12 Testing Model Performance

12.1 Overview

411. I have tested my GFCOI model sufficiently to satisfy myself that it is operating in accordance with my expectations and requirements. Key components of my tests comprised:

- the effect on simulation outcomes produced by the three different estimates of flood inflow hydrograph derived from the DNRM Helidon Gauging Station;
- water levels in the Quarry lake prior to the flood and their effect on flooding;
- calibration of the GFCOI model to peak flood heights;
- the influence of the Quarry levees on upstream flooding; and
- the use of finer spatial resolution (grid size) for modelling the effect of the Quarry breach on flooding.

394. Outcomes from my testing are presented in the following sub-sections.

395. I have undertaken a number of tests and quantified summaries of their outcomes using the following information:

- flow hydrographs at the downstream locations marked in Figure 12.1;
- depth and flow intensity hydrographs at the locations marked in Figure 12.2; and
- metrics tabulations at selected locations in and around Grantham and the Quarry, Figure 12.3.

396. As I have done previously (Section 10), I have chosen flood flow hydrographs for quantification measurement as this is a primary factor affecting flood characteristics. Although the effect on flooding is not a linear relationship, if there is an increase in flow then there will be an increase in flooding, and vice versa. The other aspect of importance is timing, which can be interpreted in the same manner as flow rate.

397. I consider that my selected locations, as shown in Figures 12.1 to 12.3, give representative coverage of flooding within and around Grantham.

398. Also, in relation to my selection of downstream flow reporting locations:

- Lockyer Creek – flows past this location affect all flooding that emanates from the downstream Lockyer Creek, including the South-Western Overbank flow and Sandy Creek back flows;
- Western Overbank – flows past this location lead directly to Grantham from the west;
- South-Western Overbank – flows past this location represent the initial breakout front that first reach West Grantham from the south-west.

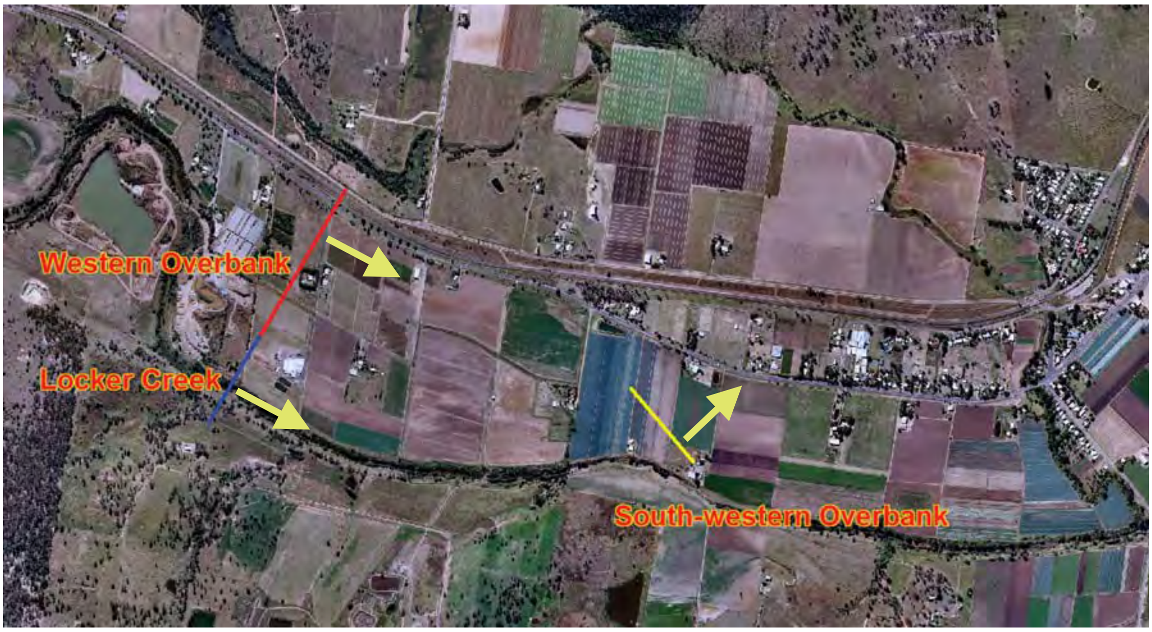


Figure 12.1 – Downstream Reporting Locations

Figure 12.2 – Flow Depth and Intensity Locations

Figure 12.3 – Metrics Locations

12.2 Helidon Gauge Flow Hydrographs

399. As discussed previously in Section 8.3, my review of the rating curve for the DNRM Helidon Gauging Station concluded that the rating was most likely in error. I subsequently developed a new rating for the station based on simulation outcomes from the LVRC model. Application of this revised rating curve to stage height records from the Helidon Station then produced an alternative flow hydrograph for this site. These are plotted in Figure 8.6.

400. Details of my revised flow hydrograph for the 10th January 2011 event are presented in Section 8.3. I have tested the suitability of my revised hydrograph by making comparison between simulation outcomes by running the GFCOI model with each of the flow hydrographs, all for the 10th January 2011 flood event:

- Original DNRM rating curve hydrograph;
- Revised GFCOI rating curve hydrograph; and
- LVRC model hydrograph.

401. I have plotted simulation outcomes for flow hydrographs at those locations indicated in Figure 12.4 below at the locations marked in Figure 12.1.

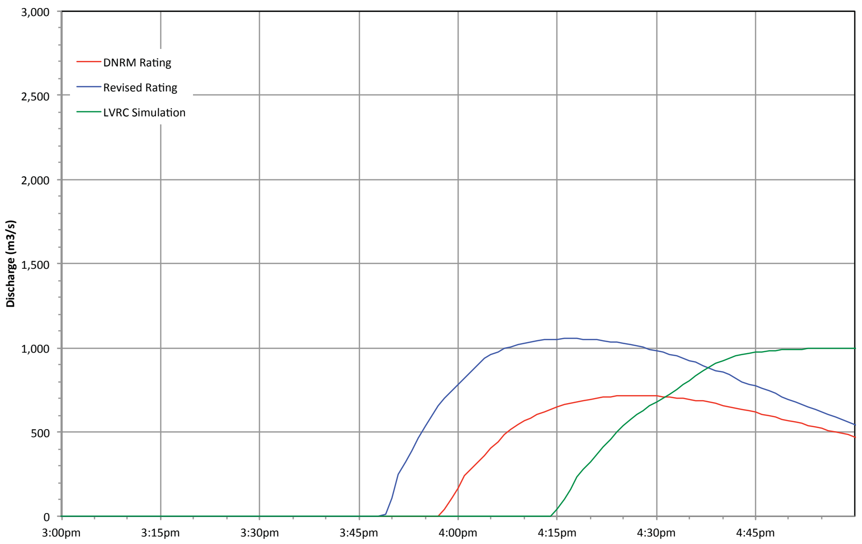
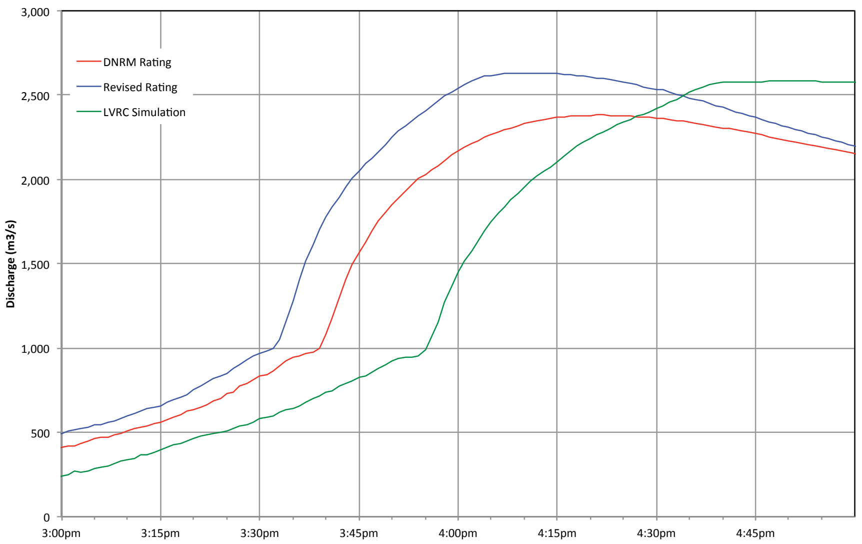
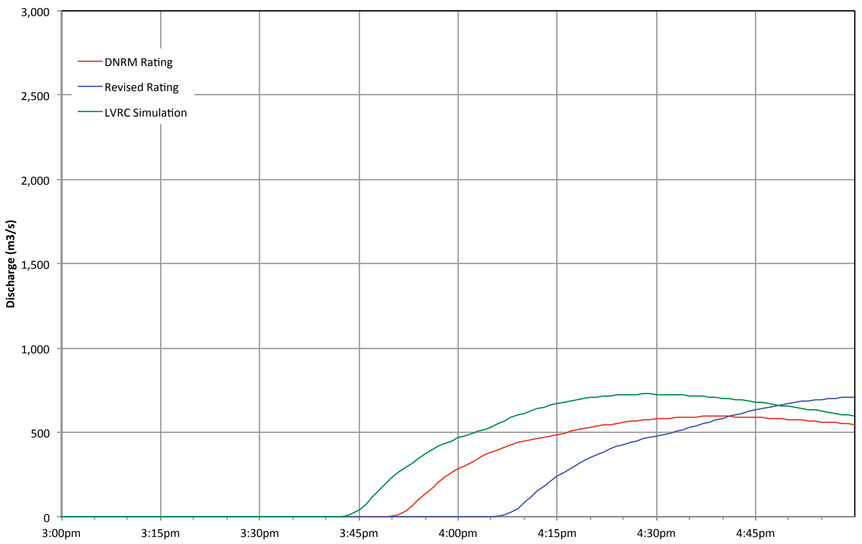
Western Overbank	
Lockyer Creek	
South-Western Overbank	

Figure 12.4 – Change in Flows Downstream from Quarry: Helidon Hydrographs

402. My interpretation of the information plotted in Figure 12.4 indicates:

- DNRM Rating based peak flow rates are around 10% lower than those for the Revised Rating and LVRC Simulation, whereas the DNRM Rating and Revised Rating peak flow rates are about the same;
- the LVRC Simulation hydrograph is lagged by about 25 minutes after the Revised Rating hydrograph, whereas the DNRM Rating is lagged by a lesser amount of about 5 to 10 minutes;
- the rate of rise of the Revised Rating flow hydrographs is greatest, most noticeably in the Western Overbank flows;
- the South-Western overbank flows are affected in a similar manner as those in Lockyer Creek, that is, the primary effect being a 20 minute lag for the LVRC Simulation, and about a 5 minute lag for the DNRM Rating, when compared to the Revised Rating hydrograph.

403. The significance of the differences shown in Figure 12.4 with respect to flood levels and timing is summarized by the selected metrics listed in Table 12.1.

Table 12.1 – Sensitivity Metrics: Helidon Hydrographs

Item	Average	Location					
		ULG_PO172	Cork_REC_6	3084_L1	3084_L3	3084_L16	3084_L36
Peak Flood Level Calibration Error (m)							
DNRM Rating (Run 053)	-0.28						
Revised Rating (Run 050)	-0.07						
LVRC Simulation (Run 054)	-0.01						
Peak Flood Level (mAHD), Time (h:mm pm)							
DNRM Rating (Run 053)		128.0 (4:16)	124.5 (4:30)	121.5 (4:41)	120.8 (4:44)	119.1 (5:05)	116.9 (6:00)
Revised Rating (Run 050)		128.1 (4:00)	124.9 (4:20)	121.7 (4:30)	121.0 (4:34)	119.3 (4:55)	117.1 (5:55)
LVRC Simulation (Run 054)		128.0 (4:32)	124.8 (4:59)	121.7 (5:10)	121.0 (5:14)	119.4 (5:37)	117.2 (6:00)
Max 30min. depth change (m), Time (h:mm pm)							
DNRM Rating (Run 053)		5.3 (2:05)	1.3 (4:30)	1.8 (4:37)	2.1 (4:32)	1.5 (4:45)	0.8 (4:49)
Revised Rating (Run 050)		5.7 (1:58)	1.7 (4:21)	2.0 (4:28)	2.3 (4:24)	1.7 (4:37)	1.0 (4:42)
LVRC Simulation (Run 054)		3.5 (2:32)	1.6 (4:47)	1.9 (4:53)	2.2 (4:48)	1.6 (5:02)	0.8 (5:03)
Time that flood depth reaches 0.5m (h:mm pm)							
DNRM Rating (Run 053)			4:15	4:13	4:05	4:19	4:31
Revised Rating (Run 050)			4:15	4:03	3:57	4:10	4:21
LVRC Simulation (Run 054)			4:15	4:30	4:22	4:35	4:47

404. The metrics listed in Table 12.1 directly correlate with the differences presented in the flow hydrograph plots as:

- both the DNRM Rating and LVRC Simulation flood inundation lag noticeably behind the Revised Rating inundation; and

- when compared to surveyed peak flood heights, the DNRM Rating produces peak levels that are on average about 0.3m low, the Revised Rating about 0.1m low, and the LVRC Simulation is in close agreement.

405. In considering these outcomes I have concluded:

- the DNRM Rating flow hydrograph is deficient in that peak flood heights are too low;
- the LVRC Simulation flow hydrograph is deficient in that its rate of rise is too slow, particularly at the upstream side of the Grantham Quarry (location ULG_PO172); and
- the Revised Rating flow hydrograph provides the best estimate of the actual flow hydrograph for the 10th January 2011 flood event at the Helidon Gauge.

12.3 Quarry Lake Water Levels

406. The level of water that was within the Grantham Quarry immediately prior to its inundation by the 10th January 2011 flood event had a direct effect on the net influence that the quarry exerted on the surrounding flood flows and levels.

407. The primary reason for the importance of lake level is that the lower the level, the greater the available capacity to absorb (or store) flood inflows into the quarry in consequence of levee breach. The significance of available capacity is not only that this volume is effectively removed from the flood, but also that outflows from the pit area back into the downstream Lockyer Creek waterway will only commence once the pit has filled.

408. To more thoroughly test out the effect of lake water levels I have undertaken two simulation runs:

- GFCOI model with IWL at 116mAHD (lower estimate) as indicated in Table 10.3, Section 10;
- GFCOI model with IWL at 120mAHD (upper estimate) being the water level adopted as the base case for the Most Likely scenario.

409. I have used simulation outcomes to quantify the changes to the magnitude, distribution and timing of the Flood hydrograph downstream of the Quarry at the locations marked on Figure 12.1. Time-series plots are presented in Figure 12.6.

Figure 12.6 – Effect of Initial Lake Level on Flow Downstream from Quarry

(a) Lockyer Creek

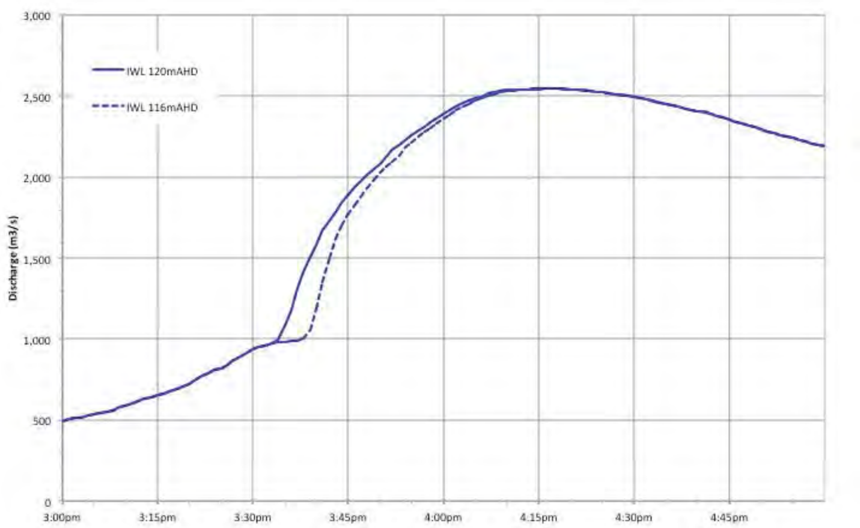
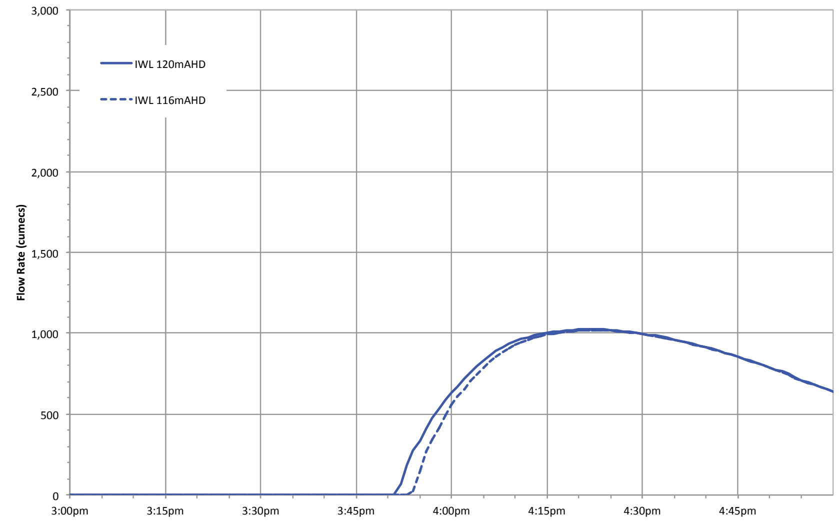
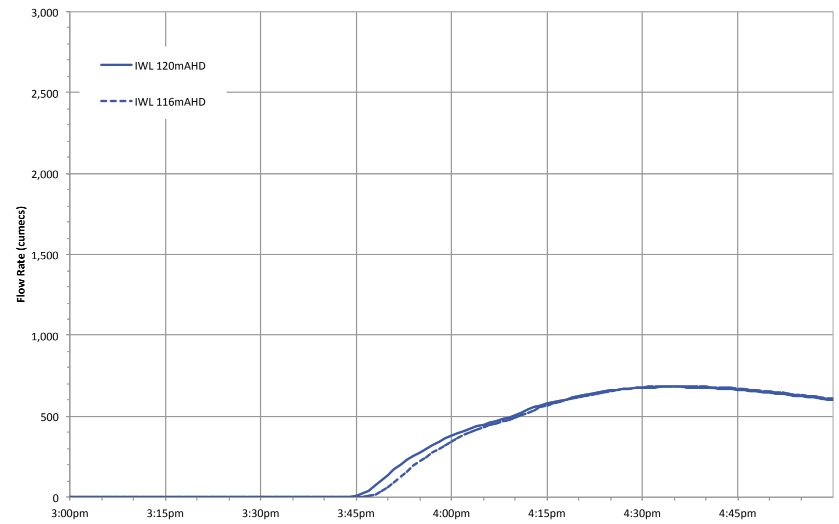


Figure 12.6 (continued) – Effect of Initial Lake Level on Flow Downstream from Quarry

(b) Western Overbank



(c) South-Western Overbank



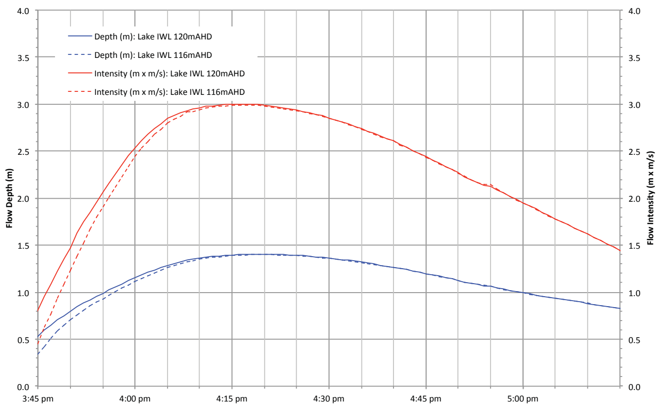
410. I observe from my review of these hydrographs that increasing the initial lake water level within the Quarry has the effect of slightly reducing the time to fill by around 5 minutes. This in-turn is seen to marginally reduce the duration that flow in Lockyer Creek while the pit fills, as indicated in Figure 12.6 (a).

