SINCLAIR KNIGHT MERZ

Provision of Hydrological Advice to Queensland Floods Commission of Inquiry

ASSESSMENT OF IMPACT OF QUARRYING OPERATIONS ON FLASH FLOODING IN GRANTHAM ON 10 JANUARY 2011

- QE06544-NHY-RP-0001-Revision0
- 16 September 2011

Provision of Hydrological Advice to Queensland Floods Commission of Inquiry

ASSESSMENT OF IMPACT OF QUARRYING OPERATIONS ON FLASH FLOODING IN GRANTHAM ON 10 JANUARY 2011

- QE06544-NHY-RP-0001-Revision0
- 16 September 2011

Sinclair Knight Merz
ABN 37 001 024 095
Cnr of Cordelia and Russell Street
South Brisbane QLD 4101 Australia
PO Box 3848
South Brisbane QLD 4101 Australia
Tel: +61 7 3026 7100
Fax: +61 7 3026 7300
Web: www.skmconsulting.com

Contents

1 Introduction 1
  1.1 Scope of this Report 1
  1.2 Reliance Statement 1
  1.3 Information Relied Upon 2
  1.4 Credentials of Report Author 2
2 Description of 10 and 11 January 2011 Flash Flood Event 3
  2.1 Brief Description of Hydrology of the Event 3
  2.2 Description of Hydraulics of Flooding in Grantham Area 4
3 Hydraulic Modelling Method 5
  3.1 Model Development 5
  3.2 Terrain Data Inputs – Actual Terrain for Event 5
  3.3 Terrain Data Inputs – Pre-Quarry Terrain 9
  3.4 Flow Hydrograph Inputs 14
  3.5 Downstream Boundary Condition 15
  3.6 Roughness and Eddy Viscosity 15
  3.7 Representation of Railway Lines Roads and Structures 16
4 Assessment of Influence of Quarry on Flood Impacts for 10 January 2011 Flood Event 18
  4.1 Model Scenarios and Results 18
  4.2 Comparison of Maps of Peak Water Levels and Maximum Velocities Between Scenarios 26
  4.3 Comparison of Hydrographs of Velocity and Water Level at Selected Locations 32
5 Conclusions 36
6 References 38

Document history and status

Revision	Date issued	Reviewed by	Approved by	Date approved	Revision type
0	16 Sep 2011	S. Dooland	S. Raby	16 Sep 2011	Issued to Client

Distribution of copies

Revision	Copy no	Quantity	Issued to
0	1	1	Jane Moynihan, Queensland Floods Commission of Inquiry

Printed:	16 September 2011
Last saved:	16 September 2011 09:31 AM
File name:	I:\QENV2\Projects\QE06544\Reports\QuarryImpact-September2011\QE06544-NHY-RP-0001-Revision0.docx
Author:	Phillip Jordan
Project manager:	Phillip Jordan
Name of organisation:	Queensland Flood Commission of Inquiry
Name of project:	Independent Hydrological Advice
Name of document:	Impact of Quarrying Operations on Flash Flooding in Grantham on 10 January 2011
Document version:	Revision 0
Project number:	QE06544

1 Introduction

1.1 Scope of this Report

The Queensland Floods Commission of Inquiry ("the Commission") has commissioned Dr. Phillip William Jordan of Sinclair Knight Merz Pty Limited ("SKM") to prepare this report on the impact of the quarry currently owned by Wagner Investments Pty Ltd on Flooding in Grantham on 10 January 2011. The sole purpose of this report and the associated services performed by SKM is set out in the contract between SKM and the Commission and in the letter from SKM to the Commission dated 11 July 2011.

1.2 Reliance Statement

In preparing this report, the author has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided by the Commission and/or from other sources. Except as otherwise stated in the report, the author has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

The author derived the data in this report from information sourced from the Commission and/or available in the public domain at the time or times outlined in this report. The passage of time, manifestation of latent conditions or impacts of future events may require further examination of risks and subsequent data analysis, and re-evaluation of the data, findings, observations and conclusions expressed in this report. The author has prepared this report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures and practices at the date of issue of this report. For the reasons outlined above, however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this report, to the extent permitted by law.

This report should be read in full and no excerpts are to be taken as representative of the findings. No responsibility is accepted by Sinclair Knight Merz for use of any part of this report in any other context.

This report has been prepared on behalf of, and for the exclusive use of the Commission, and is subject to, and issued in accordance with, the provisions of the agreement between Sinclair Knight Merz and the Commission. Sinclair Knight Merz accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this report by any third party.

The report has been prepared to analyse the impact of the 10 January 2011 flood event and only simulated hydrographs for this event have been produced. Flood behaviour in the area covered by this study may be different in a future specific flood event, particularly an event that is smaller or larger in the magnitude of the flood peak than that observed on 10 January 2011. No attempt was made in this report to speculate about flood behaviour for a theoretical design flood event with a particular annual exceedance probability.

1.3 Information Relied Upon

The report relied upon a number of documents that are in the public domain, as cited in the report and as listed in the References section (Section 6).

Three field inspections were undertaken by Dr. Phillip Jordan of some of the flood affected areas in the Lockyer Valley on 5 April, 23 July and 28 July 2011. Whilst there was still a considerable amount of visual evidence of the flooding that took place in January and the conditions that existed prior to the event, restoration activities and other changes have occurred between the flood event and the field inspections.

