds were essentially the same as determined from the analysis of the 2010 pre-flood LiDAR data. I observe that the bund heights were greater than interpreted earlier from the 2001 air photos, indicating additional earthworks over time.

173. It is possible that the bunds were in place in their pre-flood form by 2005, based on the Google Earth image. However, because this imagery is not stereographic, I cannot be certain.

174. Although relative heights can be gauged from stereo air photos, determination of absolute heights would require further photogrammetric processing, based on knowledge of camera calibration data for a particular suite of air photos, and the establishment of ground control points.

175. It is not possible from the data available for me to determine exact changes in height from the time the bunds were first commenced to those as shown by contour data in the 2008 survey and 2010 pre-flood LiDAR.

176. Although LiDAR has been increasingly used as a topographic survey method in Australia since about 2000, I am not aware of LiDAR being used prior to 2010 in the Lockyer valley region.

14.0 REFERENCES

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GOLDER ASSOCIATES PTY LTD

David Starr
Principal Geotechnical Engineer
BSc MSc FIEAust CPEng RPEQ 5836

DCS/dcs/mm

A.B.N. 64 006 107 857

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FIGURES

APPENDIX A

Instructions and Documentation & Data Provided

APPENDIX B

Site Inspection Photographs

Photograph B1: Grantham Quarry – View form main breach towards East.

Photograph B2: Grantham Quarry – Original fence post – West side of levee.

Photograph B3: Grantham Quarry – View along Western levee bank showing terrace.

Photograph B4: Grantham Quarry – Track along Western levee – view towards South.

Photograph B5: Grantham Quarry – Remnants of bunds either side of track – Western levee.

Photograph B6: Grantham Quarry – Lower terrace along Western arm of Lockyer Creek.

Photograph B7: Grantham Quarry – Erosion of Western side of levee from 2011 flood event.

Photograph B8: Grantham Quarry – Close up of banded silt and sand in erosion scar.

Photograph B9 Grantham Quarry – Erosion in terrace – Western bank.

Photograph B10 Grantham Quarry – Original fence line along Western levee.

Photograph B11 Grantham Quarry – Lower terrace at Southern end of Western levee.

Photograph B12 Grantham Quarry – Track on South Side – viewed towards East.

Photograph B13 Grantham Quarry – View along Western levee trace – towards North.

Photograph B14 Grantham Quarry – East end of Southern track.

Photograph B15 Grantham Quarry – View of Quarry from South-eastern corner.

