14 Flood Evacuation

415. I consider there are 3 evacuation routes from Grantham:

- Evacuation Route 1: Gatton-Helidon road to the west;
- Evacuation Route 2: Gatton-Helidon-Road to the east; and
- Evacuation Route 3: The railway underpass to north of the railway embankment.

416. I have prepared Figure 14.1 that shows these routes.

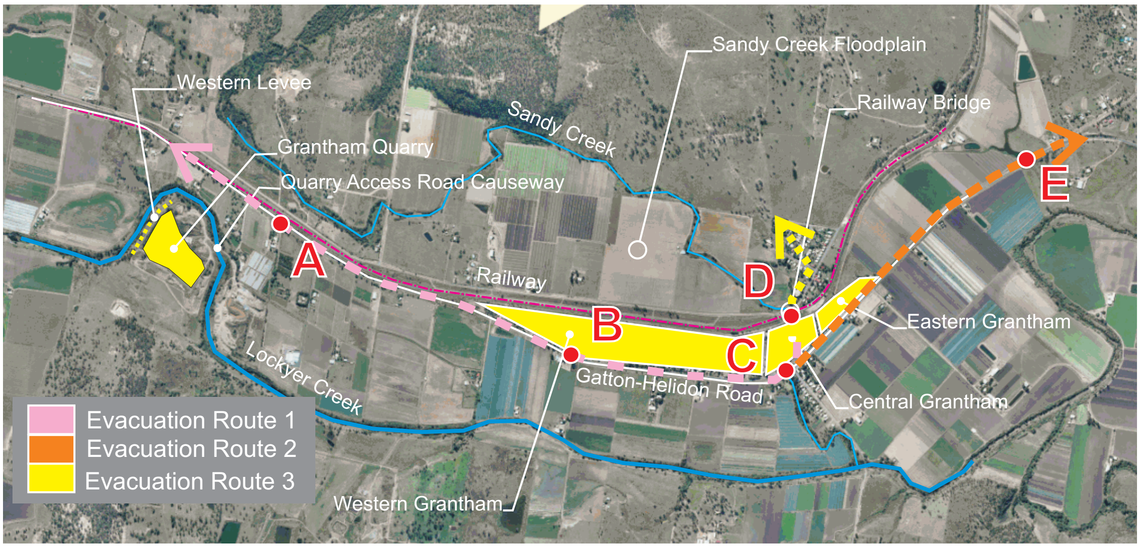

Figure 14.1 – Evacuation Routes, Grantham

417. To determine the flood times of closure of each of these routes, I examined simulation outcomes from the Most Likely, No Quarry and Worst Case (greatest drop) scenarios. From these scenarios I identified the simulated times when flow depth and intensity exceeded threshold values of 0.3m and 0.5m^2/s, respectively. I considered these thresholds as being suitable for my purposes of defining the time of road closure - that is, the time when either the depth or intensity threshold is reached. In other words, the time of closure is the earlier of the time to reach the depth threshold or the intensity threshold.

418. I have identified a number of locations as indicated in Figure 14.1 above that are the first locations along the evacuation routes at which the thresholds are reached. I note that there are two locations at D (Railway Underpass: Railway Street, and Ditchmans Road).

419. Set out below is a table indicating the estimated times of flood closure in each modelled scenario.

Table 14.1 – Critical Evacuation Route Closure Times

		Most Likely		No Quarry		Worst Case	
Location Points	**Approximate Location**	**D > 0.3m**	**V.D > 0.5m^2/s**	**D > 0.3m**	**V.D > 0.5m2/s**	**D > 0.3m**	**V.D > 0.5m2/s**
A	1615 Gatton-Helidon Road	3:50pm (+4)	3:53pm (+5)	3:46pm	3:48pm	3:49 pm (+3)	3:51 pm (+3)
B	1439 Gatton-Helidon Road	4:00pm (+3)	4:04pm (+1)	3:57pm	4:03pm	3:59 pm (+2)	4:05 pm (+2)
C	Sandy Creek Bridge, Gatton-Helidon Road	3:56pm (+1)	4:02pm (+2)	3:55pm	4:00pm	3:54 pm (-1)	3:59 pm (-1)
D (East)	Railway Underpass (Railway Street)	3:19pm (0)	4:12pm (+3)	3:19pm	4:09pm	3:18 pm (-1)	4:10 pm (+1)
D (West)	Railway Underpass (Ditchmans Road)	3:26pm (0)	4:10pm (+11)	3:26pm	3:59pm	3:25 pm (-1)	3:48 pm (-1)
E	Unnamed Culverts, Gatton-Helidon Road	4:45pm (+2)	4:52pm (+3)	4:43pm	4:49pm	4:41 pm (-2)	4:47 pm (-2)

420. I observe from Table 14.1 that the depth criterion is always reached at an earlier time than by the intensity criterion. This means that the time of closure is defined by the time that the depth criterion is reached.

421. Based on the above I consider that, compared to the No Quarry scenario:

- the Most Likely scenario produces a slightly later time of closure by up to 4 minutes; and
- the Worst Case scenario tends to produce a later time of closure of around 2 to 3 minutes in Eastern Grantham and adjacent to the Grantham Quarry, ranging to a small delay of up to 2 minutes in Western Grantham.

422. For all scenarios, I observe from Table 14.1 that Evacuation Route 3 (the northern route, as I have indicated on Figure 14.1) is the first to close. For Eastern Grantham (Railway Street side) the time of closure simulated for the Most Likely scenario is 3:19pm and for Western Grantham it is 3:26 pm.

423. I also observe from simulation results listed in Table 14.1 that Location A on Gatton-Helidon Road is next to close at 3:50pm for the Most Likely scenario. I observe that this time of closure is 4 minutes later for both the No Quarry and Worst Case scenarios. This occurrence closes Evacuation Route 1 (the western route).

424. The next road simulated to close is on Gatton-Helidon Road at Location C at 3:56pm. This time of closure is 6 minutes after the Location A closure for the Most Likely scenario (3:50pm).

425. Finally, I observe from Table 14.1 that following the time of closure of the road at Location C, Evacuation Route 2 (the eastern route) remains open for a further 49 minutes for the Most Likely scenario, until closure of the Gatton-Helidon Road at Location E at 4:45pm.

426. My conclusions are consistent with the eye-witness statement of Mr Steffens (2015) who provided a series of time-stamped photographs that he took using the camera in his mobile phone along with location and direction of view, as follows:

- at 3:53pm, the Gatton-Helidon Road near Armstrong Road, approaching Anzac Avenue was not inundated (Photo 0316), consistent with Most Likely simulation outcomes. A copy of Photo 0316 is shown in Figure 14.2 below;

Figure 14.2 – Photograph of Gatton-Helidon Road near Armstrong Road, approaching Anzac Avenue at 3:53pm

- at 3:56pm, the Gatton-Helidon Road bridge crossing of Sandy Creek had flooded over the road (Photo 0319), consistent with Most Likely simulation outcomes. A copy of Photo 0319 is shown in Figure 14.3 below;

Figure 14.3 – Photograph of Gatton-Helidon Road bridge crossing of Sandy Creek at 3:56pm

- at 3:58pm, the Gatton-Helidon Road past Citrus and approaching Sorrensen Street, Photo 0320 shows that floodwater inundation was up high against the southern side of the road (I am unable to discern the height of the water from the photograph), consistent with Most Likely simulation outcomes. A copy of Photo 0320 is shown in Figure 14.4 below;

Figure 14.4 – Photograph of Gatton-Helidon Road past Citrus and approaching Sorrensen Street at 3:58pm

- at 4:10pm, the Gatton-Helidon Road near the intersection of Dorrs Road (Photo 0323) has been completely inundated, once again consistent with Most Likely simulation outcomes. A copy of Photo 0320 is shown in Figure 14.5 on the following page;

427. Mr Steffens' observations are consistent with my assessment of the sequence of time of road closure along the Gatton-Helidon Road (depth greater than 0.3m):

- first, Sandy Creek Bridge (simulated at 3:56pm);
- second, near 1615 Gatton-Helidon Road just west of Dorrs road (simulated at 3:50pm); and
- third, near 1439 Gatton-Helidon Road near Sorrensen Street (simulated at 4:00pm).

That is, Mr Steffens drove across the flooded Sandy Creek Bridge, and past Sorrensen Street, but was then unable to proceed past Dorrs Road.

428. Based on my analysis above, my opinion is that the effect of Grantham Quarry is most likely to have resulted in delay to the time of closure of evacuation routes by up to 2 minutes.

Figure 14.5 – Photograph of Gatton-Helidon Road near the intersection of Dorrs Road at 4:10pm

429. I trust that my service to the Commission and community of Grantham has satisfied their needs and contributes to the satisfactory conclusion of the Inquiry.