411. The corresponding reduction in delay in Western Overbank flows (Figure 12.6 (b)) is equally as small, as too is the effect on the South-Western Overbank hydrograph (Figure 12.6 (c)).

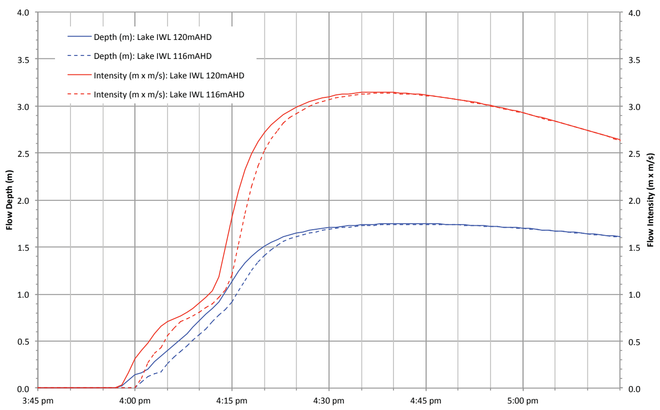
412. I have also used simulation outcomes to quantify the effect of these small changes on flooding characteristics. I have done this by producing flow depth and intensity hydrographs in Figure 12.7 at the reference locations shown in Figure 12.2 (enlarged copies of both these figures are contained in Appendix C).

413. I observe from my comparison of these hydrographs that a change in pit initial water levels has little effect on flow depth and intensity, other than a delay of the hydrographs in Eastern, Central and Western Grantham by up to around 5 minutes. It is my view that this delay can be attributed to the time taken for the inflows from Lockyer Creek to fill the quarry pit, which is dependent upon the initial water level in the pit.

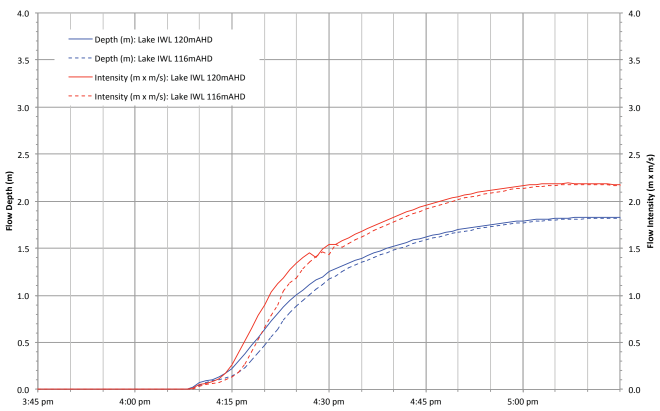
(a) Quarry Access Road



(b) 1414 Gatton-Helidon Road



(c) 12 Anzac Avenue



(d) 26 Anzac Avenue

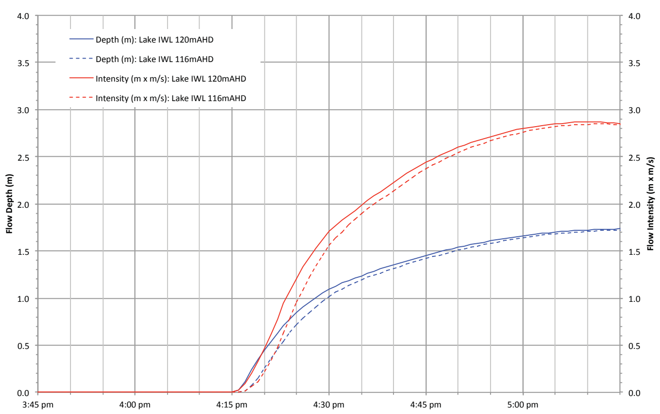


Figure 12.7 – Effect of Initial Lake Level on Flow Depth and Intensity

12.4 Peak Flood Heights

414. I have been provided with peak flood heights from:

- LVRC data that accompanied the LVRC models;
- Rickuss, Ian, Flood Level Survey Plan TM153 FL 002A; and
- Cork, Richard, statement dated 3 June 2015.

415. I have compared simulated peak flood heights from the GFCOI model for the 10th January 2011 flood event (using the Revised Helidon rating, Section 8.3) with peak flood height data from LVRC. This comparison produced an overall average difference of 0.0m.

416. I have then prepared a composite of all peak flood height data (as listed above) and compared that composite data set to the GFCOI model's simulated peak flood heights. The outcome of this second comparison is presented in Figure 12.8a and 12.8b. Point markers in these figures represent locations of peak flood heights and the associated number represents the difference between simulated and measured height (positive means simulated is higher). For ease of interpretation I have used different symbols to represent value ranges as well as providing the numerical calibration difference.

417. From Figures 12.8a and 12.8b I note that:

- the difference between the simulated peak flood heights and the measured peak flood heights from Klucks Road to Eastern Grantham range from -0.5m to +0.4m; and
- markers in the Carpendale area show simulated levels significantly in excess of observed peak heights. The difference is considerable: 1 mark of 0.9m in excess; and 4 marks of 1.3m in excess.

418. As to the last of these items, the peak flood height data associated with the markers with high error were provided by LVRC. The data was not accompanied with any certification or similar documentation from a Licensed Surveyor. I am unable to allocate any particular level of my confidence to these peak flood height markers without this supporting information. The magnitude of the error suggests to me that the reason most likely rests with some sort of systematic error associated with the survey process applied to this group of markers.

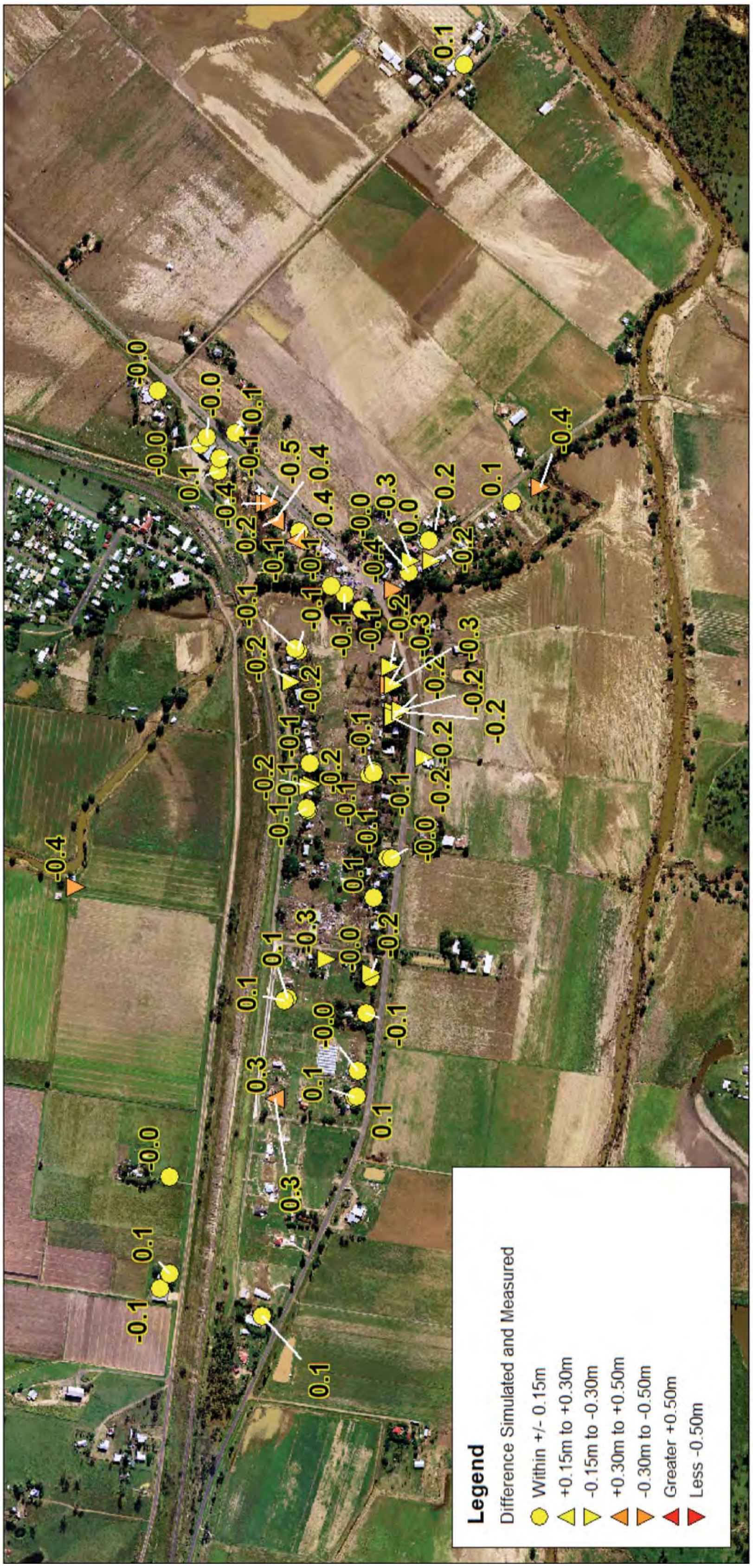


Figure 12.8a – GFCOI Model Peak Flood Height Calibration

Figure 12.8b – GFCOI Model Peak Flood Height Calibration

419. In his statement dated 3 June 2015, Mr Cork provided his own set of surveyed peak height data. An extract of this data is listed in Table 12.2 alongside simulated peak height levels from the GFCOI model. The average difference between Mr Cork's levels and simulated is -0.06m (simulated low).

Table 12.2 – Peak Flood Height Survey (Cork)

ID	Location	Surveyed Peak Flood Height (mAHD)	Simulated GFCOI Peak Height (mAHD)	Difference (m)
REC101	1336 Gatton-Helidon Road, Grantham	119.54	119.25	-0.29
REC102	1340 Gatton-Helidon Road, Grantham	119.52	119.32	-0.20
REC103	1370 Gatton-Helidon Road, Grantham	119.85	119.82	-0.03
REC104	1 Citrus Street, Grantham	120.44	120.25	-0.19
REC105	1414 Gatton-Helidon Road, Grantham	120.75	120.75	0.00
REC106	1420 Gatton-Helidon Road, Grantham	120.83	120.94	0.10
REC107	7 Sorrensen Street, Grantham	120.74	121.05	0.31
REC108	66 Railway Street, Grantham	120.43	120.49	0.06
REC109	46 Railway Street, Grantham	119.69	119.61	-0.08
REC110	44 Railway Street, Grantham	119.66	119.49	-0.17
REC111	6 Nicholls Street, Grantham	119.64	119.55	-0.10
REC112	32 Railway Street, Grantham	119.44	119.25	-0.19
REC113	28 Railway Street, Grantham	119.31	119.16	-0.15
REC114	6 William Street, Grantham	119.16	119.02	-0.14
REC115	12 Anzac Avenue, Grantham	118.26	118.12	-0.14
REC116	14 Anzac Avenue, Grantham	117.98	118.20	0.22
REC117	18 Anzac Avenue, Grantham	118.27	117.82	-0.46
REC119	26 Anzac Avenue, Grantham	117.45	117.39	-0.06
REC120	32 Anzac Avenue, Grantham	117.30	117.29	-0.01
REC203	1649 Gatton-Helidon Road, Grantham	126.55	126.56	0.01
REC302	1617 Gatton-Helidon Road, Grantham	126.12	126.00	-0.12
REC401	42 Klucks Road, Carpendale	128.82	128.96	0.14
REC601	27 Dorrs Road, Grantham	124.95	124.98	0.03
REC703	1615 Gatton-Helidon Road, Grantham	125.30	125.32	0.02
REC704	1617 Gatton-Helidon Road, Grantham	126.12	126.10	-0.02
			Average	-0.06

420. Mr Rickuss MP has also provided surveyed peak height data. An extract of this data is listed in Table 12.3 alongside simulated peak height levels from the GFCOI model. The average difference between Mr Rickuss's levels and simulated is -0.04m (simulated low).

Table 12.3 – Peak Flood Height Survey (Rickuss)

ID	Location	Surveyed Peak Flood Height (mAHD)	Simulated GFCOI Peak Height (mAHD)	Difference (m)
IR101	Lot 1 on RP84658	120.25	120.20	-0.05
IR102	Lot 304 on G34211	119.49	119.32	-0.17
IR103	Lot 105 on RP889870	117.25	117.23	-0.02
IR104	Lot 2 on RP843401	117.25	117.32	0.07
			Average	-0.04

12.5 Flood Inundation Upstream of the Quarry

421. In times of flood, a considerable volume of water will typically inundate the floodplains, flowing out from the main watercourse on the rise and returning on the fall. This natural process results in the attenuation, or slowing and spreading (flood routing), of the flow hydrograph as it moves down stream.

422. An artificial constriction to flood flows will cause water levels upstream of the constriction to rise, and hence a greater volume of floodwater will be exchanged with the floodplain during the passage of the event. A direct consequence of this is an increased amount of flood attenuation.

423. I have constructed a cross-section through the Lockyer Creek waterway at the location of the Western Levee of the quarry. The cross-section starts at the Gatton-Helidon Road and runs south for approximately 900m as indicated in Figure 12.9. The cross-section is also plotted in Figure 12.10.

Figure 12.9 – Locality of Western Levee Waterway Cross-section

424. The cross-section is orientated looking down-stream from upstream of the Western Levee. The cross-section shows the high-level left overbank area, the creek (on the northern side of the quarry), the Western Levee, and the right overland flow path (to the south of the quarry).

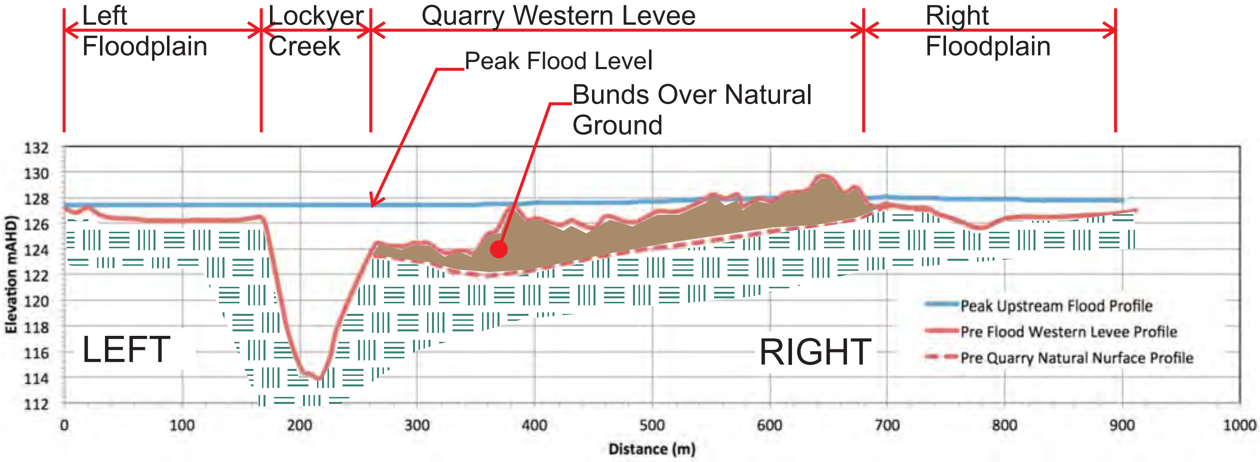


Figure 12.10 – Western Levee Waterway Cross-section

425. I have also shown the line of the pre-quarry surface estimated by Mr Starr (Geotechnical Expert) and the approximate crest line of the August 2010 Eastern Bunds that run the length of the Western Levee. The brown coloured infill between the lines of the pre-quarry surface and the Eastern Bunds represents the extent of fill associated with the bunds.

426. A thin blue line is also plotted in Figure 12.10 that represents my estimate of the peak 10th January 2011 flood level within Lockyer Creek immediately upstream from the Western Levee.

427. I have calculated the area of fill material shown in Figure 12.10 (brown infill) as well as the area of the cross-section that lies between the blue water surface line, and the line beneath it which represents the ground level for pre-quarry conditions (i.e. the line under the brown infill section). This second area calculation is representative of the flow area under pre-quarry conditions. I have listed this information in Table 12.4 including my calculated flow area for Pre-flood (August 2010) conditions (equal to the pre-quarry flow area minus the area of bund fill).

Table 12.4 – Indicative Flow Area Calculation Upstream of Quarry

Item	Area (m^2)
Pre-Quarry Flow Area	2,900
Area of Bund Material	1,150 (40% of Pre-quarry flow area)
August 2010 Flow Area	1,750 (60% of Pre-quarry flow area)

428. The information I have listed in Table 12.4 can be used to provide an indication of the constriction to flow likely to be exerted by the Western Levee system under 10th January 2011 flood conditions.

429. Assuming the levee remains intact, then from Table 12.4 it can be inferred that the presence of the Bunds would reduce the flow area by approximately 40%. That is, it would reduce the flow area to only approximately 60% of what it would have been under pre-quarry conditions. Hence I expect that water levels upstream of this constriction would rise in order to compensate.

430. The actual calculations for accurately quantifying the expected impact of flow constriction are considerably more complex than what I have done above. However, the basic principle of increasing water depth with increasing constriction of flow area remains.

431. I have examined the action of floodplain filling upstream from the quarry using the GFCOI model (my Most Likely quarry levee scenario). I have presented time-coded images of the simulated action of floodplain inundation in the immediate upstream from the quarry in Figure 12.11a to 12.11f below. The images provide colour coded flow intensity and extent of inundation at 1 hour increments from 3:00pm to 8:00pm on 10th January 2011. Vectors (arrows) show the direction of flow with the length an indicator of velocity magnitude. Larger copies of these images are included in Appendix C.