APPENDIX C

Google Earth and Nearmap imagery

APPENDIX D

Test Pit Logs & Photographs

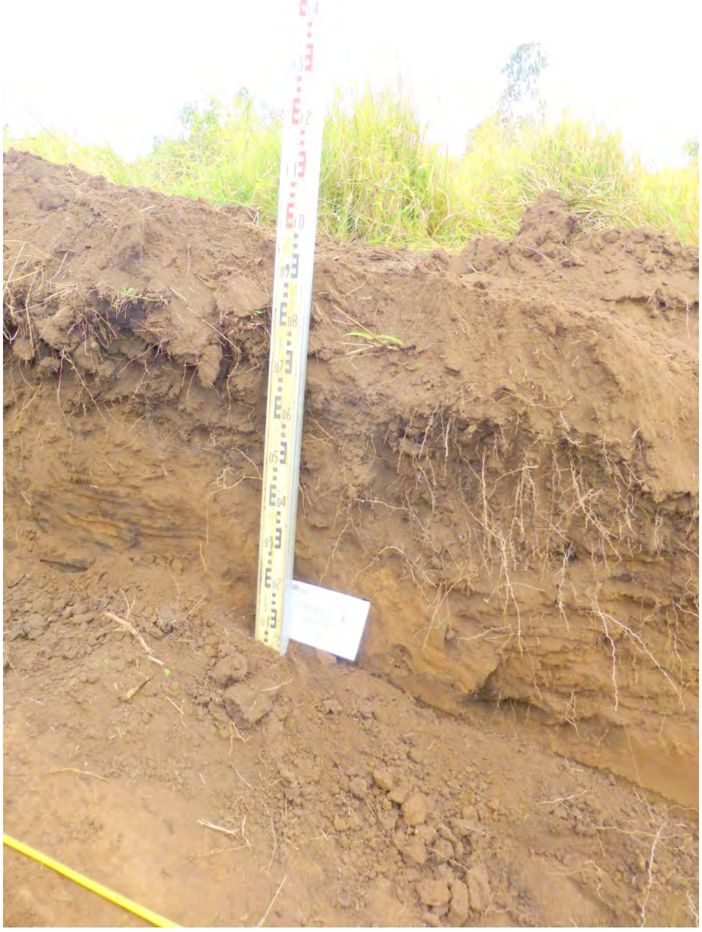
Photograph D1 – TP101 - Northside

Photograph D2 – TP101 – Eastside

Photograph D3 – TP101 – Eastside

Photograph D4 – TP101 – Eastside

Photograph D5 – TP101 – General view.