J.C. Macintosh

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Director and Principal Engineer
Water Solutions Pty Ltd

Appendix A – References

A.1 Technical References

1. Bureau of Meteorology, Southeast Queensland Floods, January 2011
2. Chow, V.T., Open Channel Hydraulics, McGraw-Hill Book Company, 1959
3. Engineers Australia, Australian Rainfall and Runoff, Revision Project 15: Two Dimensional Modeling in Urban and Urban and Rural Floodplains, Stage 1 and 2 Draft Report, November 2012.
4. Froehlich, D.C., *Embankment Dam Breach Parameters and Their Uncertainties*, Journal of Hydraulic Engineering, Vol. 134, No. 12, December 1, 2008.
5. Jordan, P., *Impact of Quarrying Operations on Flash Flooding in Grantham on 10 January 2011* for Queensland Flood Commission of Inquiry, SKM, QE06544-NHY-RP-0001, 16 September 2011.
6. Lockyer Creek Flood Risk Management Study for Lockyer Valley Regional Council, SKM, December 2014.
7. XP Rafts, Urban & Ruran Runoff Routing Software, XP Software, 2009
8. Starr, D., *Grantham Quarry - Geotechnical Investigations & Expect Opinion on Formation of Eathworks* for Grantham Floods Commission of Inquiry, Golder Associates, 1532696-001-R-Rev1, July 2015.
9. Szylkarski, S. (Project Manager), *Grantham and Wagner Quarry Review of Flood Impact 10th January 2011 Flood Event* for Nationwide News Pty Ltd, DHI, 43801776, 4 March 2015.
10. *Water Monitoring Portal, 143203C Lockyer Creek at Helidon Number 3*, DNRM, https://www.dnrm.qld.gov.au/water/water-monitoring-and-data/portal, 30 June 2015.
11. TUFLOW User Manual, GIS Based 2D/1D Hydrodynamic Modelling, BMT WBM, 2010.
12. TUFLOW 2011-09 and 2012-05 Release Notes, BMT WBM
13. TUFLOW 2013-12 Release Notes, BMT WBM

A.2 Witness Statements – Grantham Floods Commission of Inquiry (GFCOI)

1. Arndt, Frances Ann, statement dated 1 July 2015
2. Besley, Graham Francis, statement dated 2 July 2015
3. Besley, Helen, statement dated 2 July 2015
4. Cork, Richard, statement dated 2 July 2015
5. Lack, Wayne Douglas, statement dated 7 July 2015
6. Mallon, Neville Lester, statement dated 1 July 2015
7. McIntosh, Anthony, statement dated 1 July 2015
8. Richardson, Lance William, statement dated 1 July 2015

9. Sippel, Jonathan, statement dated 1 July 2015
10. Steffens, Troy Brenden, statement dated 1 July 2015
11. Zischke, Gavin Noel, statement dated 9 July 2015

A.3 Additional Material Provided by GFCOI

1. The following material concerning Mr Bruce Marshall:
    - an excerpt from the Coroner’s report regarding the inquest into the January 2011 flood deaths. That excerpt concerns the death of Mr Bruce Marshall; and
    - transcripts from 000 calls made by Mr Marshall on 10 January 2011.
2. The following additional material concerning Mrs Besley:
    - transcript of 000 call referred to at paragraph 21 of Mrs Besley’s witness statement dated 2 July 2015 (separate from her statement); and
    - excerpt of transcript of hearing before the GFCOI on 22 July 2015 (a copy is attached to Letter of Instructions No 2 provided at Appendix E);
3. Excerpt of transcript of hearing before the GFCOI on 21 July 2015 regarding the examination of Mr Sippel (a copy is attached to Letter on Instructions #4 provided as Appendix E); and
4. iPhone photographs taken on 10th January 2011 and supplied by Mr McIntosh (separate from his statement).
5. Photographs and videos of Kapernick’s Bridge as at 10th January 2011
6. Rickuss, Ian, Flood Level Survey Plan TM153 FL 002A

A.4 Submissions Provided to the GFCOI

1. Submission of John (Sean) Gillespie dated 2015
2. Submission of P J (John) Gallagher dated 2015

A.5 Witness Statements – Queensland Floods Commission of Inquiry

1. http://www.floodcommission.qld.gov.au/__data/assets/file/0006/10797/Wood_Kelvin.pdf
2. http://www.floodcommission.qld.gov.au/__data/assets/file/0004/10777/Kilah_Gilbert.pdf
3. http://www.floodcommission.qld.gov.au/__data/assets/file/0017/10772/Jenckel_Darlene.pdf
4. http://www.floodcommission.qld.gov.au/__data/assets/file/0016/10762/Geeves_Wayne.pdf
5. http://www.floodcommission.qld.gov.au/__data/assets/file/0020/10757/Bellette_Julie.pdf
6. http://www.floodcommission.qld.gov.au/__data/assets/file/0004/4882/Jamieson_Vivienne.PDF
7. http://www.floodcommission.qld.gov.au/__data/assets/file/0003/4890/Caughley_David.pdf
8. http://www.floodcommission.qld.gov.au/__data/assets/file/0005/4883/Lance_Richardson_30_Jan_2011.PDF
9. http://www.floodcommission.qld.gov.au/__data/assets/file/0010/4888/Warburton_Martin_-_20_Jan_2011.PDF
10. http://www.floodcommission.qld.gov.au/__data/assets/file/0008/4877/Damrow_Stuart.PDF
11. http://www.floodcommission.qld.gov.au/__data/assets/file/0007/4849/Jensen_Ruby.pdf

12. http://www.floodcommission.qld.gov.au/__data/assets/file/0009/4878/Darlington_Bronwyn.PDF
13. http://www.floodcommission.qld.gov.au/__data/assets/file/0020/4844/Minns_Rodney_QPS.PDF
14. http://www.floodcommission.qld.gov.au/__data/assets/file/0015/4830/Watkins_Daniel.PDF
15. http://www.floodcommission.qld.gov.au/__data/assets/file/0019/4825/Mahon_Kathy.PDF
16. http://www.floodcommission.qld.gov.au/__data/assets/file/0014/4811/Wilkin_James.PDF
17. http://www.floodcommission.qld.gov.au/__data/assets/file/0006/4758/Wilkin_Robert.PDF
18. http://www.floodcommission.qld.gov.au/__data/assets/file/0019/5239/Jones_Steven_John.pdf
19. http://www.floodcommission.qld.gov.au/__data/assets/file/0015/4713/Gollschewski_Steve_QPS.PDF
20. Arndt, Frances Ann, statement dated 29 January 2011

Appendix B – Technical Reviews

B.1 OverviewGauging Station

1. This section provides details of various ancillary technical reviews that I have undertaken during the course of my investigations. They include:

   - Helidon Gauging Station Review
   - Review of LVRC Model Stage-Discharge Relationship
   - Revised Flagstone and Ma Ma Creek Inflows
   - Downstream Flow-Height Boundary Condition
   - Western Levee and Main Breach Erosion Definition
   - Pre Quarry Surface Topography
   - Pre Railway Embankment Topography

B.2 Helidon Gauging Station Review

Introduction

2. Gauging Station 143203C Lockyer Creek at Helidon No 3 is a stream gauging station some 11 km upstream of Grantham. Key details for this gauge are summarised in the following table.

Table B.1 – Lockyer Creek At Helidon No 3 – Details

Item	Detail
Commenced	19/11/1987
Ceased	-
Latitude	27°32'32.2"S°'"
Longitude	152°06'52.2"E°'"
AMTD	99.3km
Gauge Zero	128.625m AHD
Control	Control Weir
Cease to Flow Level	0.45m
Bed Slope	0.0038
Catchment Area	357 km^2
Max Gauged Stage	3.4m (12/4/1988)
Max Gauged Flow	110 m^3/s (12/4/1988)
Max Recorded Stage	13.88m (10/1/2011)
Gaugings	88 between 3/12/87 and 20/5/15

3. A rating curve is used to convert recorded heights to estimated flow rates. DNRM hydrographers develop the DNRM rating curve based on the cross-section at the gauge and measured flow velocities across the cross-section during flow events (referred to as gaugings). The latest DNRM cross-section for the site is shown Figure B.1 and the DNRM rating curve and gaugings on Figure B.2.

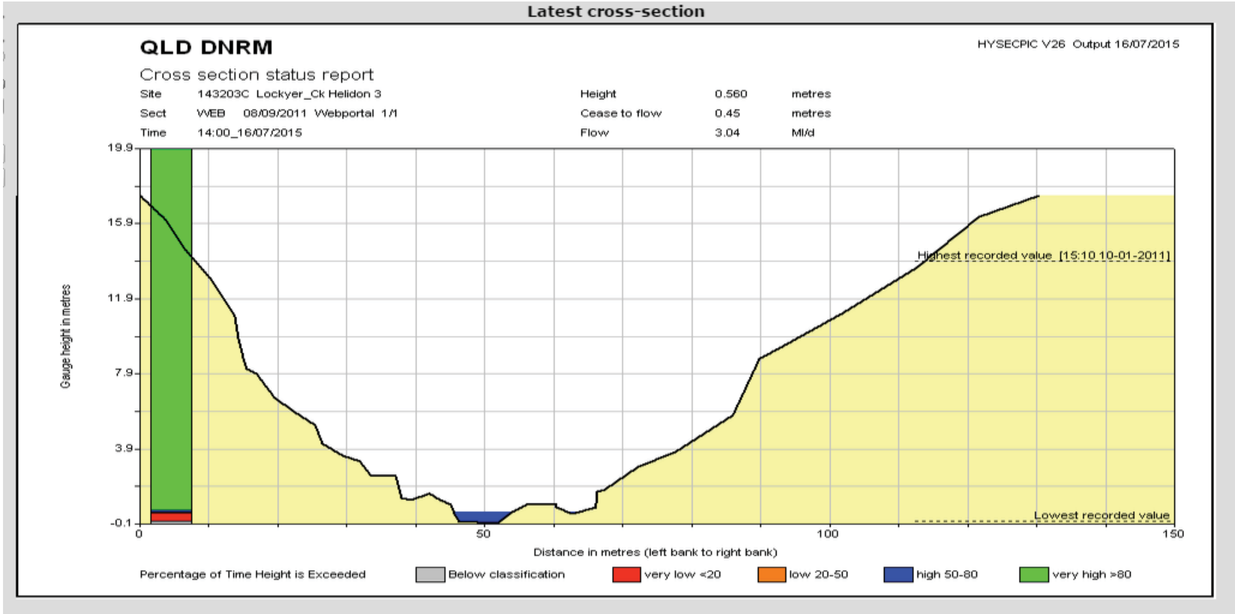


Figure B.1 – Helidon Gauging Station: Site Cross-section (DNRM Water Monitoring Portal)