(a) 3:00pm

(b) 4:00pm

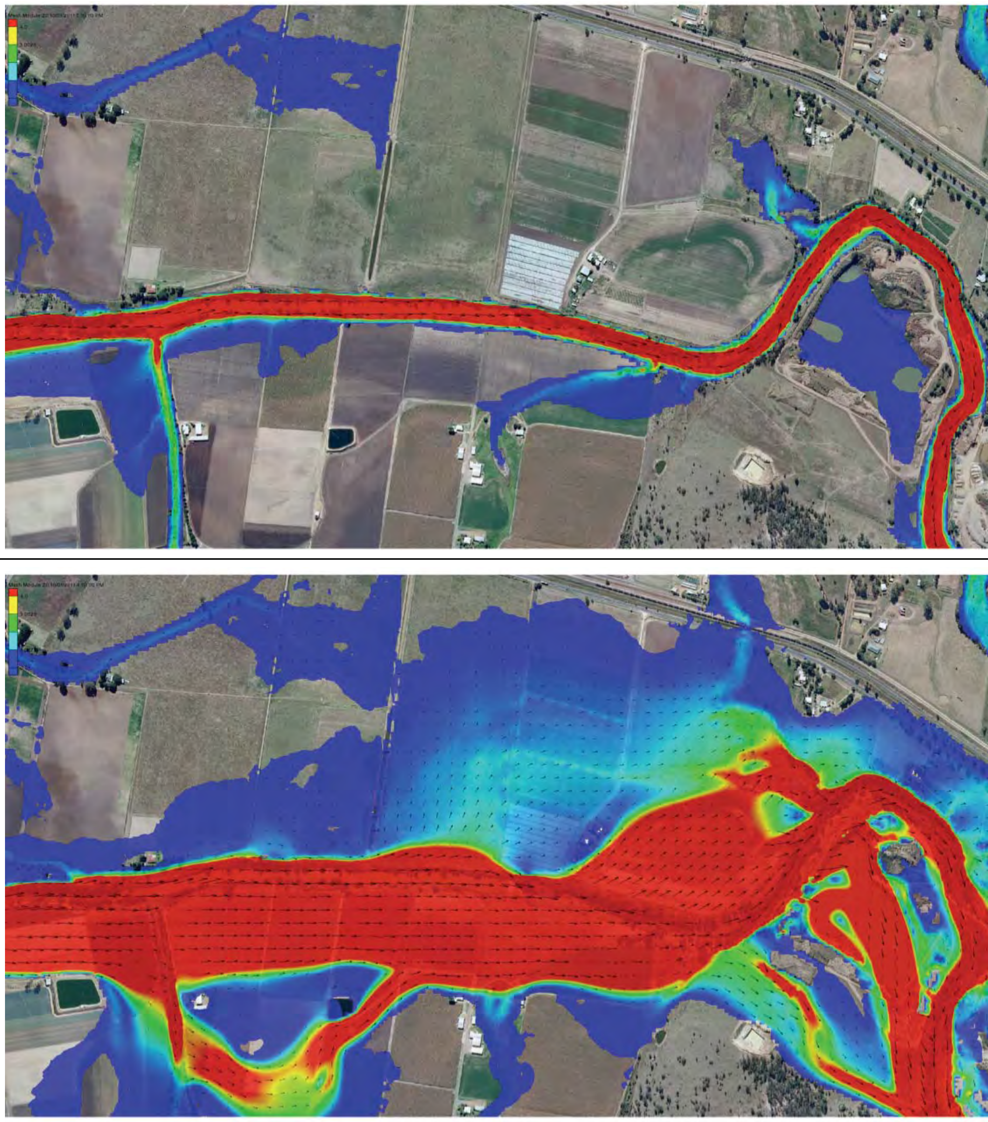


Figure 12.11 (a to c) – Flow Inundation Upstream from the Quarry

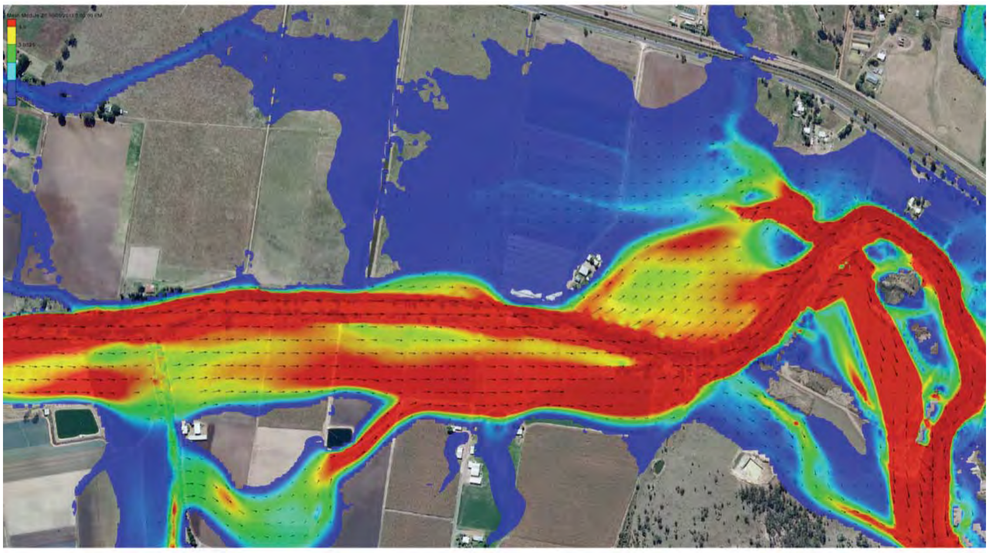
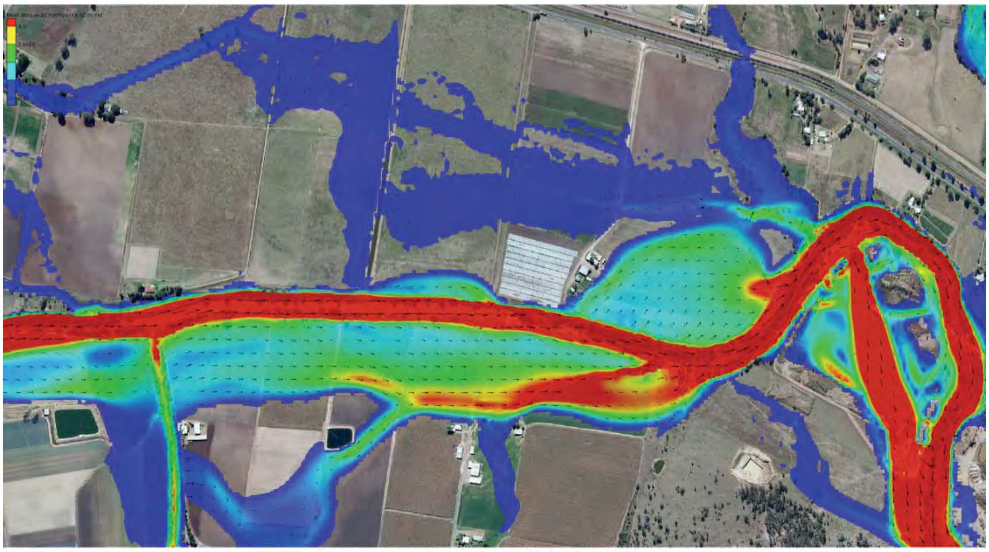
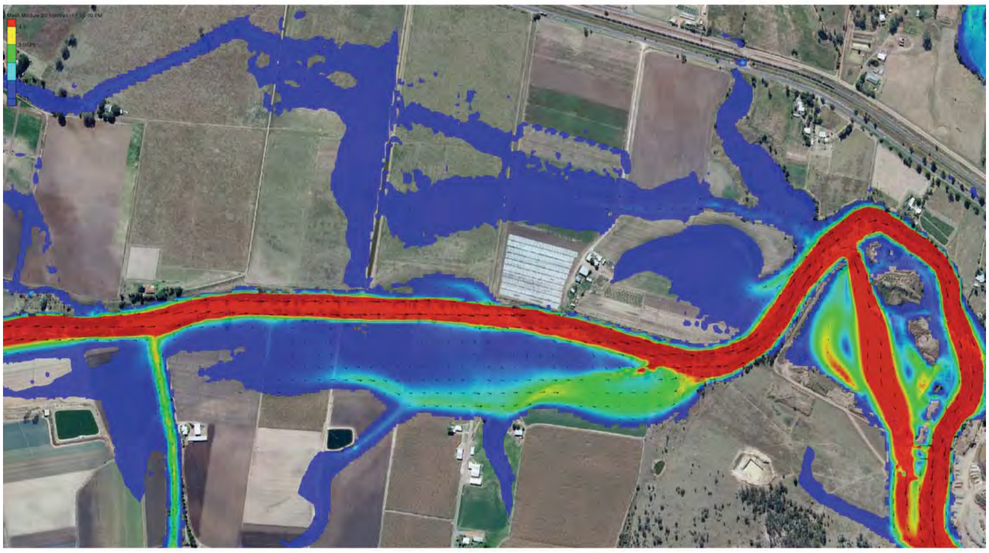
(c) 5:00pm	
(d) 6:00pm	

Figure 12.11 (c to d) – Flow Inundation Upstream from the Quarry

(e) 7:00pm



(f) 8:00pm

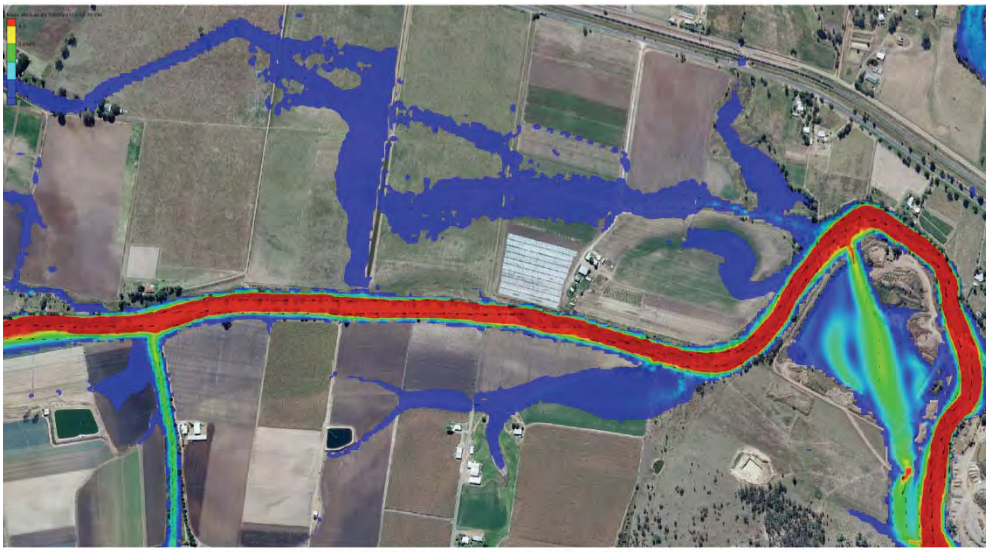


Figure 12.11 (e to f) – Flow Inundation Upstream from the Quarry

432. I have quantified the volume of floodwater stored in the waterway system between the western side of the quarry and Kapernick's Bridge and listed them in Table 12.5 at the same time-stamps associated with Figure 12.11.

Table 12.5 – Flood Storage Upstream from Quarry

Time	Volume Stored (GL)
3:00pm	1.6
4:00pm	6.3
5:00pm	5.0
6:00pm	3.5
7:00pm	1.6

433. Figure 12.11 shows that the flood commenced breaking out onto its floodplains at around 3:00pm and had largely returned to the waterway by about 7:00pm. From the information I have listed in Table 12.5 it follows that a volume of approximately 4.7GL (i.e. 6.3GL at 4:00pm minus 1.6GL at

3:00pm) flowed onto the floodplain. This was a significant volume that equates to about 45% of my estimated volume of the 10th January 2011 flow hydrograph (at Helidon) of 10.5GL to peak.

434. I notice in Figure 12.11 an oval shaped area of about 12ha located on the left bank of Lockyer Creek immediately to the west of the quarry. This area is inundated during the event.

412. In his statement to the GFCOI, Mr Sippel has observed the same inundated oval shaped area located immediately to the west of the quarry. He referred to it as a "sea of water" and marked it on a locality diagram as "Water Pooling". He also referred to water accumulating up to the bridge at Dinner Corner. For ease of reference, a copy of Mr Sippel's locality diagram is provided in Figure 12.12 below.

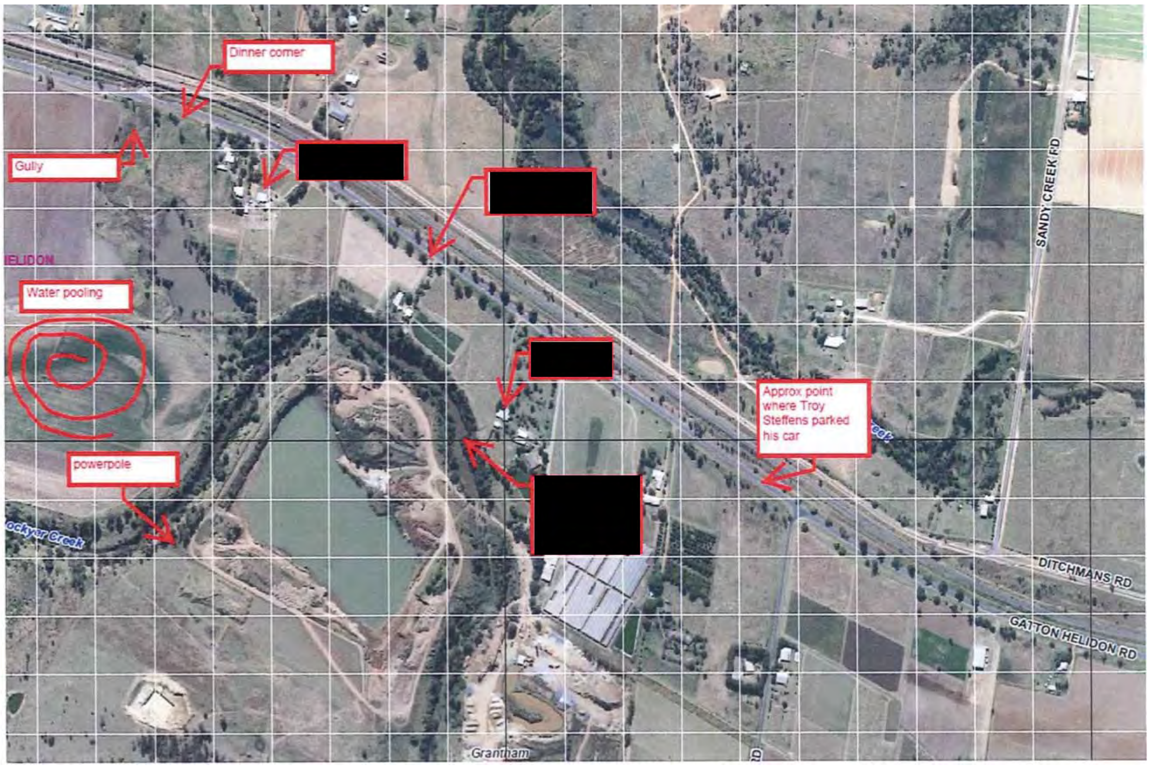
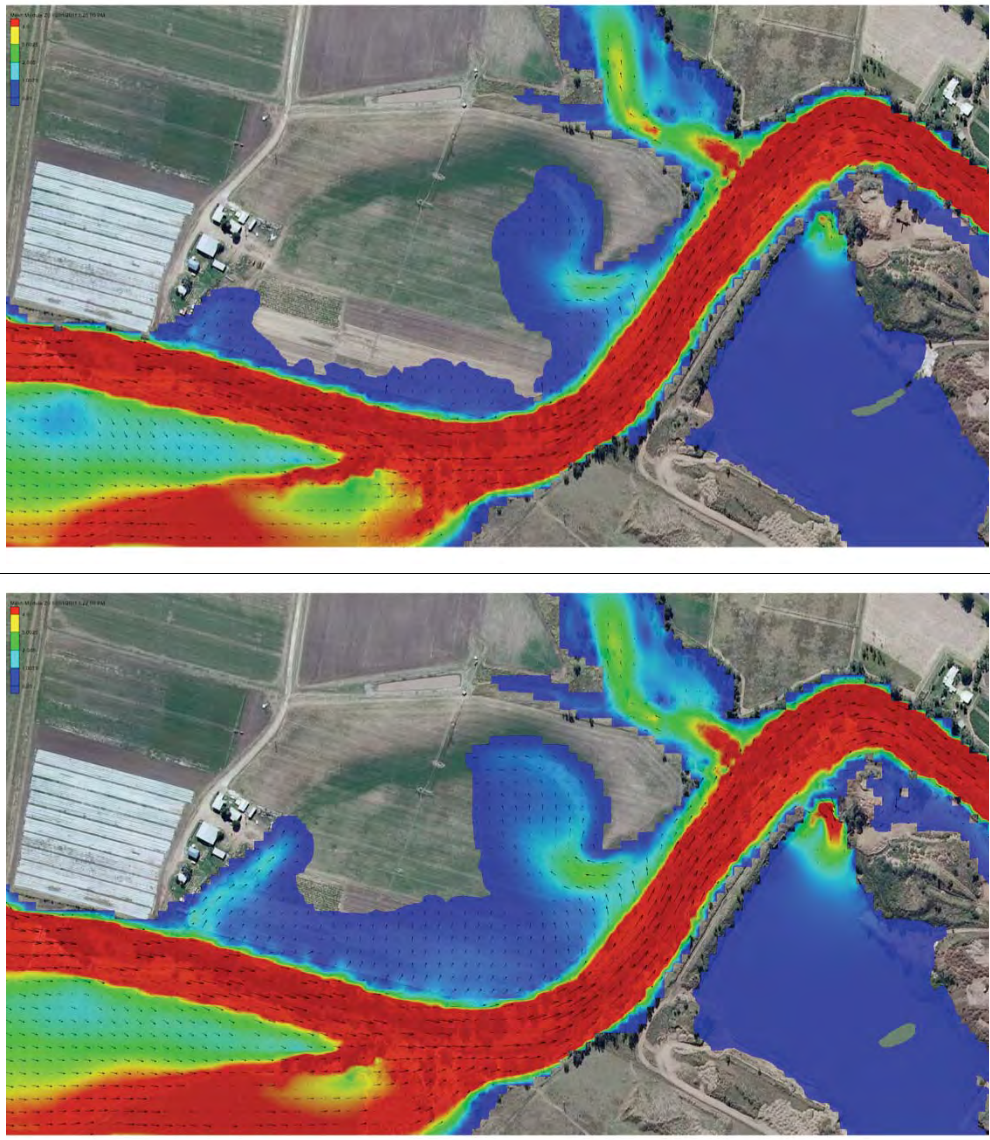


Figure 12.12 – Locality Map, Sippel 2015 LS-4

413. Further, in a report prepared by DHI for Nationwide News Pty Ltd entitled *Grantham and Wagner Quarry, Review of Flood Impact 10th January 2011 Flood Event, February 2015* (Szylkarski 2015), there is a figure that also shows this inundated area (Figure 4, DHI) in the foreground.

435. The following series of time-coded inundation images (colour coded to flow intensity) in Figure 12.13 provides a high-resolution time sequence of the inundation of this area (an enlarged copy is included in Appendix C). Importantly, the sequence also shows the interaction that occurs between water volumes and flows in this oval area and breaching of the quarry levee and creek bank, simulated commencing at about 3:25pm.