Photograph D6 – TP102 – South side

Photograph D7 – TP102 – South side base

Photograph D8 – TP104 – South

Photograph D9 – TP104 – East

Photograph D10 – TP104 – South

Photograph D11 – TP105 – South

Photograph D12 – TP105 – South

Photograph D13 – TP105 – South

Photograph D14 – TP105 – East

Photograph D15 – TP105 – East

Photograph D16 – TP106 – East

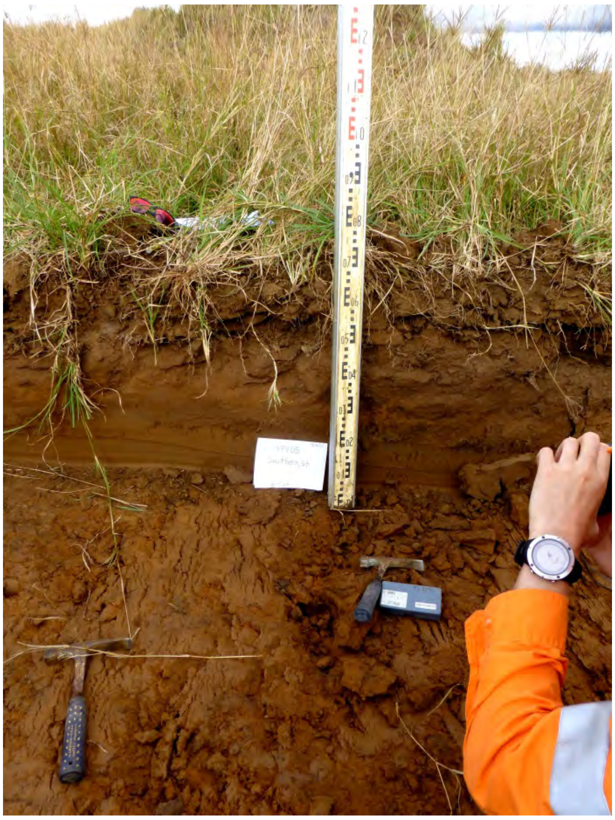
Photograph D17 – TP106 – East

Photograph D18 – TP106 – North

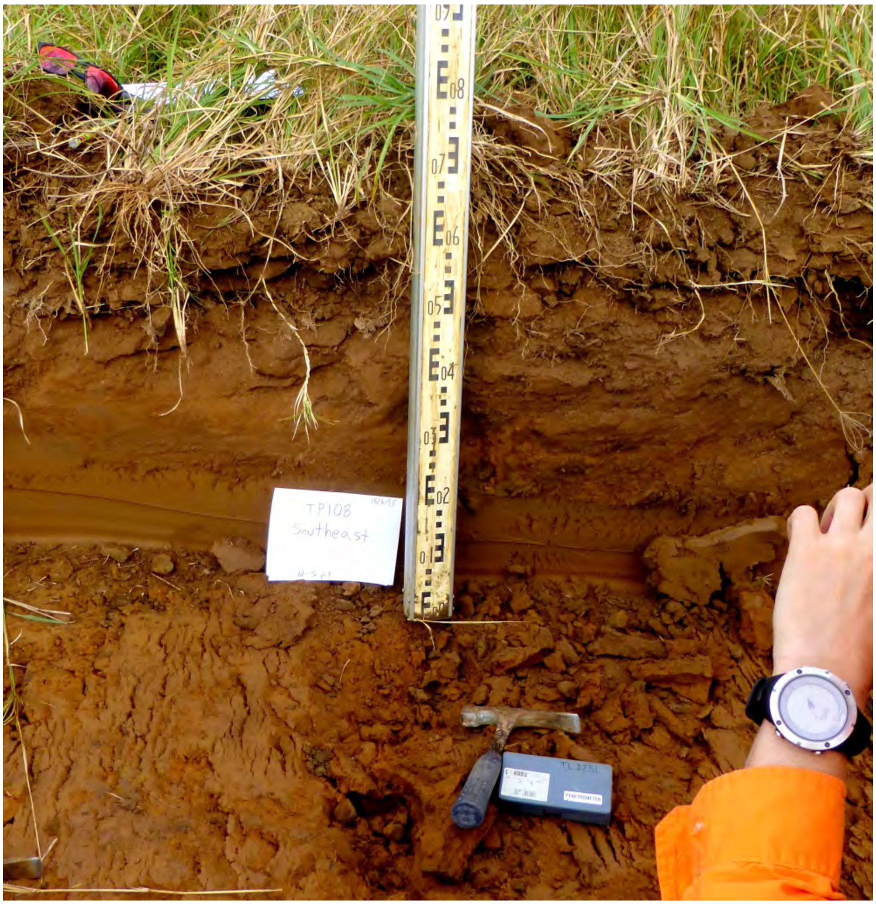
Photograph D19 – TP107 – West

Photograph D20 – TP107 – West

Photograph D21 – TP107 – West



Photograph D22 – TP108– South-east



Photograph D23 – TP108– South-east (close-up)