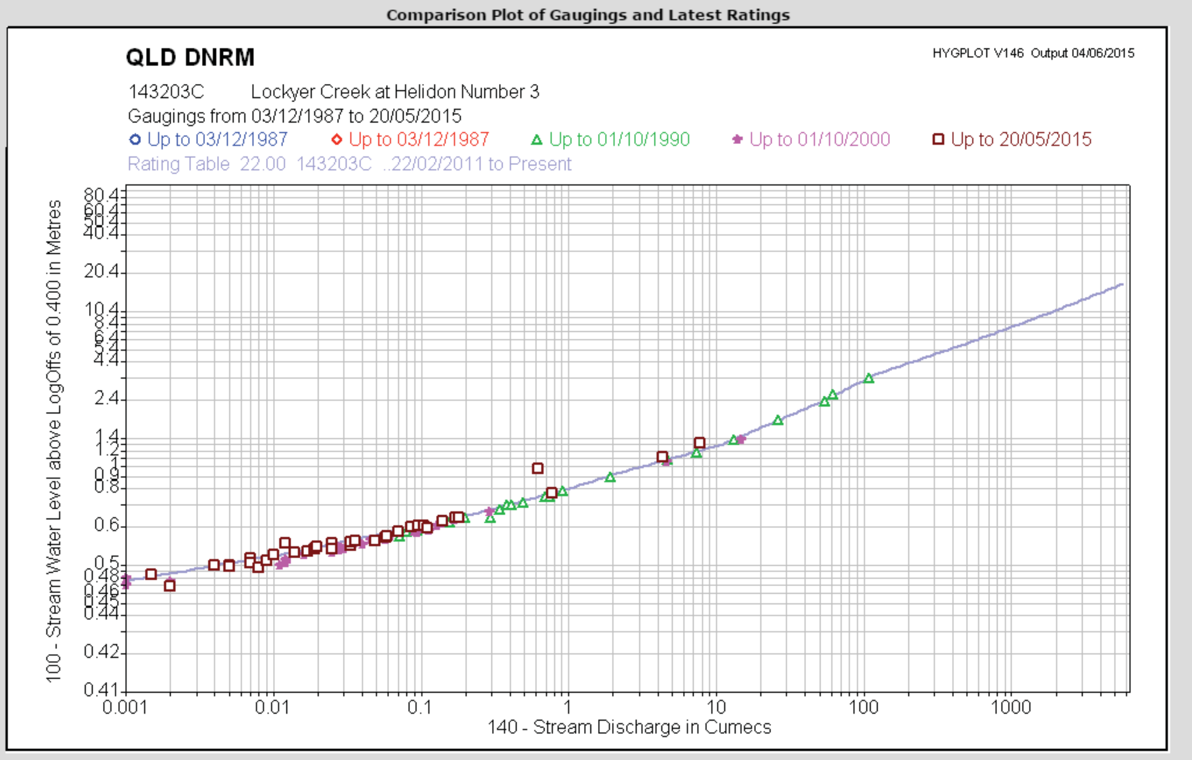


Figure B.2 – Helidon Gauging Station: Rating Curve and Gaugings (DNRM Water Monitoring Portal)

4. The peak recorded level of the 2011 flood was at 13.88m at Gauging Station143203C, some 10m higher than the historical highest gauged flow at 3.4m. This means that to estimate the flow for the 2011 flood, a considerable extrapolation of the rating curve was required. There is thus considerable uncertainty associated with DNRMs estimated peak flow rate for the 2011 flood.

5. In addition to the general uncertainty associated with such a large extrapolation, in the 2011 floods, event significant erosion and deposition occurred in some sections of the creek. If this

erosion/deposition significantly affected the controlling cross-section for Gauging Station143203C, the rated flow versus level relationship would change.

6. Also, the 2011 flood knocked down and uprooted a significant amount of vegetation along the creek. Vegetation typically has a retarding effect on flow, reducing the velocity of flow. From a flood modelling point of view, the effect of vegetation and other surface effects (e.g. boulders, fences) are usually taken account of through a specified stream roughness parameter (typically Manning's n). If a flood removes or flattens vegetation, roughness can decrease, thereby increasing velocity, and affecting the relationship between level and flow.

7. This section provides an assessment of the Gauging Station 143203C Lockyer Creek at Helidon No 3 rating curve, with particular focus on the potential effect of the estimated change in cross-section and roughness that occurred during the 2011 flood.

8. It is noted that Gauging Station 143203C Lockyer Creek at Helidon No 3 is the third location for the Helidon Stream Gauge, with the total record at Helidon extending from 1926 to the current day. The largest gauged flow since 1927 is approximately 270 m^3/s, at an estimated (translated) height at the C site of 4.4m. This is over double the maximum gauged flow for the C site, but is still over an order of magnitude lower than the likely peak flow in the 2011 flood.

Review of Change in Cross-section

9. Cross-sections for the Gauging Station143203C site were extracted from LIDAR data taken before and after the 2011 flood. A plot of the two cross-sections is shown in the figure below.

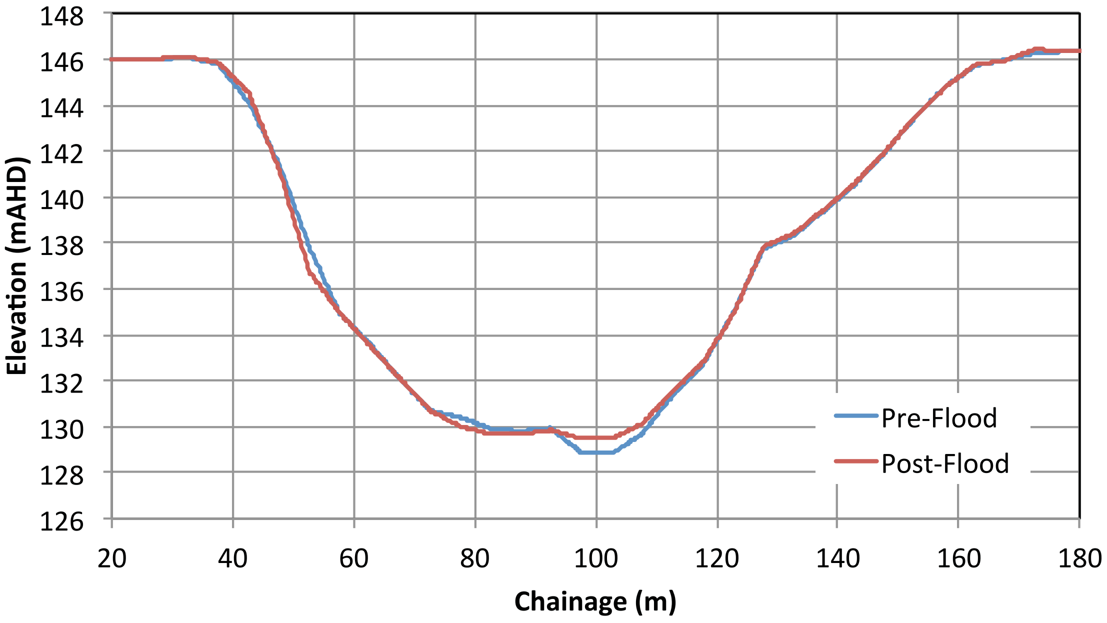


Figure B.3 – Helidon Gauging Station: Comparison of Pre and Post Flood LIDAR Cross-Sections

10. I note from the aerial photographs (2011) that there was ponded water in the cross-section in the post flood survey, and LIDAR does not typically penetrate ponded water. The cross-sections shown above are only considered valid above the ponded water level (about EL 129.5m AHD).

11. As can be seen in Figure B.3 the change in the area available for large flows (peak of the 2011 flood about 142.5m AHD) is minimal. The cross-sectional area at the peak of 2011 flood is

estimated to be approximately 880m^2 (above EL 129.5m AHD) pre flood, compared to 885m^2 post flood, a difference of approximately 0.5%.

12. This small change is likely to affect the high stage-rating curve in a linear manner, e.g. the 0.5% increase in area means that flow may increase at a particular EL by about 0.5%.

13. As this difference is relatively small, it is concluded that the change in cross-section at the Gauging Station143203C site has minimal impact on the rating curve for the site.

Review of Change in Roughness

14. The Manning's n roughness used in the modelling of flood flows for a site is typically initially based on the bed material and vegetation observed in a site inspection or from review of site photographs. A range of guidelines (such as Chow 1959) provides a table of typical roughness values for various stream and vegetation conditions.