(a) 3:20pm

(b) 3:22pm

Figure 12.13 (a to b) – Flow Inundation of Oval Area Near Quarry

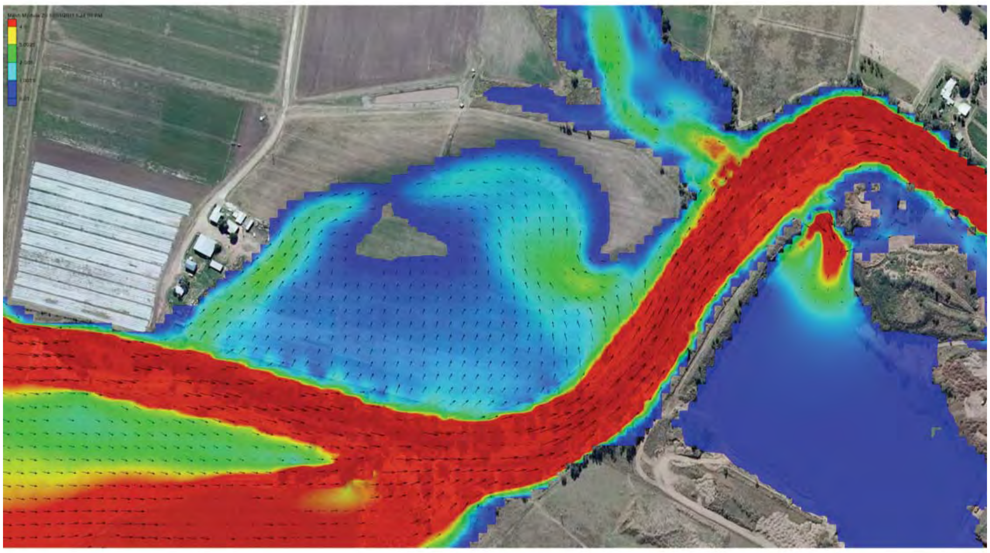
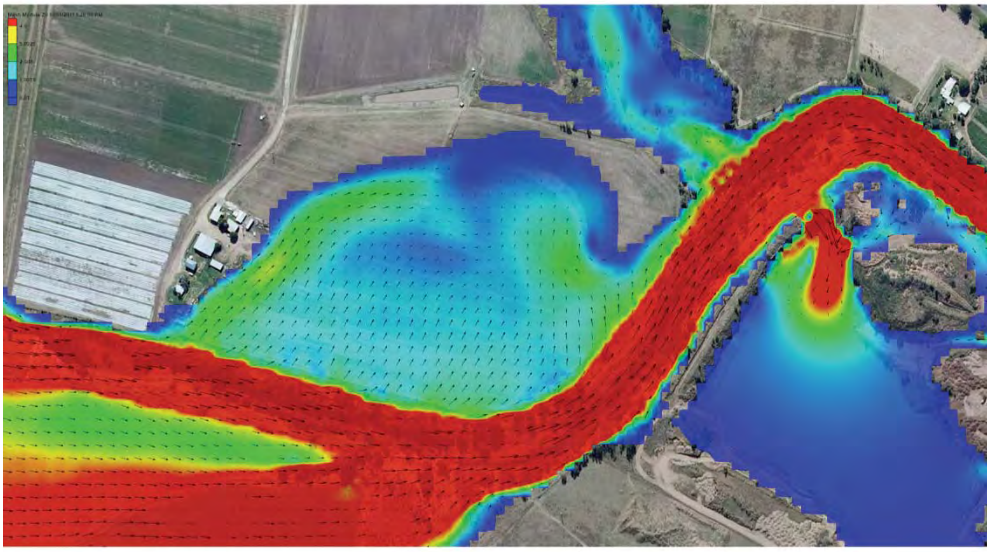
(c) 3:24pm	
(d) 3:26pm	

Figure 12.13 (c to d) – Flow Inundation of Oval Area Near Quarry

(e) 3:28pm

(f) 3:30pm

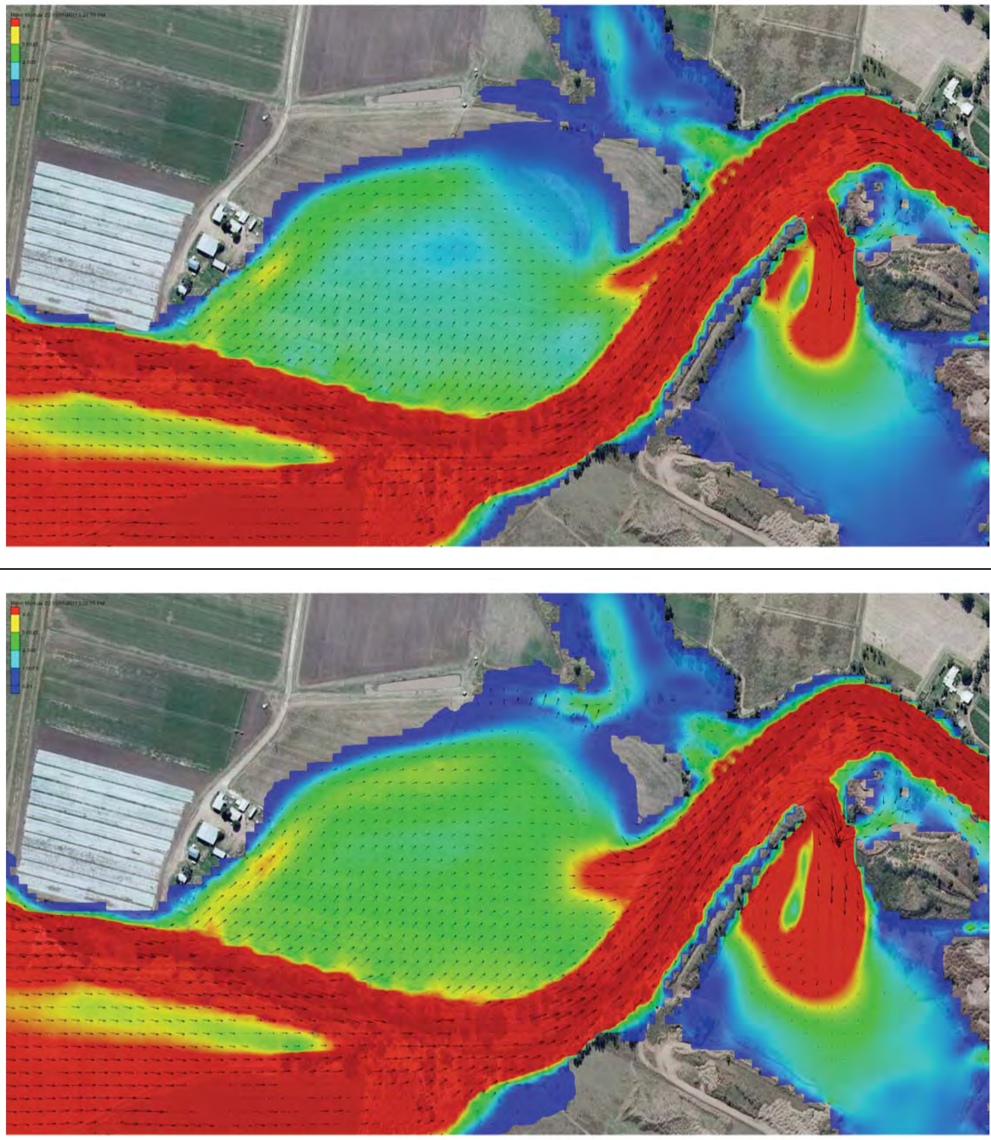


Figure 12.13 (e to f) – Flow Inundation of Oval Area Near Quarry

436. I notice from the information shown in Figure 12.12 the breakout flow into the Oval area starts just before 3:20pm. The primary point of inflow appears to be from a more defined flow path on the eastern side of the Oval. A more distributed breakout inflow is apparent along the southern side of the Oval. Inflows are seen to continue at a steady pace until 3:25pm at which time breaching of the north-western area of the Western Levee is initiated. Thereafter, the direction of flow on the eastern side of the Oval reverses with a marked increase in flow intensity.

437. I have quantified the volumes of floodwater contained over the 1.2ha area of the Oval for the period 3:00pm until 8:00pm. These volumes are listed in Table 12.6.

438. I have also included in Table 12.6 volumes associated with other modelling scenarios for reference. These other scenarios are discussed in detail in Section 10 and comprise: Worst Case (greatest drop, Trigger 124.5mAHD), Worst Case (greatest delay, Trigger 126.4mAHD), and the No Quarry Case.

Table 12.6 – Flood Storage in Oval Area Upstream from Quarry

Time	Volume Stored (GL)			
	No Quarry	**Most Likely**	**Worst Case (greatest drop)**	**Worst Case (greatest delay)**
3:00pm	0.00	0.00	0.00	0.00
4:00pm	0.38	0.16	0.41	0.43
5:00pm	0.32	0.34	0.35	0.35
6:00pm	0.21	0.22	0.22	0.22
7:00pm	0.06	0.06	0.05	0.05
Max Diff. to No Quarry	-	-9%	8%	13%

439. In Table 12.6 I have highlighted the times of maximum floodplain storage inventory. I have also included the relative differences to the No Quarry expressed as a percentage. From this information I note that there does not appear to be a great difference to the No Quarry case for the Most Likely and Worst Case (greatest drop) (within ±10%). The Worst Case (greatest delay) is greater, but still relatively small to the No Quarry case (+13%).

440. I also note that the maximum stored volumes listed in Table 12.6 are an order of magnitude smaller than that for the waterway upstream to Kapernick's Bridge. To me this indicates that although the Oval area is in close proximity to the Quarry, its relatively small flood storage and limited capacity for return discharge rate (small compared to that of the main creek channel), means that its presence is of no particular significance to the flood hydraulics associated with the quarry or failure of the western levee system.

12.6 Hydraulic Model Grid Size

441. I have configured the GFCOI hydraulic model with a 10m grid size. This is the same size used in the LVRC model. Although I consider the 10m grid size well suited for my purposes, I have considered the use of a higher resolution model that uses a 5m grid size.

442. There are benefits from using a reduced grid size, including:

- increased resolution of simulation outputs; and
- better modelling of those regions in the flow where viscous hydraulic forces become significant.

443. There are also a number of disbenefits that arise, including:

- increased model simulation times (a factor of 8 increase with a halving of grid size); and
- a need for further model recalibration.

444. For flood modelling investigations the grid size must also be sufficiently small so that the model can adequately resolve physical features of importance. A grid size of 10m is considered quite sufficient in this regard.

445. The remaining consideration that may dictate the need for a smaller grid applies to those situations where viscous forces (connected with a water property known as Eddy Viscosity) become significant. Typically this can be expected when the velocity of flow, and the transverse gradient in velocity, is high.

446. The hydraulics of overtopping of the Western Levee and subsequent rapid erosion of the Main Breach is one involving rapid changes over relatively short distances and time frames. With this in mind the possibility that model grid resolution might affect model performance was considered. I have tested it by reconfiguring the GFCOI model to have a 5m grid resolution.

447. Both the 5m grid model and the base GFCOI model (10m grid) were then used to simulate the breaching and subsequent filling of the Quarry and a comparison was made between the outcomes.

448. Figure 12.13 presents a plan view of the Quarry showing the location of a longitudinal profile through the middle of the pit.

Figure 12.13 – Quarry Cross-section Locations

449. Time-stamped profiles of the simulated water surface through the pit along the *longitudinal profile* marked in Figure 12.13 are plotted in Figure 12.14. Profiles are presented for simulation outcomes from both the 5m and 10m grid models.

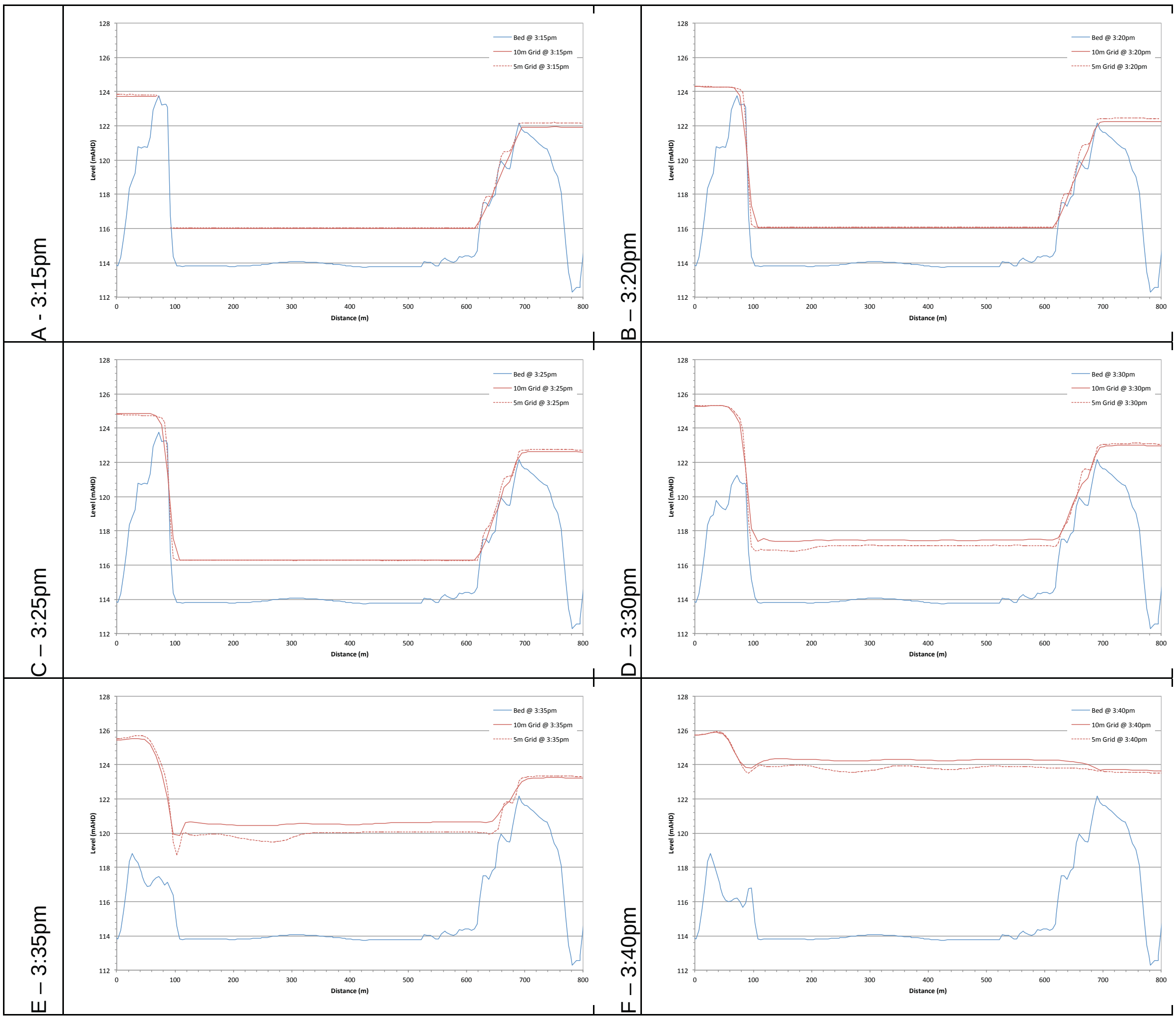


Figure 12.14 – Longitudinal Water Surface Profiles Through Quarry

450. In Figure 12.14 flow is from left to right. My review of this information led me to find that simulated water levels for the 5m grid case are always lower than those for the 10m grid, with a maximum difference of about 0.5m when inflow rates into the pit are largest (3:30pm to 3:35pm). Before and after this period the levels are seen to be much closer. Levels within Lockyer Creek are seen to be largely unaffected.

451. Hence, I conclude that although a higher resolution grid does produce a slight difference in levels, this difference is confined to within the quarry pit, does not extend beyond and, for all intents and purposes, is not significant.

13 Corroboration by Eye-witness Accounts

13.1 Overview

452. To meet with the requirements of the GFCOI it has been necessary for me to demonstrate that the GFCOI model (based on the Most Likely scenario as described in Section 10) gives simulation outputs that correspond acceptably with observations. For Grantham flooding, I consider that timing is an important reference item and provides a significant link to the observations in eye-witness accounts.

453. To address this issue I have referred to selected eye-witness accounts in order to establish the accuracy of the GFCOI model and corroborate its performance. Relevant locations referred to in those eye-witness accounts are shown in Figure 4.15 and Table 13.1 below sets out the summary of the observations made by eye-witnesses at those locations.

Figure 13.1 – Corroboration Locations

Table 13.1 – GFCOI Model Selected Eye-witness Accounts

Item	Eye-witness Material	Time (hh:mm)	Description	Location
1.1	Arndt, Frances (29 January 2011)	Before 4:07pm	Statement Item 11: Mrs Arndt observed a large sheet of water heading towards her location [redacted]) from Lockyer Creek.	A
1.2	Arndt, Frances (1 July 2015)	4:07pm	Statement Items 5 and 6: Mrs Arndt called Mr McGuire requesting assistance to help them out of the water.	B
1.3		4:09pm	Statement Items 7 and 8: The vehicle that the Arndts were travelling in along the Gatton-Helidon Road, midway between Sorrensen Street and Citrus Street, was at the point of having just lost traction with the road due to the flow and depth of floodwater.	B
1.4		4:09pm	Statement Item 8: Mrs Arndt saw a fire truck (Mr McGuire) moving backwards against the flow of floodwater.	C
2.1	Marshall, Bruce (000 Transcript and Coroners Report, 2011)	4:10pm to 4:18pm	From the Coroners Report, under *Events leading to death*, at the location of 1420 Gatton-Helidon Road, a low set timber dwelling: within 1 minute before 4:10pm the water was observed by Mr Marshall coming through the floor boards; at 4:12pm it was waist deep; and at 4:18pm it was shoulder deep.	D
3.1	Sippel, Jonathan (1 July 2015) Mallon, Neville (1 July 2015)	3:19pm to 3:22pm	Sippel Statement Items 27 and 28; Mallon Statement Item 7: During a telephone conversation Mr Mallon advised Mr Sippel that water from Lockyer Creek was starting to spill into the Quarry pit from directly opposite Mr Mallon's residence (at the pit's north-western corner).	E
3.2	Transcript of hearing before GFCOI on 21 July 2015	3:35pm (approx)	Sippel Transcript (p. 123, lines 18-25): during a telephone conversation with Mr Sippel, Mr Mallon said *he could sort of see it running into the northern edge of the pit. There was a bit of water running at the northern side but at that stage I couldn't see any sort of water running just then*; (p. 123, lines 27-33); *Well I understood that just to be behind* [redacted]*], basically, right behind* [redacted] *on the north-western corner.*	E
3.3		3:39pm	Sippel Transcript (p. 124): Mr Sippel observed water starting as a trickle flowing from Lockyer Creek into the Quarry pit at near the power pole at the pit's far south-western corner.	F
3.4	Sippel, Jonathan (1 July 2015)	4:19pm	Statement Item 55: Mr Sippel observed the floodwater lapping the edge of the Gatton-Helidon Road.	G
4.1	Besley, Helen (2 July 2015) 000 Transcript	3:00pm (after)	Statement 14: Mrs Besley and her husband were standing on a concrete slab on the north-eastern bank of Lockyer Creek adjacent the Quarry and they observed water levels in the creek begin to rise relatively rapidly, sometime after 3:00pm (estimated as 3:30pm when adjusted to match 000 call).	H
4.2		3:48pm	Statement Item 21: 000 Transcript: While attempting to evacuate the property, a wave of water picked up the vehicle Mrs Besley and her husband were in and initially deposited it in the adjoining paddock to the east.	H