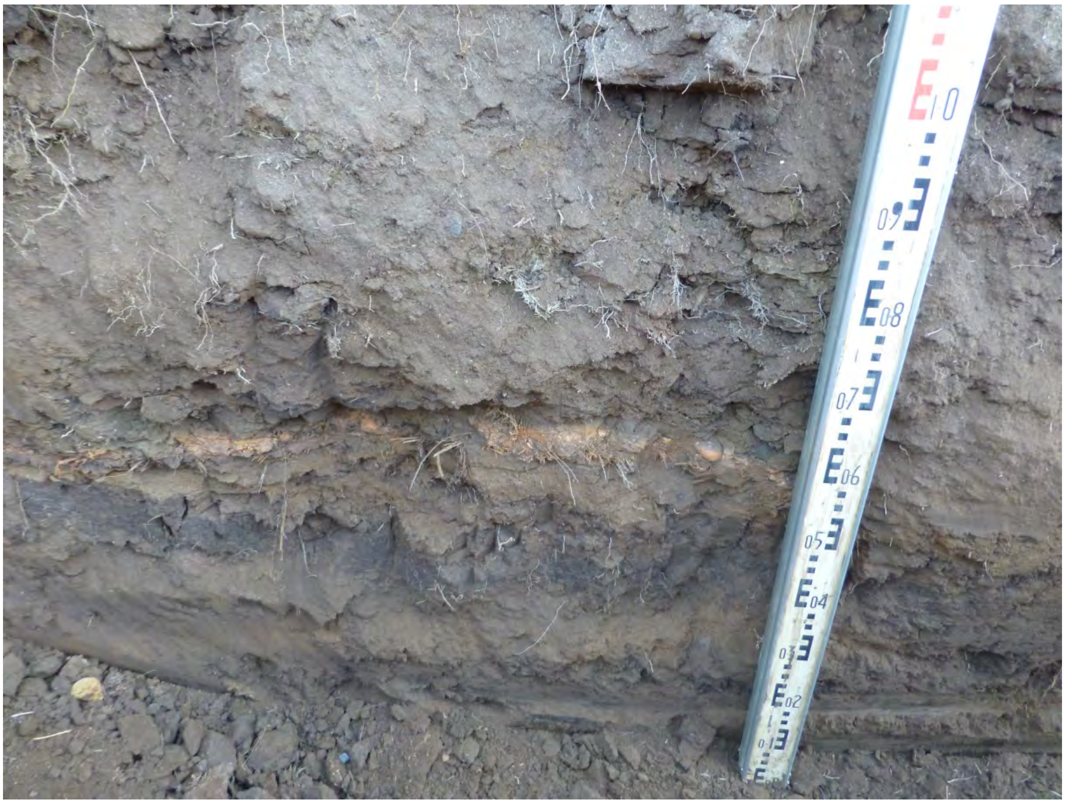
Photograph D24 – TP108– General view

Photograph D25 – TP109– West

Photograph D26 – TP109– West

Photograph D27 – TP109– East

Photograph D28 – TP110– North-east

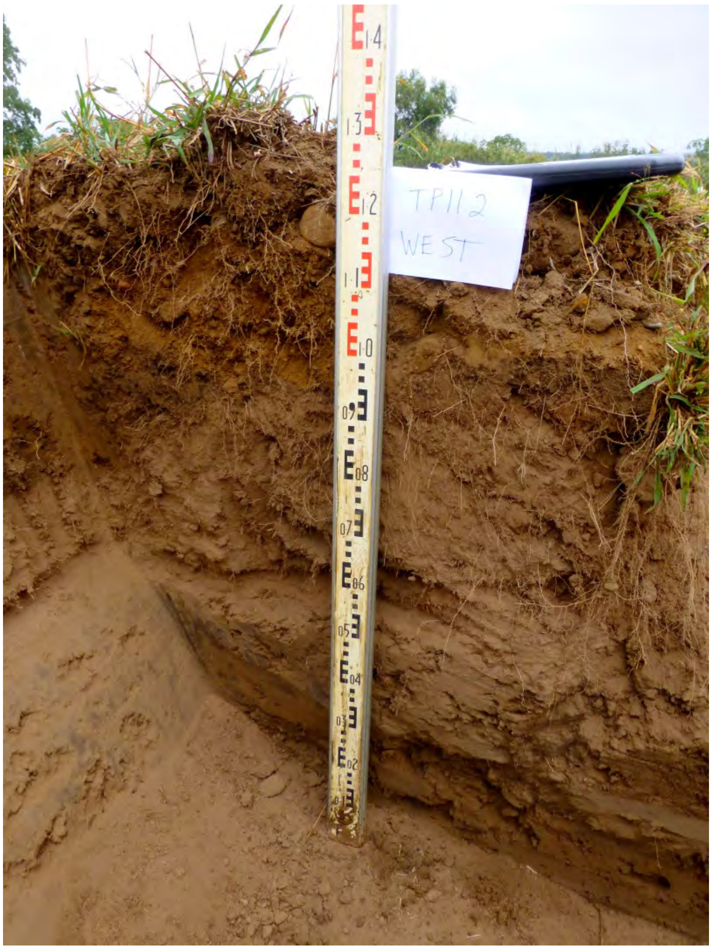


Photograph D29 – TP111– South

Photograph D30 – TP111– South

Photograph D31 – TP112– South side

Photograph D32 – TP112– Detail of fill contact



Photograph D33 – TP112– West side

Photograph D34 – TP112– General View South

Photograph D35 – TP112– General View East

Photograph D36 – TP113– North face – fill contact

Photograph D37 – TP113– Contact between two fill layers

Photograph D38 – TP114 - Excavation in progress

Photograph D39 – TP114 – North side

Photograph D40 – TP114 – South side

Photograph D41 – TP114 – Eastern end

Photograph D42 – TP114 – General view of trench looking East.

Photograph D43 – TP114 – North side

Photograph D44 – TP115 – North

Photograph D45 – TP115 – Details of fill contact.

Photograph D46 – TP116 – Backfilling breach

Photograph D47 – TP116 – Backfilling breach

Photograph D48 – TP117 – South

Photograph D49 – TP117 – Detail contact coarse sand layer.