15. If calibration data is available, roughness is typically a key calibration parameter, with the values used adjusted within reasonable ranges to provide a close match to observed flood behaviour.

16. Photographs of the site, from the DNRM Water Monitoring Portal, are provided in Figure B.4 to Figure B.6 and aerial photography of the site pre/post event in Figure B.7.

Figure B.4 – Helidon Gauging Station: View Downstream (DNRM Water Monitoring Portal)

Figure B.5 – Helidon Gauging Station: View Upstream (DNRM Water Monitoring Portal)

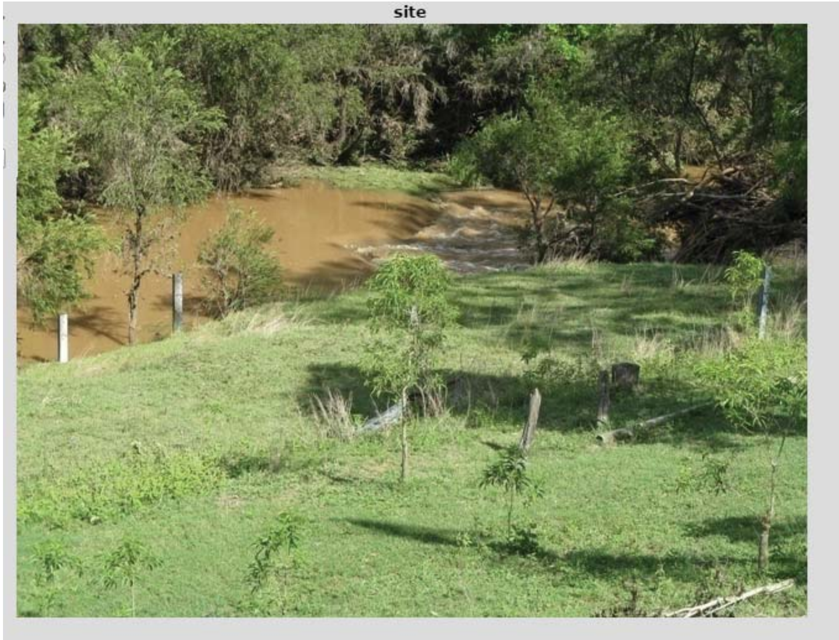


Figure B.6 – Helidon Gauging Station: View of Site (DNRM Water Monitoring Portal)

Figure B.7 – Helidon Gauging Station – Pre and Post Aerial Photography (Station at Red Circle)

17. Based on these photographs:

- The central channel is reasonably clear with a gravel/cobbles bed.
- Dense vegetation is present on the low banks
- the right bank above the low bank is largely cleared, and grass appears grazed/short.
- Higher up the left bank has some light to medium forest cover.

18. The average cross-sectional roughness for these conditions for large floods is estimated to be in the range 0.035 to 0.08.

19. Post-flood, much of the vegetation has been removed, although the canopy of the fallen trees still provides some impedance to flows. Roughness post-flood is estimated in the range 0.03 to 0.06.

20. An estimated roughness was back-calculated from the DNRM rating curve using the Manning's equation. A flood slope of 0.035 was adopted, based on the local flood slope measured from

debris after the 2011 flood by DNRM hydrographers. This technique provided an estimated average cross-sectional Manning's n of 0.06 for large floods.

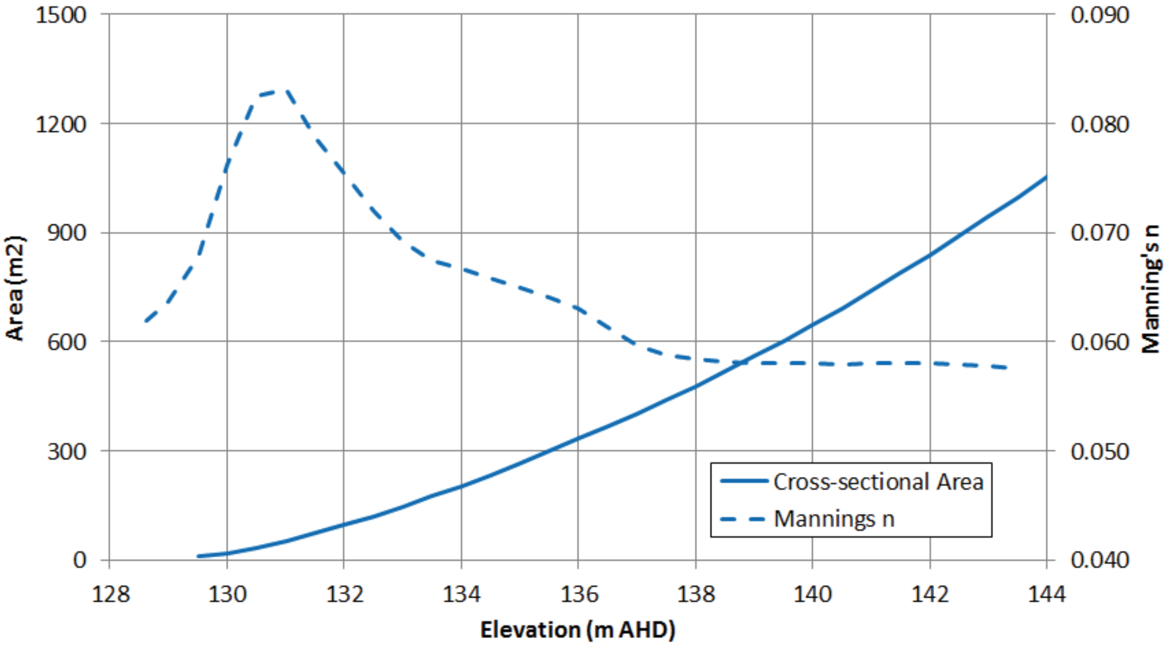


Figure B.8 – Helidon Gauging Station: Estimated Cross-sectional Area and Back-calculated Manning's n

21. Manning's n roughness is a very influential parameter in the Manning's equation for flow. If the roughness is halved, the flow is doubled for a particular flood level.

22. To provide an appreciation of the potential effect of the change in roughness, an estimated rating curve for average cross-sectional Manning's n of 0.035, 0.06, and 0.08 is provided in the figure below.

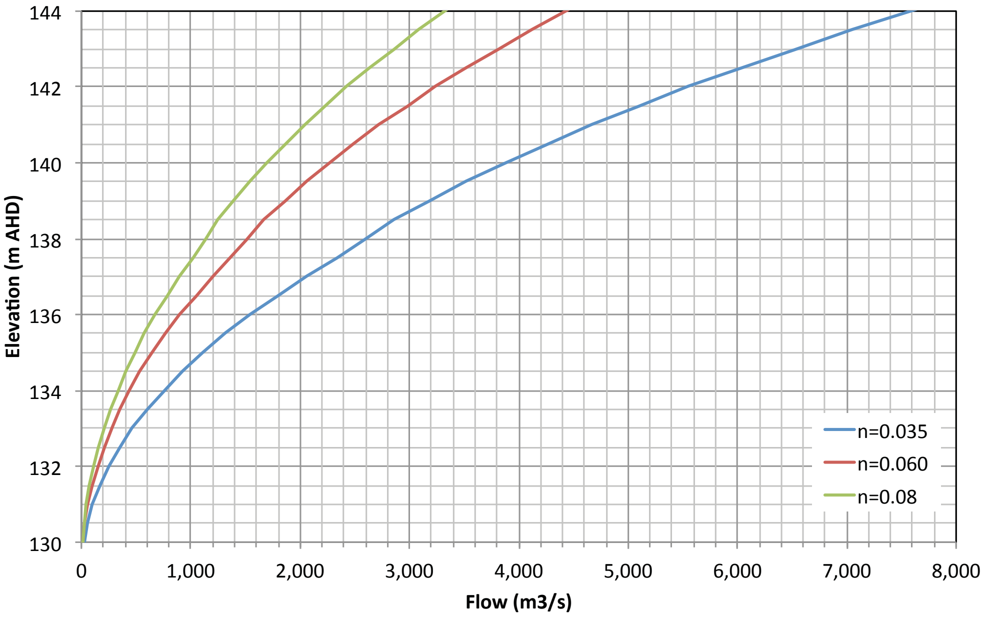


Figure B.9 – Sample Rating Curves at a Range of Roughness

23. It is noted that a calibrated Manning's n (such as the back-calculated one from the rating curve) often accounts for a wide range of factors besides boundary roughness (e.g. bends in the river, expansion and contraction). Also, a rare flood such as on 10th January 2011 would be expected to knock down trees, and flatten tall grass. Hence the 'normal' rating for high stage flow should provide some account for the flattening of the vegetation and other normal characteristics of high stage flow.

B.3 Review of LVRC Models Stage-Discharge Relationship

24. Figure B.10 provides a comparison between the flow hydrograph calculated from the DNRM rating curve at Helidon (Gauging Station 143203C) and the flow hydrograph extracted from the LVRC hydraulic model results. Also shown is the hydrograph based on Dr Jordan's rating curve extracted from the Jordon model.