Item	Eye-witness Material	Time (hh:mm)	Description	Location
4.3		3:59pm	Statement Item 25: 000 Transcript: Mrs Besley and her husband were washed from their perch on their car by one of a number of waves.	I
5.1	Lack, Wayne (7 July 2015)	3:47pm to 4:09pm (photo)	Attachment WDL-3: Time-stamped photographs showing: • floodwater around the base of the fuel bowser slab at Marnell Fuels (LIDAR level est. 115.1mAHD); (Picture 002.jpg in attachment WDL-3, taken at 3:47pm); • floodwater around the base of rubbish bin at Grantham General Shop (LIDAR level est. 115.5mAHD); (Picture 010.jpg in attachment WDL-3, taken at 4:05pm); and • floodwater over the base of the fuel bowser slab at Marnell Fuels (LIDAR level est. 115.3mAHD); (Picture 020.jpg in attachment WDL-3, taken at 4:09pm).	J
5.2		4:23pm (approx)	Statement Items 20 and 21: Mr and Mrs Lack were located at [redacted] and observed the level of floodwater rise from about 6 feet (1.8m) deep to 11 to 12 feet (3.4m to 3.7m) in a matter of seconds.	K
5.3		4:32pm (Photo)	Attachment WDL-3: Time-stamped photograph showed floodwater at the base of the stay pole adjacent the Railway Yards (LIDAR level 117.4mAHD); (Picture 028.jpg)	L
5.4		5:00pm (photo)	Attachment WDL-3: Time-stamped photograph showed floodwater at the base of the power pole adjacent the Railway Yards (LIDAR level 117.9mAHD); (Picture 040.jpg).	L
6.1	Richardson, Lance (1 July 2015)	Period 4:15pm to 4:53pm	Statement Item 18: Mr Richardson was at the Grantham Hotel (12 Anzac Avenue) and observed a significant rise in the level of floodwater.	M
7.1	McIntosh, Anthony (1 July 2015) iPhone photographs Video 1 in attachment AM-3 to his statement.	3:08pm (approx)	Statement Item 22: Video recording with audio taken just before Lockyer Creek broke its banks.	N
7.2		4:41pm	Photograph IMG_0236.jpg: Mr McIntosh recorded an open expanse of flood inundation from his residence at Klucks Road to the Gatton-Helidon Road to the north and the western side of the quarry to the north-east	N

13.2 Arndt, Frances (1 July 2015)

Item	Witness Material	Time (hh:mm)	Description	Location
1.1	Arndt, Frances (29 January 2011)	Before 4:07pm	Statement Item 11: Mrs Arndt observed a large sheet of water heading towards her location [redacted]) from Lockyer Creek.	A
1.2	Arndt, Frances (1 July 2015)	4:07pm	Statement Items 5 and 6: Mrs Arndt called Mr McGuire requesting assistance to help them out of the water.	B
1.3		4:09pm	Statement Items 7 and 8: The vehicle that the Arndts were travelling in along the Gatton-Helidon Road, midway between Sorrensen Street and Citrus Street, was at the point of having just lost traction with the road due to the flow and depth of floodwater.	B
1.4		4:09pm	Statement Item 8: Mrs Arndt saw a fire truck (Mr McGuire) moving backwards against the flow of floodwater.	C

454. For ease of reference, I have also included two locality maps, Figures 13.2 and 13.3. Figure 13.2 shows Mrs Arndt's house, marked red square (also Location A). Figure 13.3 shows the approximate location of Mrs Arndt's car just before it was washed off the road, marked red square (also Location B). The yellow square shown in Figure 13.3 depicts the location of trees where Mr and Mrs Arndt were pushed to after abandoning their vehicle.

Figure 13.2 – Mrs Arndt's House

Figure 13.3 – Arndt's Vehicle Location

455. I have prepared simulation graphics covering the area of relevance to this statement produced by the GFCOI model at the times of 4:00pm, 4:07pm, and 4:09pm (Figure 13.4). The graphics shows colour coded flow intensity and the area of land affected by inundation. The times selected match statement times, with the exception for the observation summarized in Item 1.1 of the table above, where I have estimated 4:00pm on the basis of my understanding of what Mrs Arndt said she was doing at the time.

Figure 13.4 – GFCOI Flow Intensity Simulations

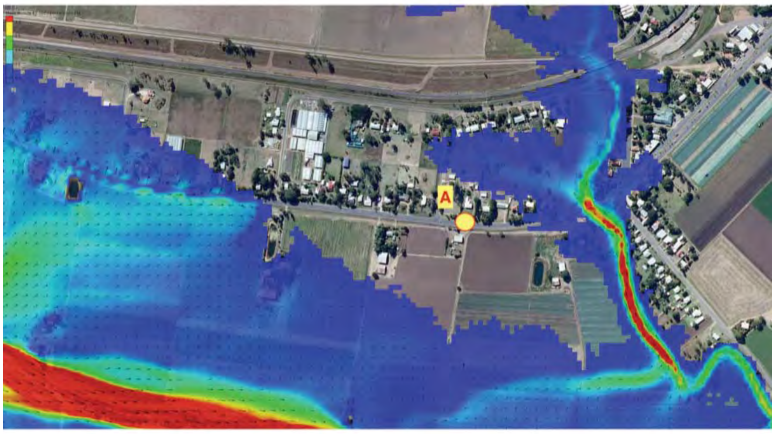
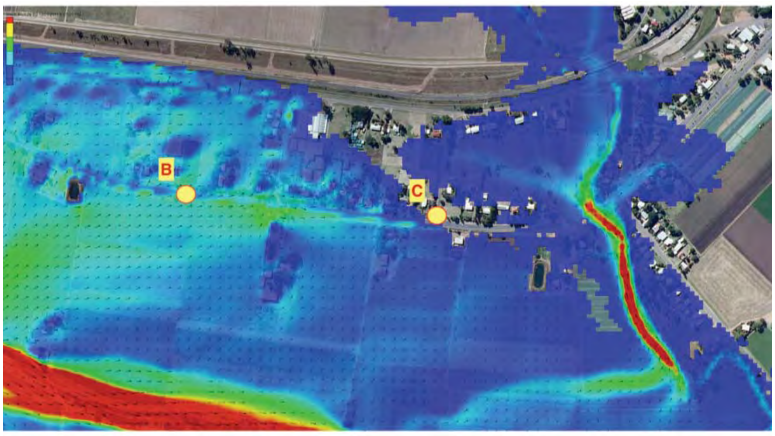
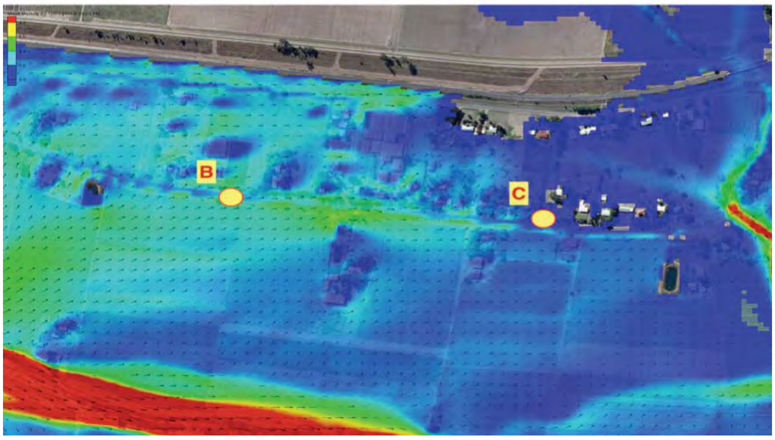
(a) 4:00pm	
(b) 4:07pm	

Figure 13.4 (continued) – GFCOI Flow Intensity Simulations

(c)4:09pm



456. As shown by the simulation graphics, the information given by Mrs Arndt corroborates the model simulation. In particular it shows the following:

a) 4:00pm – floodwater is approaching Grantham from Lockyer Creek to the south, as described by Mrs Arndt at location A.

b) 4:07pm – Mrs Arndt is at location B in her car with her husband and calls both 000 and Mr McGuire (at close to location C) for help.

c) 4:09pm – Mrs Arndt's car is losing traction on the road due to the flood flows and receives a call from Mr McGuire apologising that he cannot help. Mrs Arndt observes that Mr McGuire's fire truck (near to location C) is being forced backwards by the flow of water.

457. I also extracted simulation outcomes at Location B (on the Gatton-Helidon Road) to produce a plot of simulated flow depth and intensity (the product of flow depth and velocity), Figure 13.5.

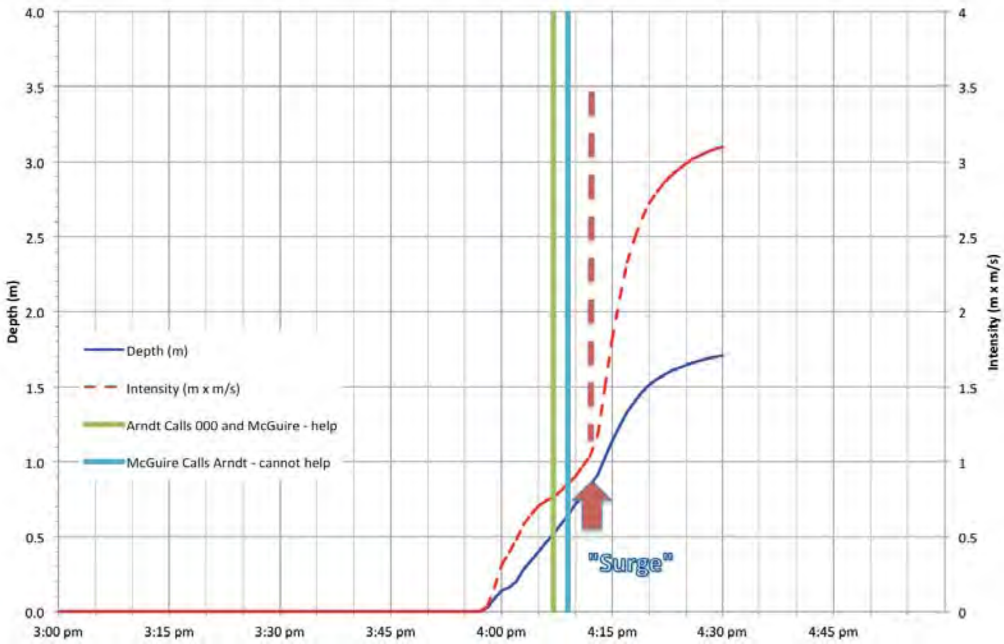


Figure 13.5 – Simulated Flow Characteristics at Mr and Mrs Arndt Location B

458. Flow intensity, is often used to establish the likely stability of an object in the path of flood flows, in this case, the likely stability of the Arndts' vehicle. Typically, flow intensities greater than $0.5m^2/s$ are capable of creating conditions that are unsafe for a vehicle.

459. I consider that the information shown in Figure 13.5 is consistent with the rise and timing of floodwaters as described by Mrs Arndt, including the occurrence of what I consider to be a surge in flow at 4:12pm.

13.3 Marshall, Bruce (000 Transcript and Coroners 2011)

Item	Witness Material	Time (hh:mm)	Description	Location
2.1	Marshall, Bruce (000 Transcript and Coroners Report, 2011)	4:10pm to 4:18pm	From the Coroners Report, under *Events leading to death*, at the location of [redacted] a low set timber dwelling: within 1 minute before 4:10pm the water was observed by Mr Marshall coming through the floor boards; at 4:12pm it was waist deep; and at 4:18pm it was shoulder deep.	D

460. The location of Mr Marshall's home at [redacted] is indicated on Figure 13.6 as location D. For ease of reference below is a locality map showing his home.

Figure 13.6 – Locality of Marshall Home

461. I have extracted simulation outcomes at Location D to produce a plot of simulated flow depth, Figure 13.7.

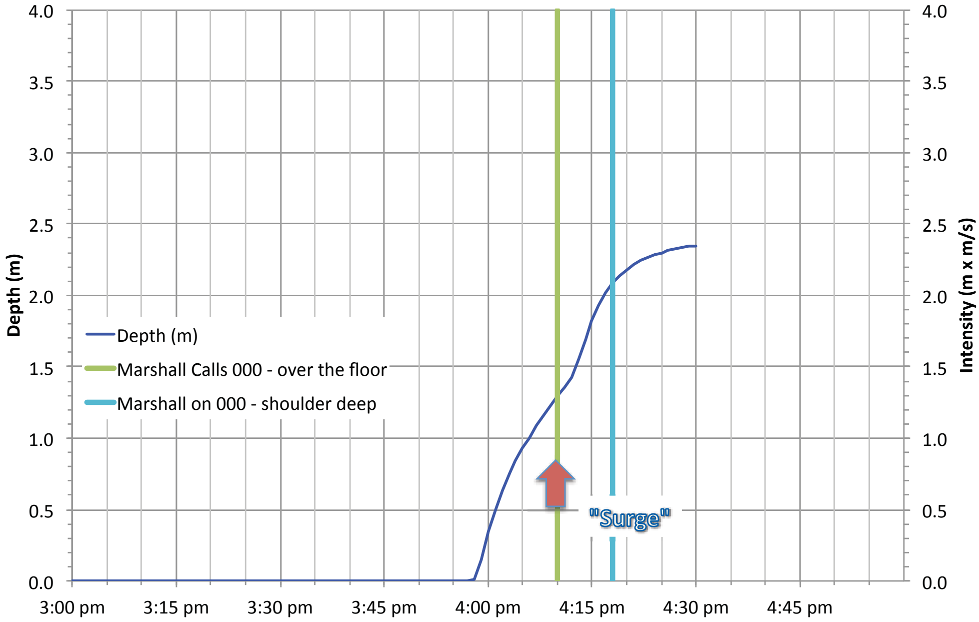


Figure 13.7 – Simulated Flow Characteristics at Mr Marshall's House (Location D)

462. Being a low-set timber dwelling, I expect that the floor level of Mr Marshall's home was about 1m from the ground. Figure 13.7 shows the flood depth at 4:10pm as being about 1.3m, or about 0.3m above floor level. On the same basis, the depth of water in the dwelling at 4:18pm would have been about 1.1m. I note that the flood depth is changing rapidly during this period of initial inundation: that is, 2m over 20 minutes. I consider that the simulation model is entirely consistent with the account given by Mr Marshall in his 000 call.

13.4 Sippel, Jonathan (1 July 2015)

Item	Witness Material	Time (hh:mm)	Description	Location
3.1	Sippel, Jonathan (1 July 2015) Mallon, Neville (1 July 2015)	3:19pm to 3:22pm	Sippel Statement Items 27 and 28; Mallon Statement Item 7: During a telephone conversation Mr Mallon advised Mr Sippel that water from Lockyer Creek was starting to spill into the Quarry pit from directly opposite Mr Mallon's residence (at the pit's north-western corner).	E
3.2	Transcript of hearing before GFCOI on 21 July 2015	3:35pm (approx)	Sippel Transcript (p. 123, lines 18-25): during a telephone conversation with Mr Sippel, Mr Mallon said *he could sort of see it running into the northern edge of the pit. There was a bit of water running at the northern side but at that stage I couldn't see any sort of water running just then*; (p. 123, lines 27-33); *Well I understood that just to be behind* [redacted] *basically, right behind* [redacted] *the north-western corner.*	E
3.3		3:39pm	Sippel Transcript (p. 124): Mr Sippel observed water starting as a trickle flowing from Lockyer Creek into the Quarry pit at near the power pole at the pit's far south-western corner.	F
3.4	Sippel, Jonathan (1 July 2015)	4:19pm	Statement Item 55: Mr Sippel observed the floodwater lapping the edge of the Gatton-Helidon Road.	G

463. For ease of reference, below is a locality map (Figure 13.8) showing the location of his home:

- Mr Sippel's home and its proximity to the Grantham Quarry pit and Gatton-Helidon Road;
- the north-west corner of the quarry, Location E;
- the south-western corner of the quarry, near the power pole, Location F; and
- Dinner Corner on Gatton-Helidon Road, Location G.

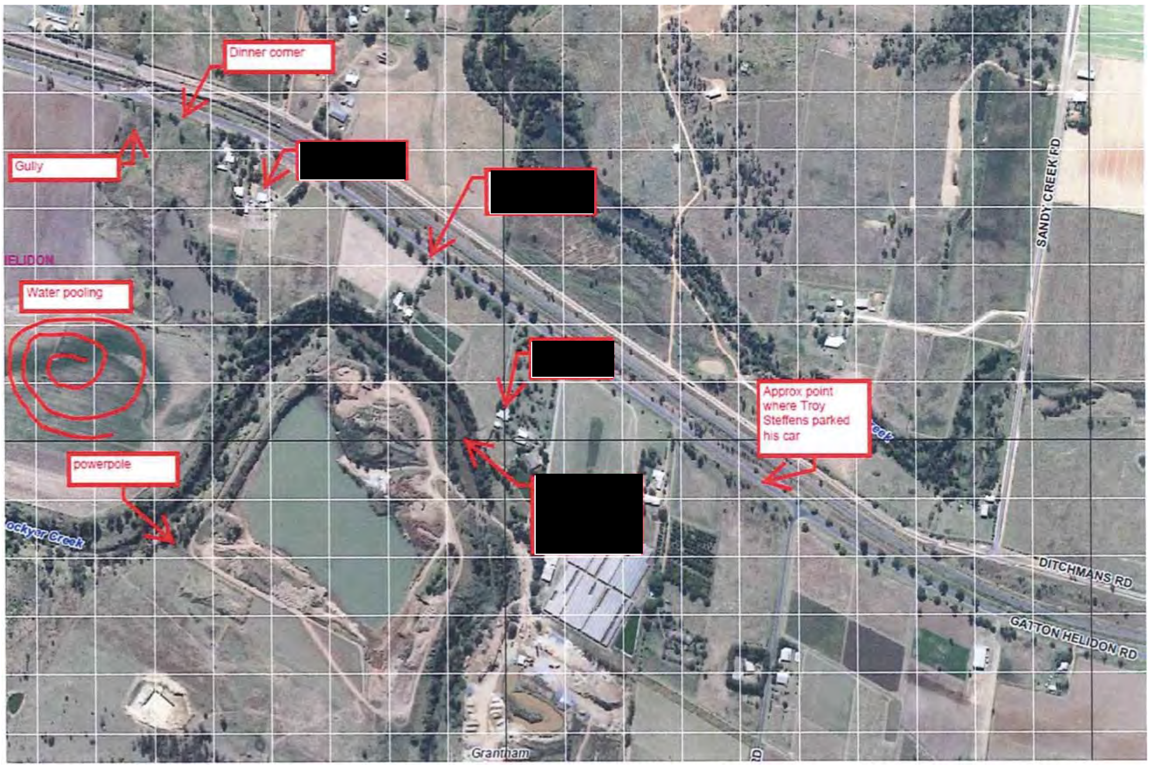


Figure 13.8 – Mr Sippel's Locality

464. I have prepared a graphic showing the simulated extent of inundation and intensity of flood flow around the quarry at 3:19pm, Figure 13.9. This corresponds to Mr Sippel's recollection in his statement of a mobile call when Mr Mallon tells Mr Sippel that creek water is starting to spill into the Quarry at its north-western corner (around the stockpile of loam), Location E.