Photograph D50 – TP118 – East

Photograph D51 – TP118 – Details of contact coarse sand.

Photograph D52 – TP119 – North

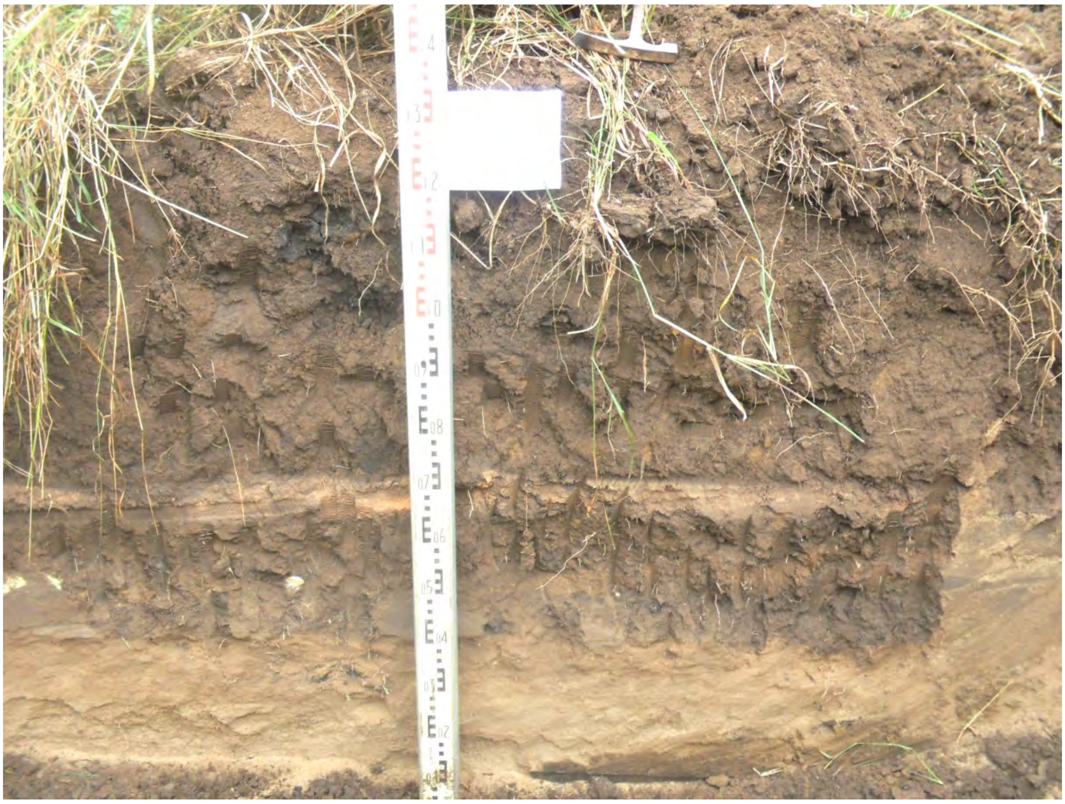
Photograph D53 – TP119 – South

Photograph D54 – TP119 – East

Photograph D55 – TP120 – North

Photograph D56 – TP121 – Fill interface

Photograph D57 – TP121 – West



Photograph D58 – TP122 – South

Photograph D598 – TP122 –South

Photograph D60 – TP123 – South-east

Photograph D61 – TP123 – South-east

Photograph D62 – TP124 – East

Photograph D63 – TP125 – North

Photograph D64 – TP125 – North

Photograph D65 – TP125 – Survey interface

APPENDIX E

Curriculum Vitae - David Starr

Africa	+ 27 11 254 4800
Asia	+ 86 21 6258 5522
Australasia	+ 61 3 8862 3500
Europe	+ 44 1628 851851
North America	+ 1 800 275 3281
South America	+ 56 2 2616 2000

solutions@golder.com
www.golder.com

Golder Associates Pty Ltd
147 Coronation Drive
Milton, Queensland 4064
Australia
T: +61 7 3721 5400

Golder Associates