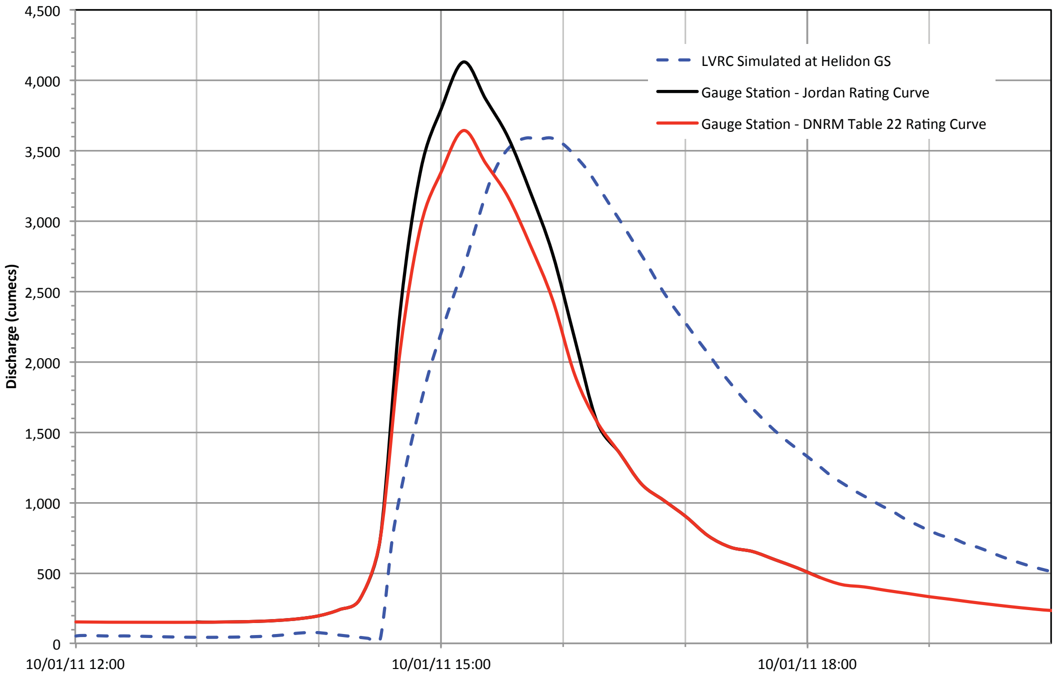


Figure B.10 – Helidon (143203C): Comparison of Flow Hydrographs

25. From the figure above it appears that the calibration of the LVRC models have prioritised providing a good match to the estimated peak flow rate for the 2011 flood based on the DNRM rating curve. However, the match on the rising and falling limbs, the timing of the peak, and the estimated total flood volume is considered poor.

26. As described in Section B.2, with the Helidon Gauging Station having a maximum gauged stage / flow of 3.4m, 110m^3/s, the extrapolation of the rating curve to the peak of the 2011 flood at 13.88m, 3600m^3/s is very significant, over 10m in height and an order of magnitude in flow. There is thus considerable uncertainty associated with the estimated flows for large recorded flood levels. However the timing of the rising and falling limbs recorded by Gauging Station143203C considered being reasonably accurate.

27. Figure B.11 provides a range of rating curve for various assumed roughness, and it is considered that this range provides a reasonable appreciation of the accuracy of the rating curve at high

stage. At the peak of the 2011 flood (142.5m AHD) Figure B.11 indicates that the equivalent flow may be between 2,600 and 6,000m^3/s.

28. Based on the above, it is considered likely that the errors in the high stage rating curve has led to excessive routing being included in the LVRC models in order to match the peak flow rate from the DNRM Rating Curve.

29. A full recalibration of the LVRC models to address this issue would require several months of work. As an alternative, a simple technique has been applied to correct the DNRM rating curve. This revised rating curve will then be used to re-calculate the ‘recorded’ flows at Helidon, which will then be applied as the upstream boundary condition for the GFCOI model.

30. The technique applied is summarised below:

1. The simulated time – flow rate – stage height information from the LVRC model at Helidon was extracted (Figure B.10)
2. The volume of flow in the LVRC simulated hydrograph to the peak of the event was calculated to be 10.5GL. (While the timing of the LVRC event appears poor, it is considered that the volume of the event to the peak estimated in the LVRC model should be reasonable.)
3. The LVRC model flow rate – stage height data was used to construct an interim rating curve at Helidon on the rising and falling limbs of the event (Figure B.10). It is noted that the level versus discharge relationship is different on the rising and falling limb. This effect, referred to as hysteresis, is common in floods, and occurs owing to the steeper flood slope that generally occurs on the rising limb of a flood.
4. The “interim" rising limb rating curve was applied to the rising limb of the recorded stage height hydrograph at Helidon to produce an “interim” rising limb stage discharge hydrograph.
5. The volume of flow in the “interim” hydrograph to peak was calculated and compared to the volume to peak in the LVRC model (10.5GL). The interim rating curve was then scaled in order to provide a match between these two figures.
6. The same scaling factor was applied to the LVRC falling limb hydrograph.

31. The revised rising limb and falling limb rating curves developed from the above technique, for application to the recorded levels for the 2011 flood at Helidon, are presented in Figure B.11 below.

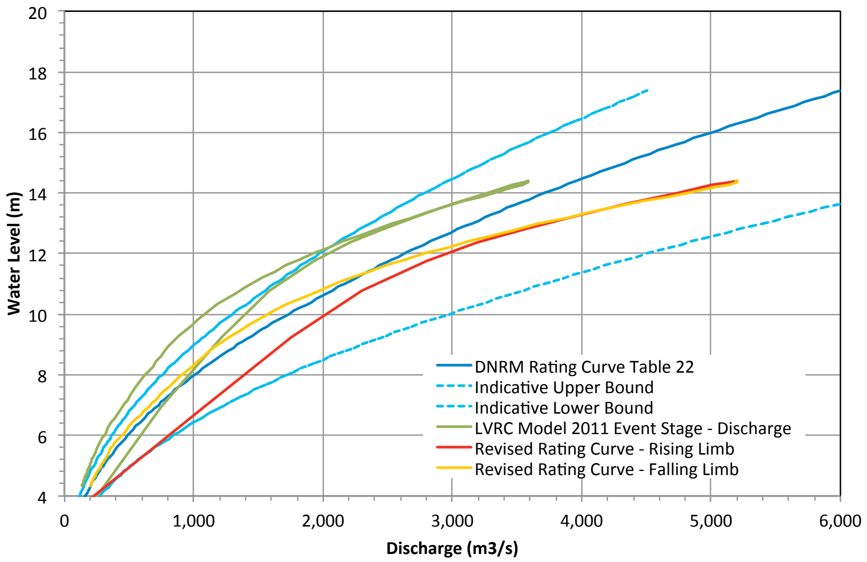


Figure B.11 – Helidon (143203C): Revised Rating Curve for 2011 flood

32. Figure B.11 shows some indicative bounds on the DNRM Rating Curve. These indicative bounds were determined based on adjusting the DNRM Rating Curve by the range of Manning's n values examined in Section B.2. The plot shows the revised rating curves falls within these reasonable bounds.

33. It was concluded that the revised rising and falling limb rating curves are reasonable, and thus they were applied to the recorded levels at the Helidon Gauging Station. The resultant hydrographs are plotted in the figure below.

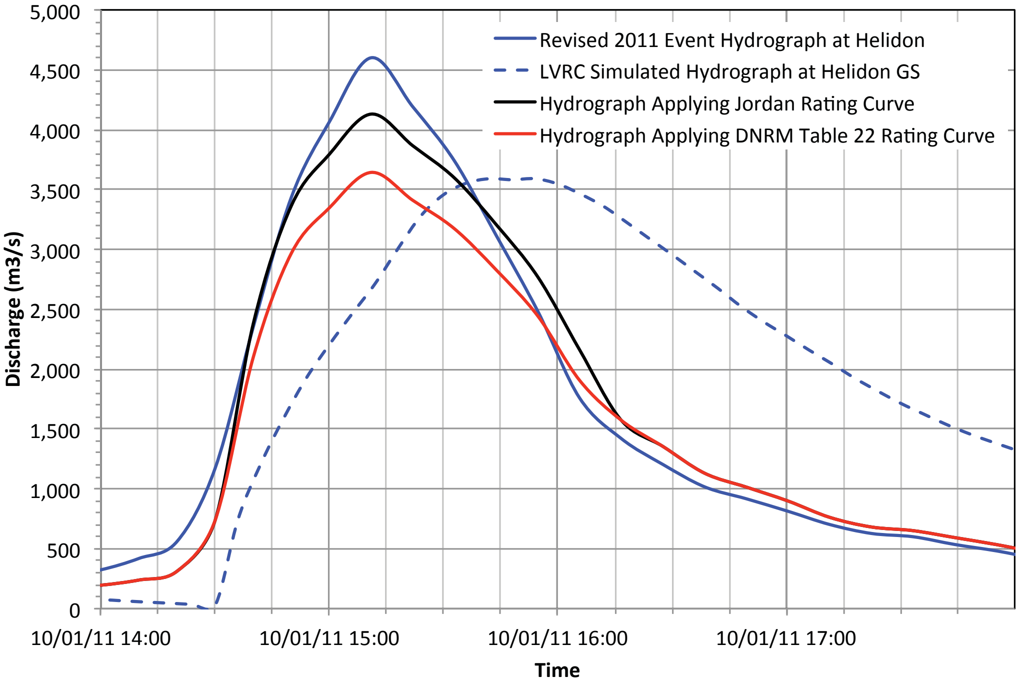


Figure B.12 – Helidon (143203C): Revised Hydrograph for 2011 flood

34. The revised 2011 flood hydrograph was applied to the upstream boundary condition in the GFCOI model.

35. It is considered that the revised hydrograph provides a much-improved match to the timing of the rising and falling limbs of the event, and provides a reasonable estimation of the peak flow rate and flood event volume. Testing the GFCOI model indicated that this hydrograph provides reasonable results in the area of interest near Grantham, and thus was adopted as the upstream boundary condition for the GFCOI model.