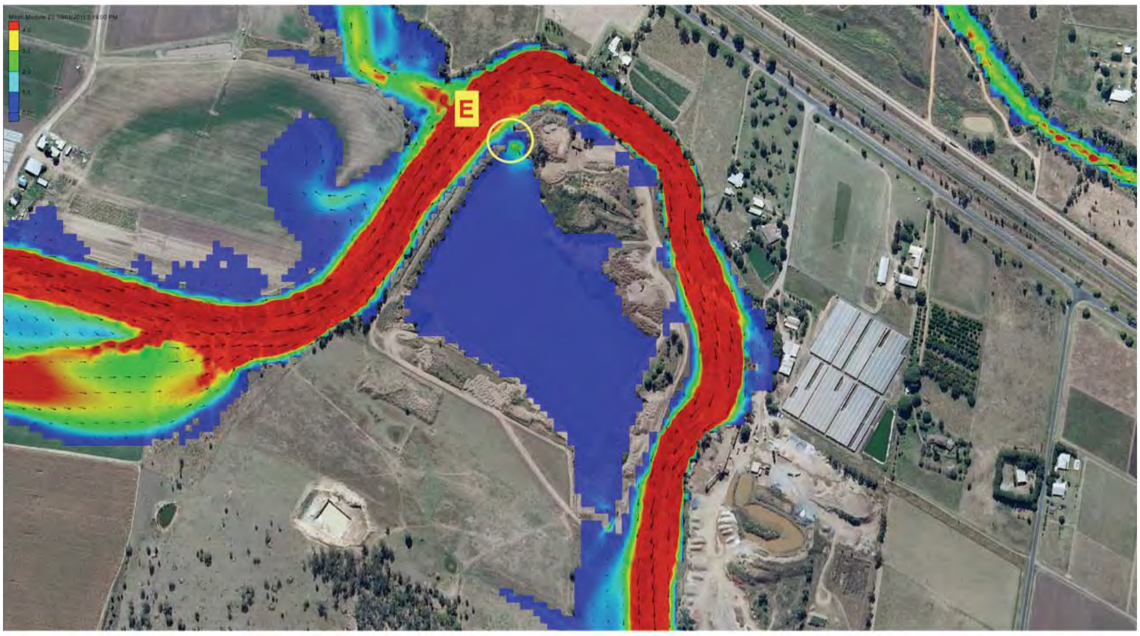


Figure 13.9 – Simulated Flow Intensity at 3:19pm

465. I have also prepared a graphic showing the simulated extent of inundation and intensity of flood flow around the quarry at 3:35pm, Figure 13.10. This corresponds to Mr Sippel's recollection as indicated in the 2015 transcript of the hearing before the GFCOI of a telephone call he had with Mr Mallon wherein Mr Mallon tells him that that he could sort of see water running into the northern edge at the pit on the north-western corner.

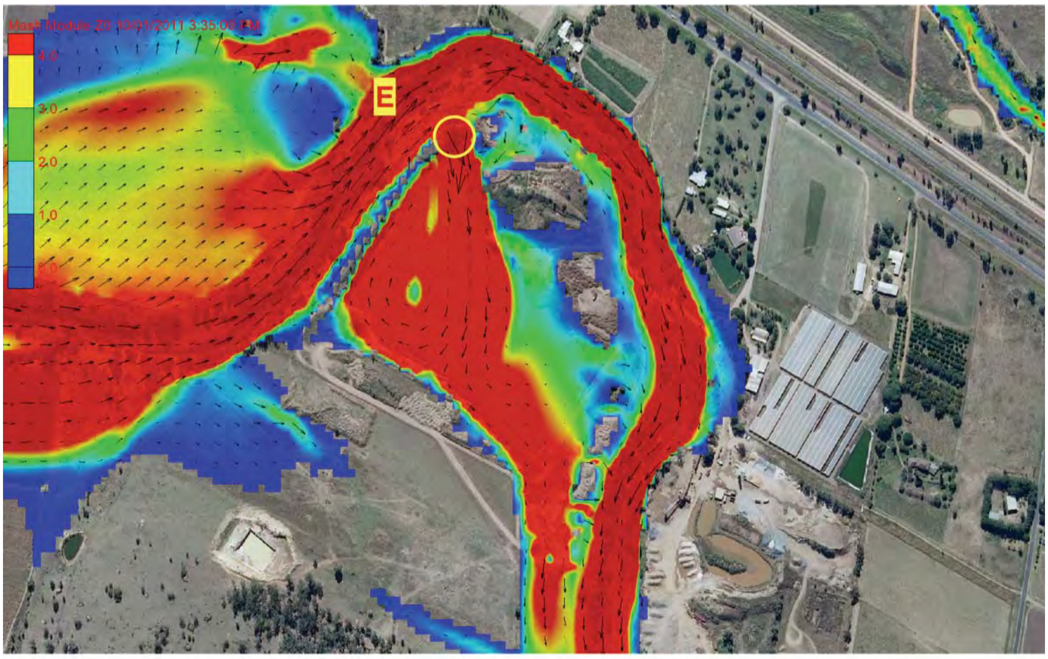


Figure 13.10 – Simulated Flow Intensity at 3:35pm

414. I have also produced a time history plot from the GFCOI model of the rate of flow into the Quarry pit at Locations E and F, Figure 13.11. I observe from this graph that the flow is simulated to first enter the pit at Location E, simulated at 3:17pm, rising rapidly (off the chart) such that by 3:35pm

the flow rate into the pit at Location E exceeds 100 m^3/s. This situation is also consistent with the simulated time of the initiation of the Main Breach at 3:25pm – that is, as at 3:17pm the breach had not initiated (although water was already overflowing the Western Levee into the pit) and by 3:35pm the inflows from the breach were well established. The simulated inflow occurrence at Location E is corroborated by Mr Mallon's observations whether made at 3:19pm or 3:35pm.

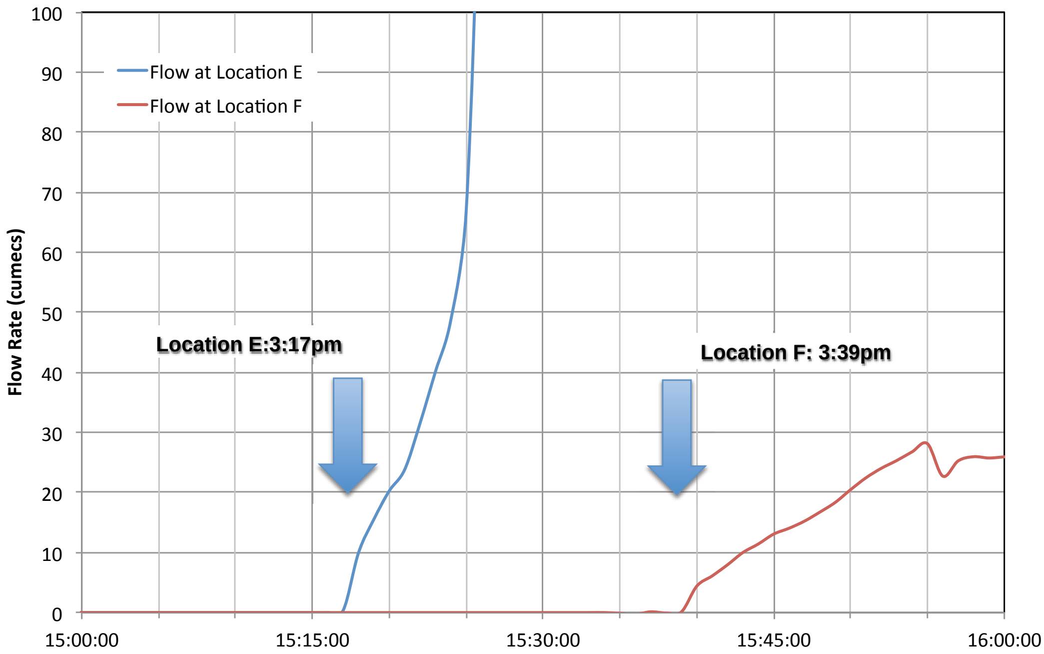


Figure 13.11 – Simulated Flow History at Locations E and F

466. I have prepared a graphic showing the simulated extent of inundation and intensity of flood flow around the quarry at Location F at 3:39pm, Figure 13.12.

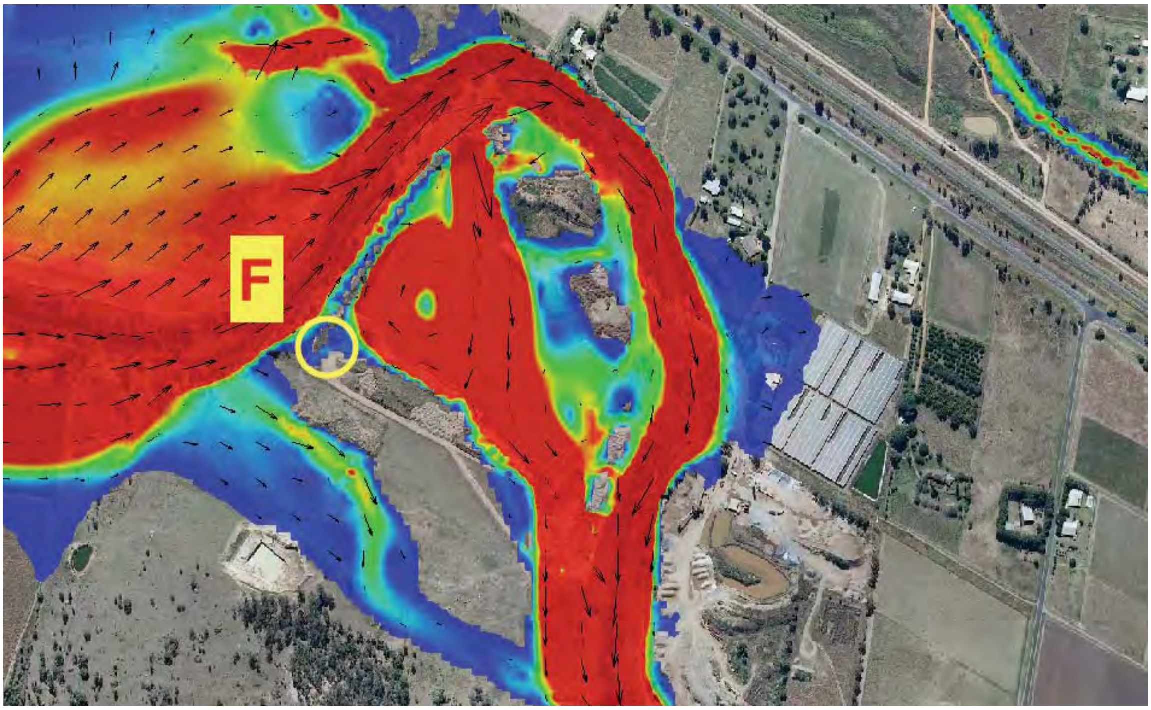


Figure 13.12 – Simulated Flow Intensity at 3:39pm, Location F

467. I further note that Figure 13.11 above also includes a time history plot from the GFCOI model of the rate of flow into the model at Location F. This plot indicates that at around 3:39pm the inflow into the pit would have just commenced. I consider this to be quite consistent with Mr Sippel's account of the situation.

468. Both the graphic presented in Figure 13.12 and the time history plot are consistent with Mr Sippel's account. The simulated results are therefore corroborated by Mr Sippel's observations.

469. In Mr Sippel's statement at just before 4:19pm he is standing in Mr Mallon's driveway. He then describes leaving the Mallons' property and making his way back towards his family that he had left on the road at Dinner Corner. Mr Sippel states that he got back to his family at 4:19pm.

470. I have extracted a simulation graphic of inundation and flow intensity at a location around Dinner Corner and Mr Mallon's driveway at 4:19pm (Figure 13.13 below). This time corresponds to Mr Sippel's reference to floodwater lapping the Gatton-Helidon Road. It is not clear from Mr Sippel's statement whether this observation is made from Mr Mallon's driveway looking west, or Dinner Corner looking east.

471. In Figure 13.13 I have marked the location of inundation on the road between Dinner Corner and Mr Mallon's driveway with a yellow circle. Mr. Sippel's statement indicates that, as at 4:19pm, the road was dry, but floodwater was lapping the road.

472. From first inspection of the simulation graphic (Figure 13.13) it appears as though the modelling may be inconsistent with Mr Sippel's observations.

473. I have examined the simulation output in greater detail and found that the simulated depth of water along the road between Mr Mallon's driveway (Location G) and the yellow circled location was only between 0.1m and 0.2m deep at 4:19pm. Considering the relatively shallow water depths involved, I am satisfied that the GFCOI model remains reasonably consistent with Mr Sippel's observations.

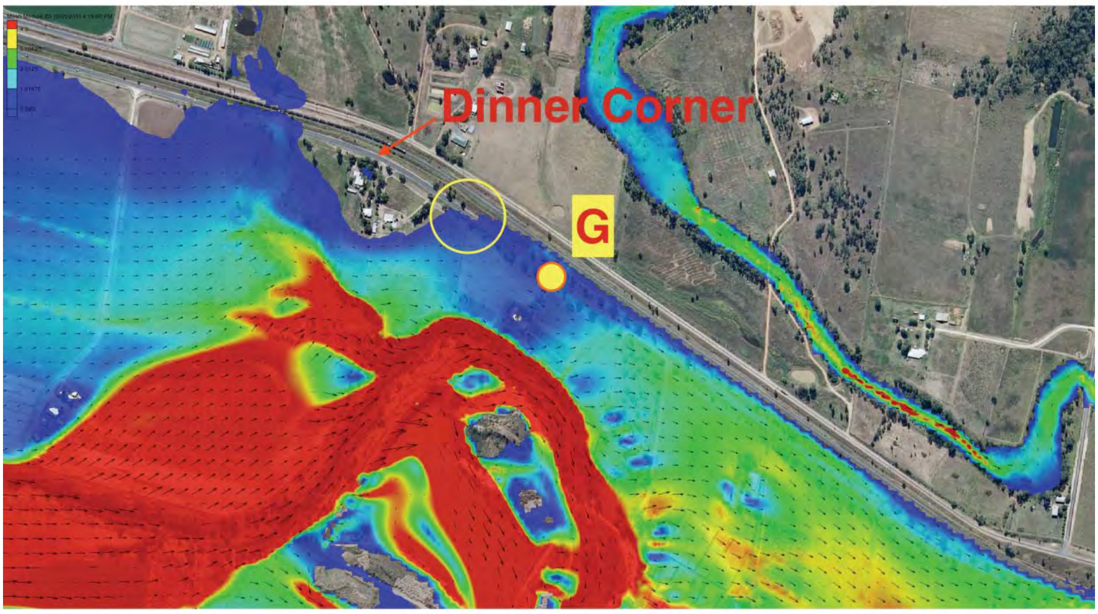


Figure 13.13 – Simulated Flow Intensity at 4:19pm, Location G

13.5 Besley, Helen (2 July 2015)

Item	Witness Material	Time (hh:mm)	Description	Location
4.1	Besley, Helen (2 July 2015) 000 Transcript	3:00pm (after)	Statement 14: Mrs Besley and her husband were standing on a concrete slab on the north-eastern bank of Lockyer Creek adjacent the Quarry and they observed water levels in the creek begin to rise relatively rapidly, sometime after 3:00pm (estimated as 3:30pm when adjusted to match 000 call).	H
4.2		3:48pm	Statement Item 21: 000 Transcript: While attempting to evacuate the property, a wave of water picked up the vehicle Mrs Besley and her husband were in and initially deposited it in the adjoining paddock to the east.	H
4.3		3:59pm	Statement Item 25: 000 Transcript: Mrs Besley and her husband were washed from their perch on their car by one of a number of waves.	I

474. For ease of reference below is a locality map (Figure 13.14) showing Mr and Mrs Besley's home and its proximity to the Grantham Quarry and Quarry Access Road.

Figure 13.14 – Mr and Mrs Besley's Residence

475. I have plotted in Figure 13.1 what I understand is the location of the concrete slab from which Mrs Besley viewed the flood flows within Lockyer Creek before it broke its banks, near Location H. I have extracted a stage hydrograph from the GFCOI model from the centreline of Lockyer Creek immediately adjacent to this viewing platform as indicated in Figure 13.15.

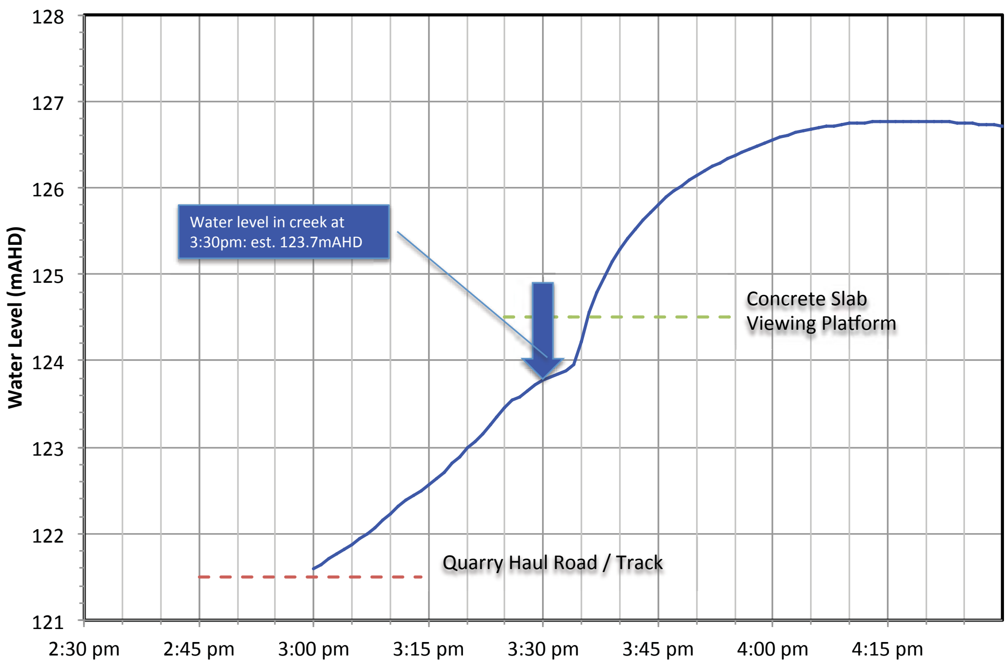


Figure 13.15 – Simulated Stage Hydrograph in Lockyer Creek Adjacent Location H

476. For reference, I have marked on Figure 13.15 my estimates of the level of the viewing platform (approximately 124.5mAHD) and the quarry haul road located 3m directly below the viewing platform (121.5mAHD).

477. In the excerpt of the 2015 transcript Mrs Besley referred to observing water flowing over the location of the haul road that she thought was the creek in her statement. In my opinion, from the simulation results plotted in Figure 13.16, flood levels in Lockyer Creek at this location had already risen and inundated the road by this time. Also, as shown by the figure above, shortly after this time (3:35pm) the creek levels began to rapidly rise.

478. I have extracted a simulation graphic of inundation and flow intensity at locations around H and I, at 3:30pm as shown in Figure 13.16.