B.4 Revised Flagstone and Ma Ma Creek Inflows

36. The side catchment inflows for the Tuflow model from Flagstone Creek and Ma Ma Creek for this study were determined as follows:

- the RAFTS model prepared by Jacobs was obtained (File LC_Jan2011_WS01_MatchSKM.xp) together with the relevant rainfall data also obtained from Jacobs (Jan11_6min_111014.his);
- the Upper Flagstone Creek and Ma Ma Creek RAFTS catchments (above the relevant gauging station) were removed; and replaced with a file of the recorded flows at Gauging Station 143233A Flagstone Creek at Brown-Zirbels Road and Gauging Station 143213C Ma Ma Creek at Harms; and
- no change was made to sub-catchment or routing parameters below the gauging station locations.

37. The RAFTS model was re-run with the above changes. The hydrographs of the Flagstone Creek and Ma Ma Creek inflows to Lockyer Creek were then extracted from the RAFTS model for use as input to the TUFLOW model.

38. A plot of the changes to the inflow files are provided below in Figures B.13 and B.14.

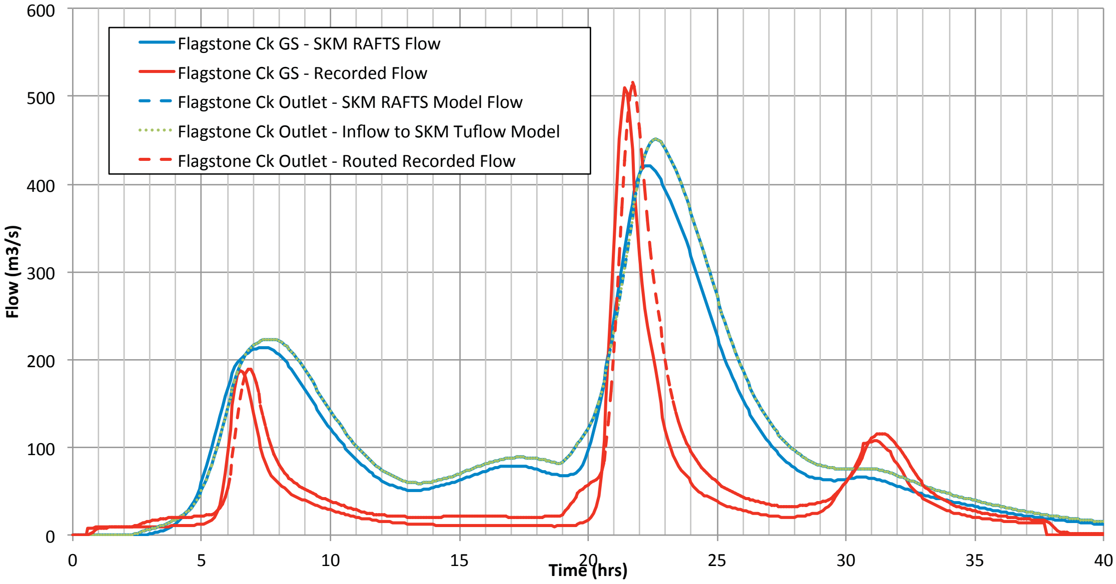


Figure B.13 – Flagstone Creek Revised Hydrology

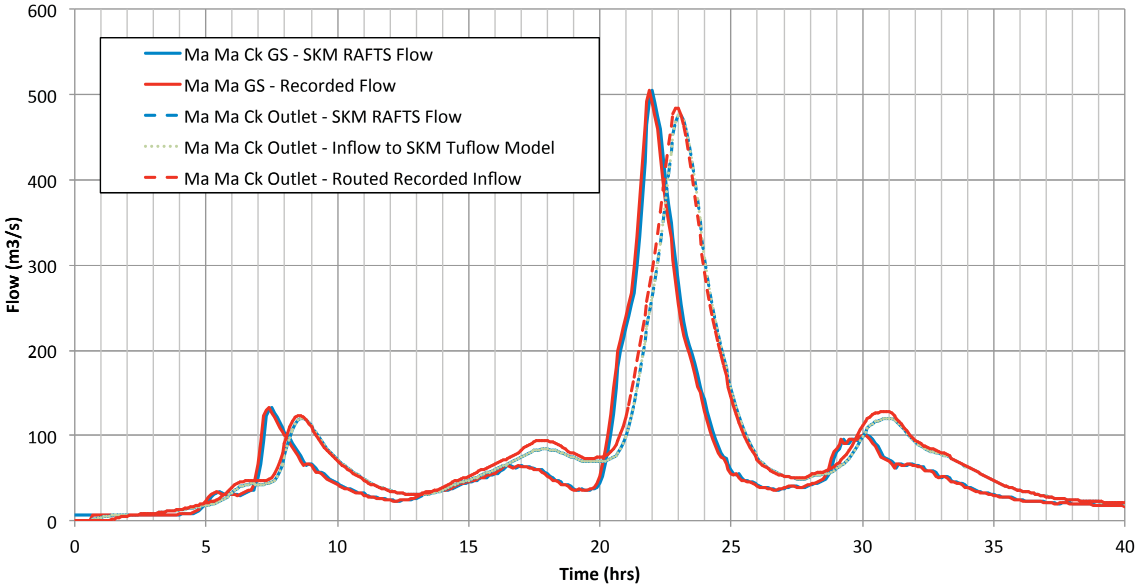


Figure B.14 – Ma Ma Creek Revised Hydrology

B.5 Downstream Flow-Height Boundary Condition

39. The downstream extent of the GFCOI model is a short distance downstream from the Gatton-Helidon Road crossing of Lockyer Creek. Modelling requires the definition of a rating curve at this location so that simulated flow rates can be matched with their associated flood level.

40. In his modelling work for the QFCOI in 2011, Dr. Jordan used a fixed level at this location set at 114.2mAHD for all flow rates. The LVRC (2014) model modified this relationship for application to their sub-model of the Upper Lockyer Creek to Grantham domain (ULG). These rating curves are plotted in Figure B.15 below.

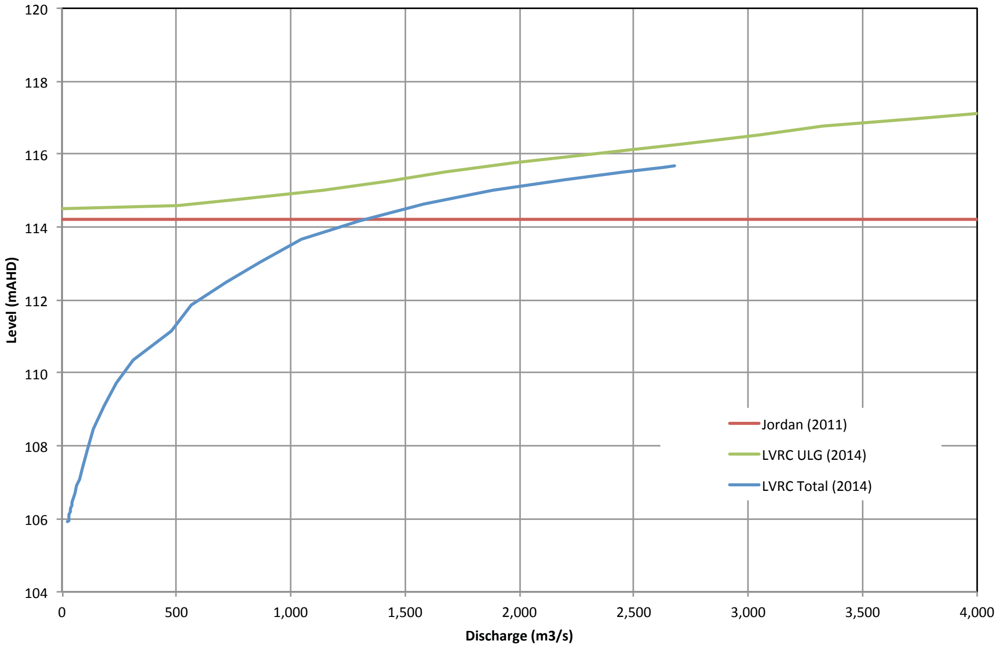


Figure B.15 – Downstream Boundary Rating Curves (Gatton-Helidon Road)

41. In reviewing the information shown in Figure B.15 it will be immediately seen that the LVRC ULG model boundary condition rating curve has a relatively flat gradient, typical of rating curves for overbank floodplain flow paths. This observation is confirmed when it is realized that the bed level of Lockyer Creek is at least 10m lower than the zero flow intercept of the LVRC ULG rating.

42. The significance of the impact of the LVRC ULG rating on simulated flood levels is indicated in Figure B.15 which presents a snap-shot of modelled inundation extent when the flood flow in Lockyer Creek is yet to reach the downstream end of the model. Of course, the inundation at the downstream end of the model, with no flow in the creek, is obviously incorrect. It is however largely inconsequential as flooding of the overbank floodplain areas at the downstream location had negligible impact on the flow depth and intensity in Grantham for the 2011 flood.

43. However, even though this affect of the LVRC model rating is not important for large flood flows, it can effect the simulation of the initiation of flooding. This particular aspect is of key interest to investigations at Grantham.

44. To resolve the situation, simulation outcomes produced by the LVRC model were interrogated to extract modelled flow rate and level information a short distance downstream from the Gatton-Helidon Road Bridge crossing of Lockyer Creek. This derived relationship is also plotted in Figure B.15 and labelled “LVRC Total (2014)”.

45. Simulation results obtained using the same model as used to produce Figure B.16 (following page), but with the revised rating curve (LVRC model) are presented in Figure B.17 (following page). It is seen that inundation of the floodplain areas about the downstream end of the model is no longer apparent, as expected since there is no flow in the downstream creek at 3:00pm being the time shown.

Figure B.16 – Initial Flood Flow Inundation using LVRC ULG Downstream Rating

Figure B.17 – Initial Flood Flow Inundation using Revised Downstream Rating

B.6 Western Levee and Main Breach Erosion Definition

46. I have presented details of the definition of the eroded Western Levee and Main Breach in Section 8.6. In the GFCOI model, these items have been defined by five discrete areas where the ground surface levels are set to vary from pre flood to post flood levels over a defined period of time (10 minutes in the base model). Each of these five erosion areas has also been assigned a "trigger" to signal the flood level when simulation of the erosion process should commence. The arrangement of the modelled erosion areas and associated trigger positions is shown in Figure B.18.

Figure B.18 – Western Levee and Main Breach Arrangement

47. Trigger levels for initiation of erosion of the levees and creek bank are listed in Table B.2 along with the simulation time of initiation from the base GFCOI model.

Table B.2 – Simulated Levee and Breach Initiation

Item	Trigger	Flood Level (mAHD)	Initiation Time (hh:mm)
Levee 1	A	127.6	3:45 pm
Levee 2	A	127.6	3:45 pm
Levee 3	B	127.6	3:56 pm
Levee 4	A	127.6	3:45 pm
Levee 5	B	127.6	3:56 pm
Main Breach	C	125.0	3:25 pm

48. Correct simulation of erosion and creek bank occurrence was checked by extracting time-series plots of trigger location flood level and selected spot heights on the levee embankments from simulation results. These are plotted in Figure B.19 and confirm correct simulation according to intention.

49. Review of the information also shows, for the initiation parameters used, breach erosion initiating at 3:25pm and levee erosion initiating between around 3:45pm and 3:56pm. All erosion mechanisms are seen to be completed 4:06pm (that is, 10 minutes after the last trigger).

50. It is also interesting to note that the formation of the breach appears to impact on Lockyer Creek flood levels at the Trigger C location where the levels are see to remain almost constant over the period 3:25pm to 3:35pm, whereas levels at the other trigger locations continue to rise.

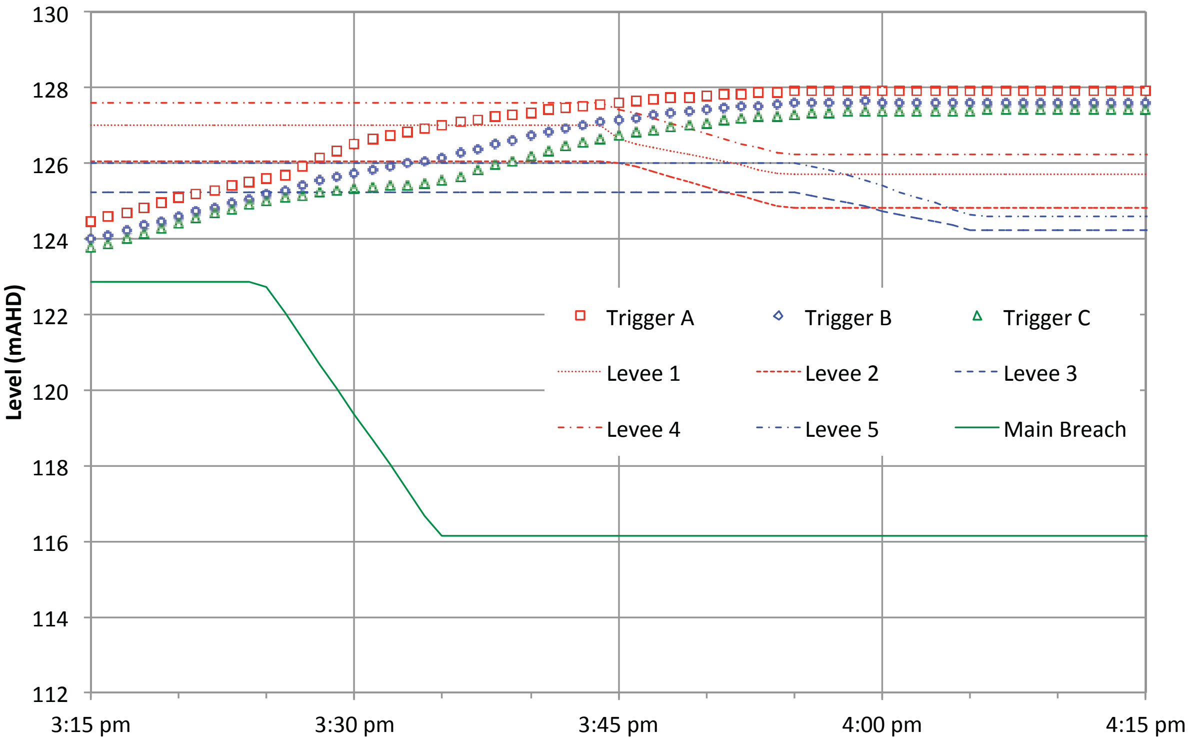


Figure B.19 – Water Surface Levels, Western Levee and Main Breach Erosion Development

B.7 Pre Quarry Surface Topography

51. The GFCOI arranged for Mr Starr (Golder Associates) to undertake field investigations to establish, amongst other tasks, his assessment of the likely natural surface levels around the site of the Quarry. I understand that he did this by carefully digging a number of inspection pits at selected locations around the perimeter of the quarry, and then by inspection of the walls of the test pits identified the locations of various soil horizons. A licensed surveyor was used to capture the location and level of the various soil horizon marks. Mr Starr then interpreted this information to produce his assessment of the most likely natural surface.

52. Mr Starr was unable to establish direct evidence of what the natural surface was within the area now occupied by the pit. However, he did refer to historical photographs of the area and was able to form an opinion as to the likely lie of the land in this area.

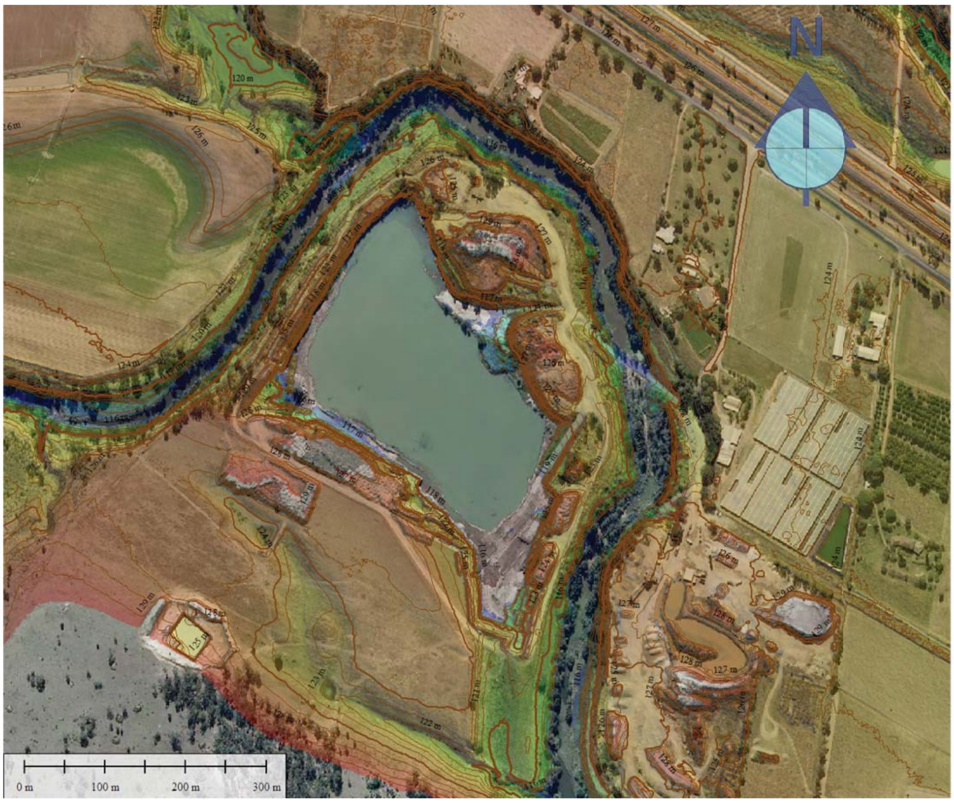
53. My interest in the natural (pre quarry) surface was to make assessment as to how the presence of the Quarry might have effected the characteristics of the 10th January 2011 flood event. To do this I needed to represent the natural surface at the Quarry site in my hydraulic model. This surface would not have any quarry pit, associated levee banks or material stock / spoil piles. I took no account of those changes to the natural surface at other locations within the study area.