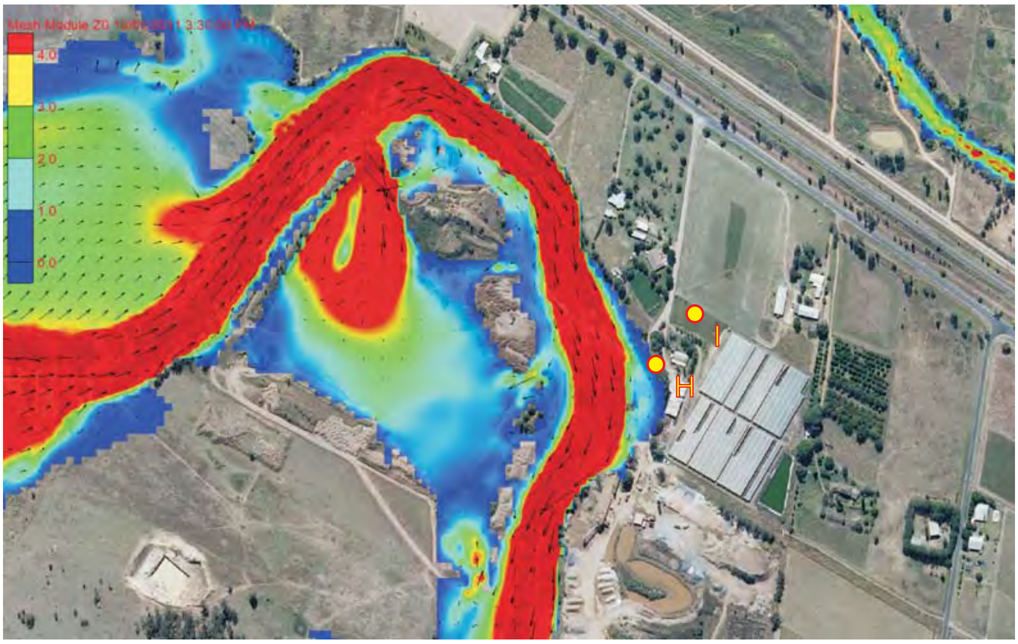


Figure 13.16 – Simulated Flow Intensity at 3:30pm, Locations H and I

479. I note from this figure that at 3:30pm the GFCOI model simulates that the quarry lake was close to filling from creek inflows. My modelling investigations has found that once the pit filled levels would then rise relatively rapidly within Lockyer Creek around the eastern side of the quarry in response to the resumption of full flows in the creek downstream of the quarry (during quarry filling my assessment was that it absorbed a significant proportion of creek flows for a short period). This characteristic is entirely consistent with Mrs Besley's statement of events that included reference to water levels beginning to rise rapidly.

480. I have also extracted simulation graphics of inundation and flow intensity at locations around H and I, at the times of 3:48pm and 3:59pm as shown in Figure 13.17 and 13.18 below.

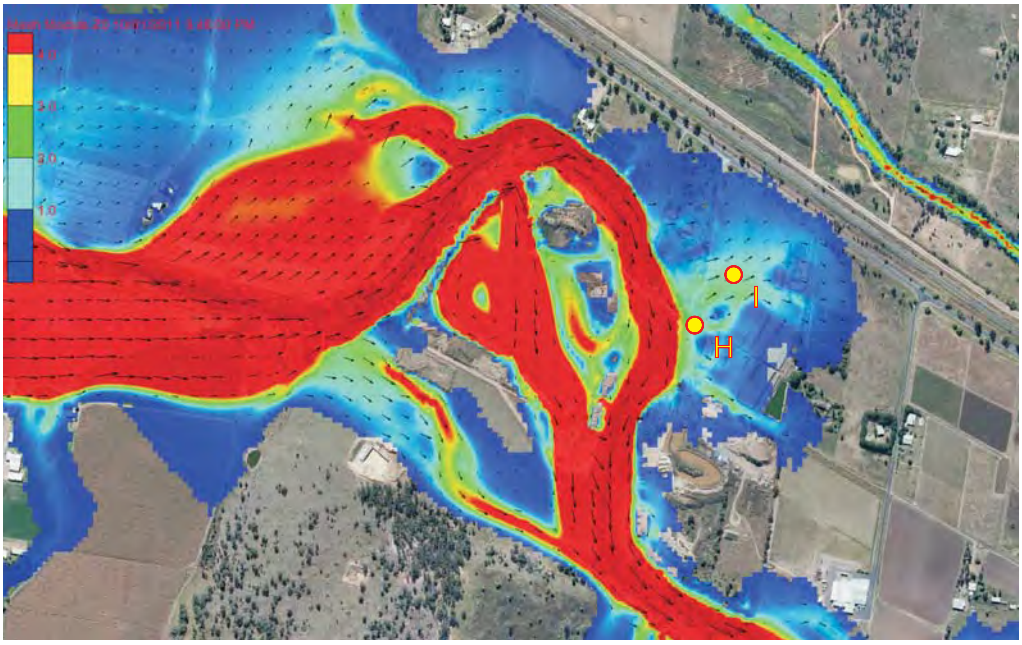


Figure 13.17 – Simulated Flow Intensity at 3:48pm, Locations H and I

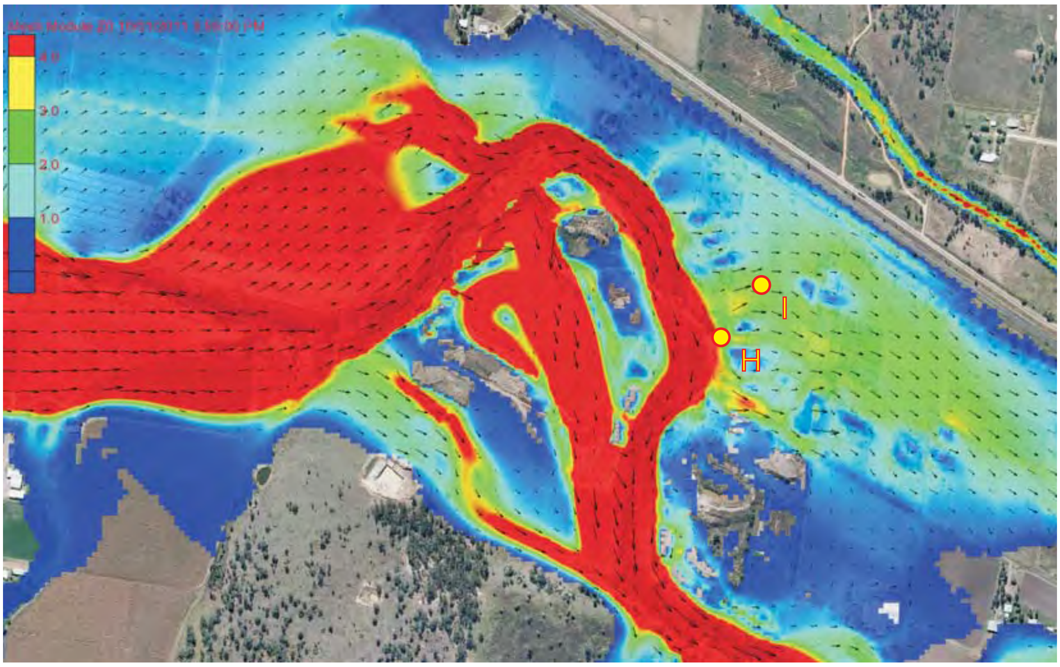


Figure 13.18 – Simulated Flow Intensity at 3:59pm, Locations H and I

481. I observe from Figure 13.17 that breakout flows from Lockyer Creek are developing in depth and flow intensity, with highest intensities associated with the breakout in the region of locations H and I. These simulation outcomes are consistent with Mrs Besley's statement in as much as:

- the initial inundation of the area around Location H was relatively rapid and quite sufficient to have impacted the Besleys' vehicle in a manner described by Mrs Besley;
- the direction of the breakout flows across Quarry Access Road (indicated by the arrows) was in an easterly direction; and
- the intensity of flow is seen to reduce in the direction of flow towards the east and, in my view, is likely to have created a flow situation whereby the impact on the Besleys' vehicle was also reduced (water around the vehicle shallower and not moving as fast).

482. I also observe from Figure 13.18 that the extent and intensity of the breakout flow appears to have increased sufficiently so as to create a more established overbank flow towards Grantham. In this respect, I observe that flow intensity had increased at location I (approximate location of vehicle). In my view, the simulation outcomes are consistent with Mrs Besley's observations of increasing flood impacts on the vehicle that Mr and Mrs Besley were clinging to between 3:48pm and 3:59pm.

483. In Figure 13.19, I have plotted additional data that I have extracted from simulation modelling which shows flow depth and flow intensity (the product of flow depth and velocity) at close to Location I. As I have noted previously, in my opinion, flow intensities greater than 0.5 m^2/s are typically capable of creating conditions that are unsafe for a vehicle. I observe in Figure 13.19 that flow intensities at around the location of the Besleys' vehicle are simulated to rapidly increase to a value of greater than 2 m^2/s over a period of less than 30 minutes. In my opinion, the water depths indicated in Figure 13.19 are also consistent with Mrs Besleys' account of her situation that has her vehicle grounded sufficiently at 3:48pm to give opportunity for her and Mr Besley to escape the vehicle through the windows and to perch on their window sills. The subsequent

increase in flow depth and intensity I observe in Figure 13.19, in my opinion, is consistent with the 000 transcript that indicates the time of the Besleys being washed from the vehicle.

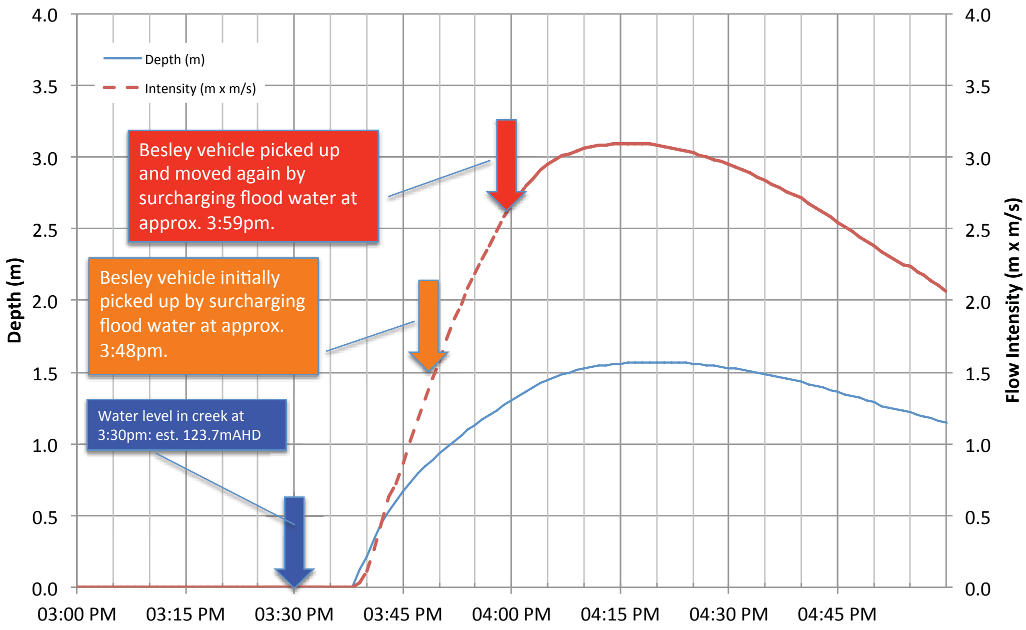


Figure 13.19 – Simulated Flow Characteristics at Mrs Besley's Location I

13.6 Lack, Wayne (7 July 2015)

Item	Witness Material	Time (hh:mm)	Description	Location
5.1	Lack, Wayne (7 July 2015)	3:47pm to 4:09pm (photo)	Attachment WDL-3: Time-stamped photographs showing: • floodwater around the base of the fuel bowser slab at Marnell Fuels (LIDAR level est. 115.1mAHD); (Picture 002.jpg in attachment WDL-3, taken at 3:47pm); • floodwater around the base of rubbish bin at Grantham General Shop (LIDAR level est. 115.5mAHD); (Picture 010.jpg in attachment WDL-3, taken at 4:05pm); and • floodwater over the base of the fuel bowser slab at Marnell Fuels (LIDAR level est. 115.3mAHD); (Picture 020.jpg in attachment WDL-3, taken at 4:09pm).	J

484. For ease of reference below is a locality map (Figure 13.20) showing Mr Lack's home and its proximity to Grantham and Gatton-Helidon Road.

Figure 13.20 – Mr Lack's Residence Location

485. Mr Lack's photographs between 3:47pm and 4:09pm are reproduced in Figures 13.21 to 13.23, below.

Figure 13.21 – Mr Lack's Photograph showing water around base of the fuel bowser slab (Picture 002.jpg)

Figure 13.22 – Mr Lack's Photograph showing water around base of bin (Picture 010.jpg)

Figure 13.23 – Mr Lack's Photograph showing water over base of the fuel bowser slab (Picture 020.jpg)

486. I have extracted simulated levels at Location J and at 28 Anzac Avenue (Marnell Fuels, approximately 50 east along Anzac Avenue from Location J), from the GFCOI model and plotted them in Figure 13.24.

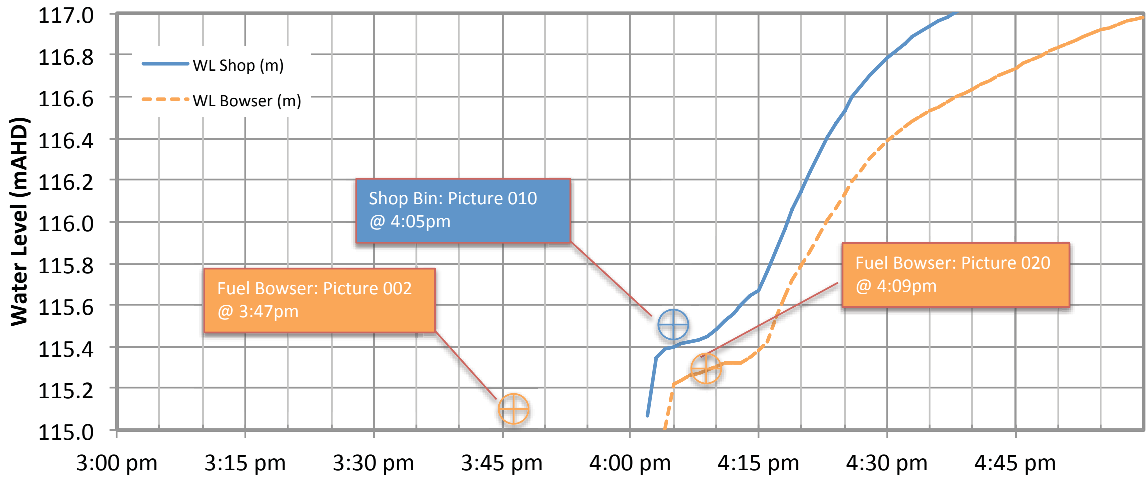


Figure 13.24 – Simulated Flow Characteristics Location J

487. I observe from Figure 13.24 that:

- The water shown in Picture 002 taken at 3:47pm is at a level close to ground level at this location (115.1mAHD). In my view, this is the reason why there is no simulated water showing at this point in time, because the model cannot differentiate between ground level and water level at the onset of inundation when the water is at the depth indicated;
- There is a small variation between the water level shown in Picture 010 taken at 4:05pm with that simulated, with simulated being about 0.1m lower than that shown in Picture 010; and
- There appears to be a match between the water level shown in Picture 020 taken at 4:09pm with that simulated.

Item	Witness Material	Time (hh:mm)	Description	Location
5.2	Lack, Wayne (7 July 2015)	4:23pm (approx)	Statement Items 20 and 21: Mr and Mrs Lack were located at [redacted] and observed the level of floodwater rise from about 6 feet (1.8m) deep to 11 to 12 feet (3.4m to 3.7m) in a matter of seconds.	K

488. I have plotted simulated water depths at the Lack's location (Location K) in Figure 13.25. Mr Lack's observations are also overlaid on the plot. Comparison shows that although a marked increase in rate of rise is simulated between around 4:15pm and 4:25pm, the maximum rate is around 0.5m over 10 minutes, which is different from Mr Lack's description of 1.5m to 1.8m over a matter of seconds. However, in my opinion Mr Lack's description is consistent with a rapid increase in water levels over a relatively short period of time.

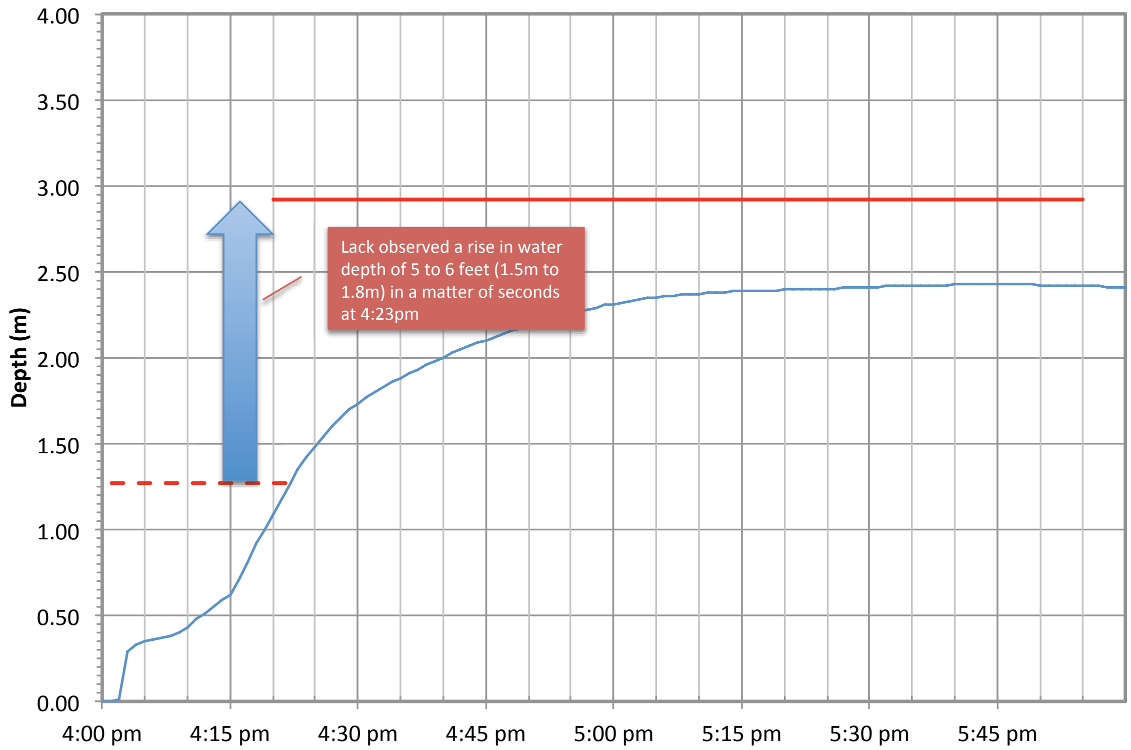


Figure 13.25 – Simulated Water Depth at Location K

Item	Witness Material	Time (hh:mm)	Description	Location
5.3	Lack, Wayne (7 July 2015)	4:32pm (Photo)	Attachment WDL-3: Time-stamped photograph showed floodwater at the base of the stay pole adjacent the Railway Yards (LIDAR level 117.4mAHD); (Picture 028.jpg)	L
5.4		5:00pm (photo)	Attachment WDL-3: Time-stamped photograph showed floodwater at the base of the power pole adjacent the Railway Yards (LIDAR level 117.9mAHD); (Picture 040.jpg).	L

489. Mr Lack's photographs taken at 4:32pm and 5:00pm are reproduced in Figures 13.26 and 13.27, below for Location L.

Figure 13.26 – Mr Lack's photograph showing floodwater at the base of the stay pole (Picture 028.jpg)

Figure 13.27 – Mr Lack's photograph showing floodwater at the base of the power pole (Picture 040.jpg)

490. I have plotted the simulated water level at location L in Figure 13.28. Mr Lack's observations are also overlaid on the plot. I observe a small variation between the time and / or level of Mr Lack's observations and those simulated. I observe that the 4:32pm photographic record appears close

to simulation, and my estimated level for the 5:00pm photograph appears to be about 50mm different to that simulated.