54. The method that I used to recreate the natural surface was to:

- start with the pre flood surface topography from the LIDAR survey;
- using 3D computer terrain modelling software, superimpose the Dr. Starr's assessment of the natural surface over the perimeter of the quarry pit;
- infill the internal pit area by interpolation across the void from natural surface levels around the perimeter, taking into account an apparent depression running generally from the north-western corner of the pit to the south-east corner.

55. I have produced contour plots of the resulting interpreted natural surface (pre quarry) and also of the pre flood (with quarry) conditions for comparison, as shown in Figure B.20.

Grantham Quarry (Pre Flood)



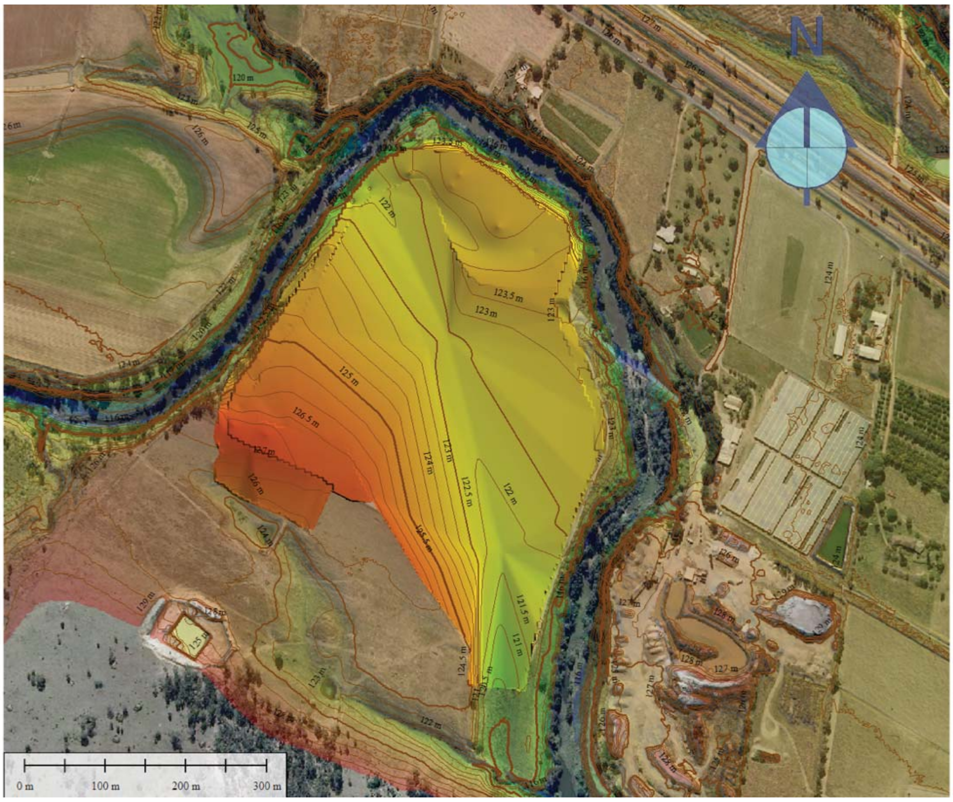
Pre Quarry	

Figure B.20 – Surface Topography at the Grantham Quarry Site

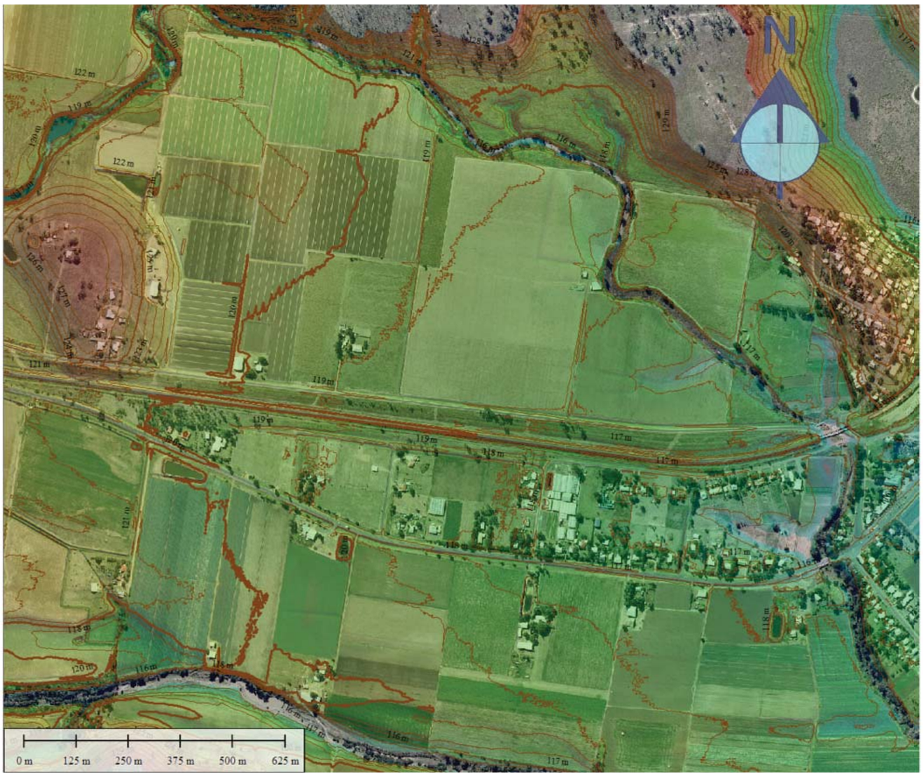
B.8 Pre Railway Embankment Topography

56. From my review of 10th January 2011 flooding characteristics at Grantham I see that the railway embankment has clearly had an effect on the concentration and direction of flood flows. In particular I notice that prior to overtopping the railway embankment, the rapidly rising floodwaters appear to have been funnelled into the area beyond the embankment via the relatively narrow railway crossing of Sandy Creek and Ditchmans Road. Eye-witness accounts and the substantial accumulation of debris left remaining on the southern side of this crossing further substantiate this impact.

57. I have undertaken an assessment using the GFCOI model to quantify the likely impact of the railway line on these flooding characteristics. To do this I modified the GFCOI model to effectively remove the rail embankment from the surface topography, in a similar fashion to the technique used to create my estimate of the natural surface pre Quarry.

58. I have produced contour plots of the resulting interpreted natural surface (this time, pre railway embankment) and also of the with railway embankment conditions for comparison, as shown in Figure B.21.

With Railway Embankment (existing)



Pre Railway Embankment

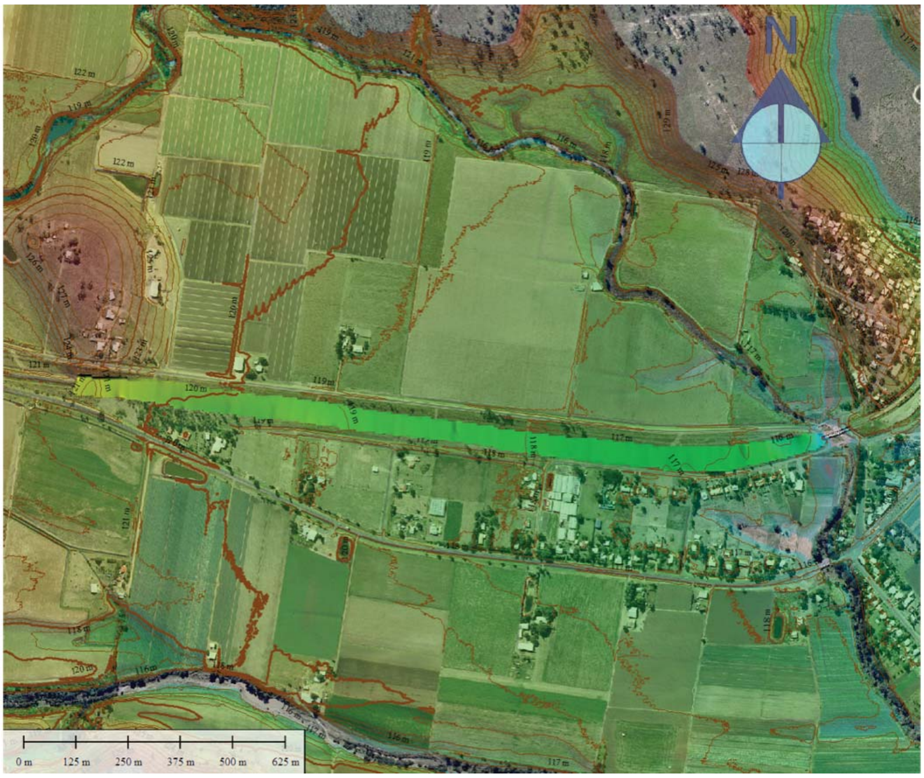


Figure B.21 – Surface Topography at the Grantham Quarry Site