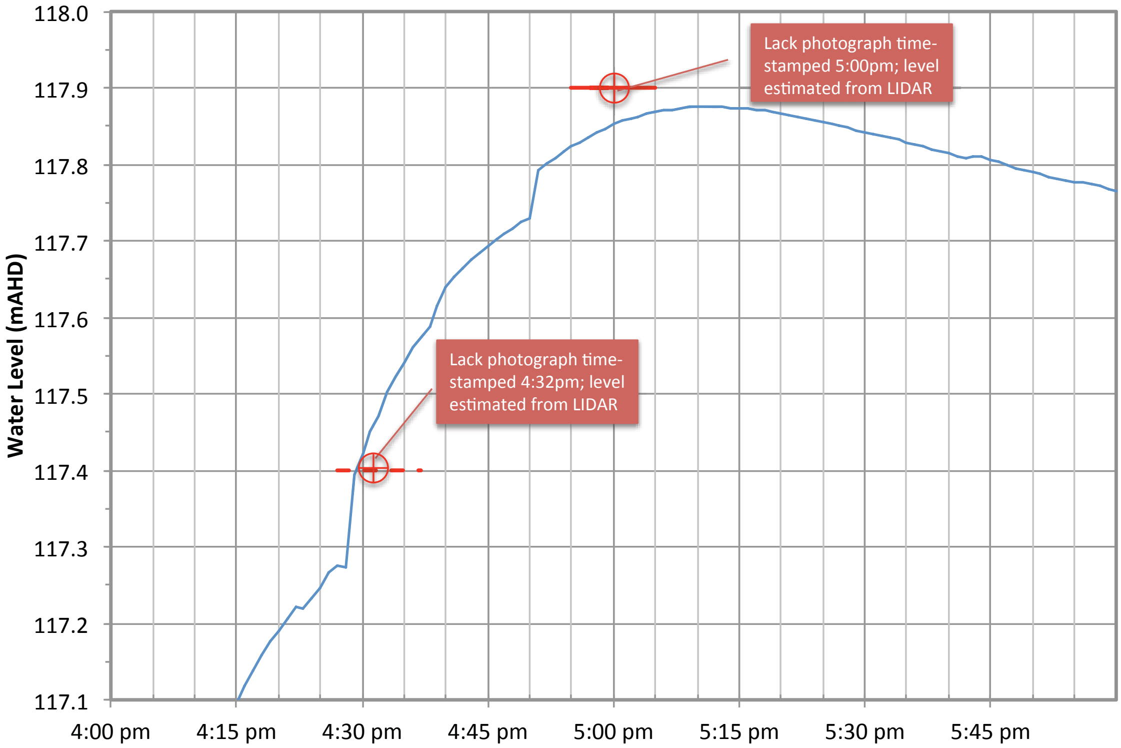


Figure 13.28 – Simulated Water Level at Location L

491. My overall consideration is that there appears to be good corroboration between Mr Lack's observations and simulation results covering all stages of flood rise to close to the peak at around Location L.

13.7 Richardson, Lance (1 July 2015)

Item	Witness Material	Time (hh:mm)	Description	Application
6.1	Richardson, Lance (1 July 2015)	Period 4:15pm to 4:53pm	Statement Item 18: Mr Richardson was at the Grantham Hotel (12 Anzac Avenue) and observed a significant rise in the level of floodwater.	M

492. For ease of reference below is a locality map (Figure 13.29) showing Mr Richardson's location at the Grantham Hotel.

Figure 13.29 – Mr Richardson's Location (Grantham Hotel)

493. I have extracted simulated water depths from the GFCOI model and plotted these at Mr Richardson's location (Location M) in Figure 13.30. Mr Richardson's observations in relation to the time over which he observed the rise in water levels is also plotted in the graph below.

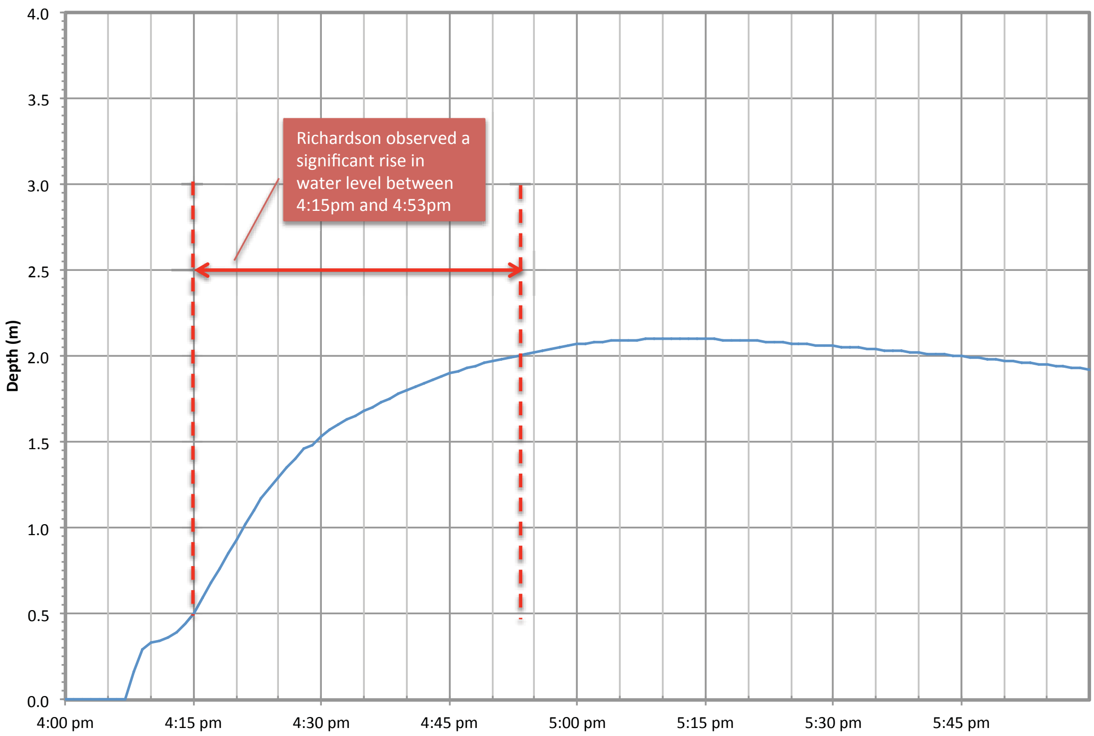


Figure 13.30 – Simulated Water Depth at Location M

494. Comparison between my simulation and Mr Richardson's observations shows correlation of a significant rise in water level over the stated period. From my simulation, I observe a rise of 1.5m over 38 minutes, or an average rate of 2.4m/hr.

495. I have also viewed the video files included with Mr Richardson's statement. It is my opinion that these videos provide a good presentation of a number of characteristics of the flooding that have been referred to by other eye-witnesses, and in particular, the relatively rapid rate of rise of floodwater, the associated significant increase in velocity, and flow intensity.

13.8 McIntosh, Anthony (1 July 2015)

Item	Witness Material	Time (hh:mm)	Description	Application
7.1	McIntosh, Anthony (1 July 2015) iPhone photographs Video 1 in attachment AM-3 to his statement.	3:08pm (approx)	Statement Item 22: Video recording with audio taken just before Lockyer Creek broke its banks.	N
7.2	McIntosh, Anthony (1 July 2015)	3:15pm	Statement Item 22: Mr McIntosh provided time-coded photographs of Lockyer Creek. One of these photographs is taken at 3:15pm (photograph IMG_0228.jpg)	N
7.3		4:41pm	Photograph IMG_0236.jpg: Mr McIntosh recorded an open expanse of flood inundation from his residence at Klucks Road to the Gatton-Helidon Road to the north and the western side of the quarry to the north-east	N

496. Mr McIntosh lives on the southern side of Lockyer Creek on Klucks Road, approximately 600m upstream of the Grantham Quarry, Location N in Figure 13.1. For ease of reference below is a locality map (Figure 13.31) showing Mr McIntosh's home and its proximity to Lockyer Creek and the quarry.

Figure 13.31 – Mr McIntosh's Location

497. Mr McIntosh took a video of the flooding in Lockyer Creek from his home at just before 3:09pm (Video 1, Attachment AM-3). I have reviewed this video file and have observed that the flow shown was confined within the main channel of the creek but was close to bank full. At the very beginning of the video I heard Mr McIntosh say "… 5, 6 m in 15 minutes". I understood this to mean that at 3:08pm, the water in Lockyer Creek had risen 5 to 6 metres over a duration of 15 minutes. I observe from my assessment of the recorded stage hydrograph at the Helidon Gauge (Section 8.3) that Mr McIntosh's estimate is of the same order of those recorded at the Helidon Gauge (a maximum of 1m in 4 minutes, or about 4m in 15 minutes).

498. Mr McIntosh also provided a photo file named IMG_0228.JPG in Figure 13.32 This photograph was taken using an iPhone on 10 January 2011 and is time coded at 3:15pm.

Figure 13.32 – Lockyer Creek at 3:15pm Location N (Image IMG_0228.JPG)

499. The significance of this photograph is that in the background it captures the approximate point in time when Lockyer Creek appears to be just starting to break its banks at Location N. In the foreground the inundation is on account of water backing up along a natural drainage depression that runs west (left) to east (right) and joins Lockyer Creek near to the quarry.

500. I have extracted a simulation graphic of inundation and flow intensity at around location N at 3:10pm as shown in Figure 13.33.

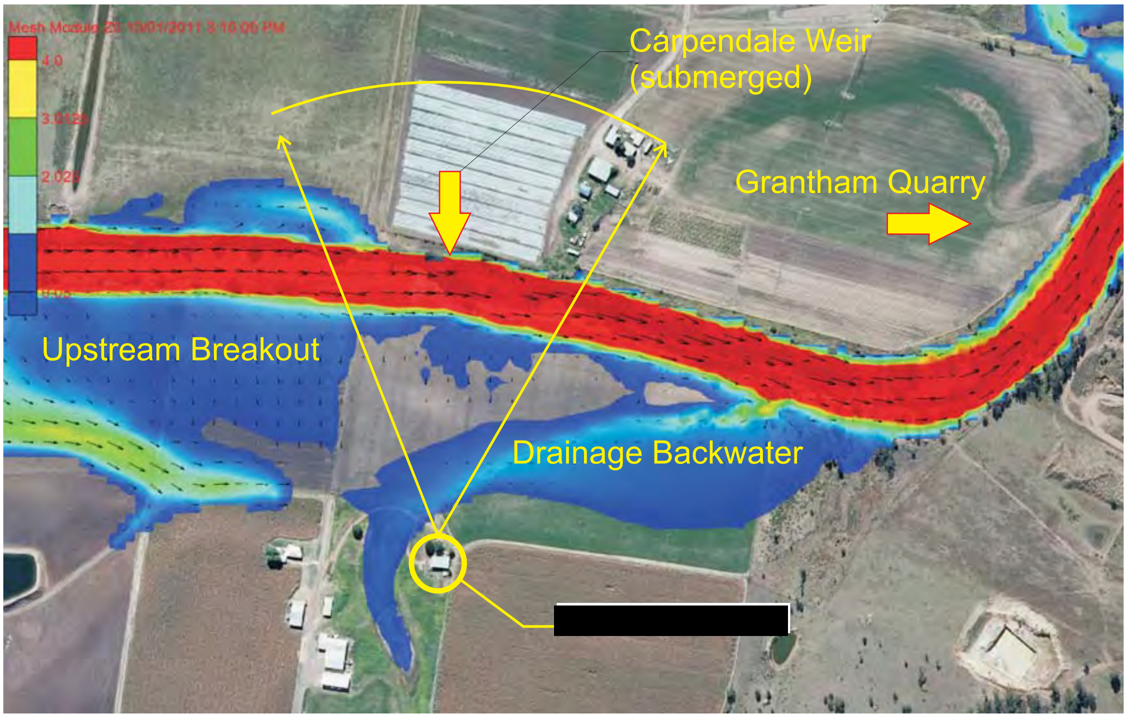


Figure 13.33 – Simulated Flow Intensity at 3:10pm, Location N

501. While I observe that this image is associated with a simulation time of 3:10pm, 5 minutes earlier than that for the photograph shown in Figure 13.32, it shows a good visual comparison between simulation and in the photograph.

502. I found visual comparisons of the oblique flood inundation photo shown in Figure 13.32 difficult to interpret as scale, local relief and the effects of ground cover all introduced uncertainty. Given this I consider there is reasonable corroboration.

503. Mr McIntosh has also provided a photograph taken at 4:41pm that captured the extent of floodwater at that time from his residence at Klucks Road, with a line of sight from his residence extending to the Gatton-Helidon Road in the north and to the western side of the Grantham Quarry to the north-east. A copy of the photograph is at Figure 13.34.

Figure 13.34 – Photograph of Lockyer Creek Floodplain at 4:41pm Location N, Mr McIntosh's Residence (IMG_0236.jpg)

504. I have extracted a simulation graphic of inundation and flow intensity at around location N at 4:41pm as shown in Figure 13.35.

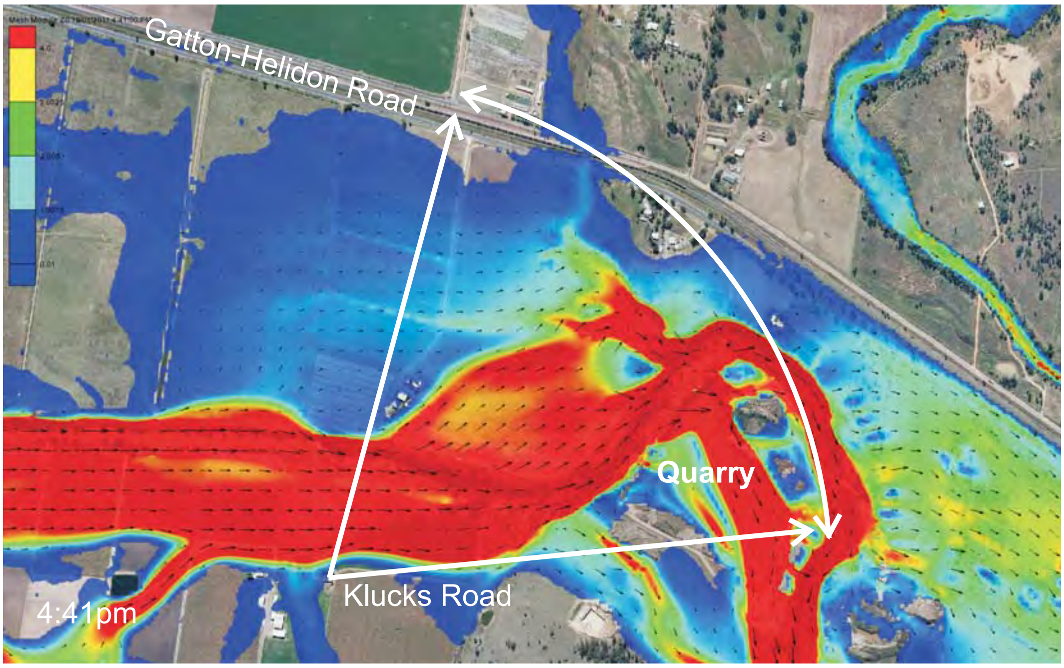


Figure 13.35 – Simulation of Lockyer Creek Floodplain at 4:41pm Location N

505. By comparison between the photograph at Figure 13.34 and simulation outcomes shown in Figure 13.35, I observe good correlation with the extents of the inundation. I also observe raised

mounds of earth located at the northern and southern end of the quarry's Western Levee. However, I am unable to make a comparison between the section of Western Levee embankment in between the two locations as shown in the simulation and the photograph because of trees obscuring the view of the full length of the Western Levee.

13.9 Outcomes

506. The outcomes of my review of the various eye-witness accounts and their corroboration to the GFCOI model are summarised as follows:

- Mr McIntosh, Item 7.1: reasonable corroboration of the time of breakout of Lockyer Creek upstream, of the quarry (Klucks Road).
- Mr Sippel and Mr Mallon, Items 3.1 and 3.2: corroboration of the time of initial inflows of water into the quarry pit at both its north-western and south-western ends;
- Mrs Besley, Items 4.1, 4.2 and 4.3: corroboration of the circumstances and sequence of creek breakout of development of overbank flows at the hairpin bend near the Quarry Access Road;
- Mr Sippel, Item 3.3: corroboration with the timing and extent of inundation on the Gatton-Helidon Road to the north of the Quarry;
- Mr Marshall, Item 2.1: corroboration of the time, depth and rate of flood inundation at 1420 Gatton-Helidon Road;
- Mrs Arndt, Item 1.1; corroboration of the timing, source and direction of breakout flow from Lockyer Creek to the south-west of 1348 Gatton-Helidon Road;
- Mrs Arndt, Items 1.2, 1.3, 1.4: corroboration of the time, depth, direction, intensity of flow and rate of inundation on the Gatton-Helidon Road, just east from 1420 Gatton-Helidon Road;
- Mr Lack, Item 5.1: reasonable corroboration of the timing and depth of inundation of Eastern Grantham;
- Mr Lack, Item 5.2: reasonable corroboration of the timing and occurrence of a relatively rapid rise in flood levels and flow rates around Eastern Grantham, but inconsistency in the magnitude;
- Mr Lack, Items 5.3 and 5.4: corroboration of peak flood levels near the railway yard; and
- Mr Richardson, Item 5.2: corroboration of a significant rise in flood levels around the eastern side of Sandy Creek close to the Central Grantham.

507. On the basis of my review, I have concluded that the GFCOI model (based on the Most Likely scenario) reasonably simulates characteristics of importance for the purposes of my investigations. In this regard, I have ensured that the model was capable of not only correctly simulating the peaks of the event, but more importantly the timing and sequence of flooding characteristics.

508. The coverage that I have considered ranged from the very beginning of the flooding at Klucks Road, the commencement of flow into the quarry inundation, the breakout of water from the hairpin bend in the creek adjacent to the quarry, the overtopping of Gatton-Helidon Road, and the flood's rise and passage through Grantham.