1.4 Credentials of Report Author

The author of this report is Dr. Phillip William Jordan. Dr. Jordan is a Senior Hydrologist and has been employed by Sinclair Knight Merz since January 2003. Dr. Jordan holds a Bachelor of Engineering (Civil) with First Class Honours from the University of Queensland (awarded 1993) and a Doctor of Philosophy from Monash University (awarded 2001). Dr. Jordan's Ph.D. thesis was on the "Effect on Flood Modelling of Rainfall Variability and Radar Rainfall Measurement Error." He is a Member of Engineers Australia, a Certified Practicing Engineer (C.P.Eng.) and is Registered by the Board of Professional Engineers in Queensland (R.P.E.Q.) Dr. Jordan worked as a civil engineer for the Queensland Water Resources Commission / Queensland Department of Primary Industries / Queensland Department of Natural Resources between 1994 and 1997. He worked for SMEC Victoria as a consulting hydrologist between 2000 and 2001. From July 2001 to December 2002 he was employed by the Bureau of Meteorology to perform research on the application of dual polarisation weather radar to quantitative rainfall measurement and flood forecasting. In his more than eight years working with Sinclair Knight Merz, Dr. Jordan has worked on a number of consulting projects involving hydrological and hydraulic analysis and modelling. Dr. Jordan has co-authored six papers that have been published in international and Australian peer reviewed journals and he has been author or co-author for twenty-four papers that have been presented at national and international conferences. Dr. Jordan has also acted as peer reviewer for papers submitted to several international journals and conferences.

2 Description of 10 and 11 January 2011 Flash Flood Event

2.1 Brief Description of Hydrology of the Event

The *Interim Report* of the Queensland Floods Commission of Inquiry (2011), Australian Government Bureau of Meteorology (2011e), Insurance Council of Australia Hydrology Panel (2011a), (2011b) and Sinclair Knight Merz (2011) discussed the meteorological and hydrological causes of flooding in the Lockyer Valley on 10 and 11 January 2011.

During the period between 9 and 12 January 2011 inclusive an active monsoon trough extended across northern Queensland and over the Coral Sea, linking a series of low pressure systems. A high pressure system over the southern Tasman Sea directed moist easterly winds into the Southeast corner of Queensland (Australian Government Bureau of Meteorology, 2011e). The south-westward movement of an upper level low pressure system across the Southern Queensland coast on 9 January directed moist tropical air into southeast Queensland. This caused intense rainfall to move into the Sunshine Coast and the catchment of the Brisbane River (including Lockyer Creek) (Australian Government Bureau of Meteorology, 2011e).

It is difficult to provide an accurate timing for the commencement of water level rises in the upper tributaries of Lockyer Creek. Intense rainfall would have commenced at about 12:00 noon in the northern most part of the catchment and was widely spread through the catchments of Fifteen Mile, Six Mile, Alice, Rocky and Murphys Creeks by 12:42 pm. Because of the saturated condition of the catchment and the steep terrain present in the catchments of Fifteen Mile, Six Mile, Alice, Rocky and Murphys Creeks, it is most likely that runoff and rapid increases in overland flow and flows in watercourses would have commenced in these tributaries within minutes after the commencement of intense rainfall.

Water levels started to rise abruptly at the streamflow gauge on Lockyer Creek at Helidon at 2:20 pm on Monday 10 January 2011 (see Figure 3–8).The streamflow gauge at Helidon operated by the Bureau of Meteorology failed at 2:53 pm and “anecdotal evidence suggests that the flood at Helidon township peaked around 1530 hours” (Insurance Council of Australia Hydrology Panel, 2011a). The peak flow at the Helidon gauge was estimated by hydrographers from the Queensland Department of Environment and Resource Management after the flood event to be 4100 m^3/s.

The Sandy Creek at Sandy Creek Road streamflow gauge shows the commencement of a rapid rise in water levels from 2:43 pm on 10 January 2011, although it is possible that the initial water level rises recorded on Sandy Creek at Sandy Creek Road were caused by runoff generated from the Sandy Creek catchment instead of water backing up Sandy Creek from Lockyer Creek. Rapid water level rises leading to out of bank flows from Lockyer Creek at Grantham could have commenced as early as 2:45 pm on 10 January. Insurance Council of Australia Hydrology Panel

(2011b, p. 53) is reasonably consistent with this timing, estimating that the on-set of flooding was between 3:00 pm and 3:30 pm. They also estimated the peak flow at Grantham to be between 3,500 and 4,000 m^3/s.

2.2 Description of Hydraulics of Flooding in Grantham Area

Lockyer Creek travels in a west to east direction upstream of the quarry currently owned by Wagner Investments Pty Ltd. Near the south western corner of the quarry pit, the Lockyer Creek channel takes a bend toward the north and travels in a north easterly direction for approximately 500 metres. On this reach of Lockyer Creek flood waters in moderate floods can break out on to the low area of flood plain on the left bank of the creek but high ground between the creek channel and the quarry pit constrains flows to the creek channel in this reach in all but very large floods.

Lockyer Creek then takes another near-to-right-angle bend and travels in a south easterly direction for approximately 200 metres. In this reach, in all but very large floods flows would be constrained to the creek channel by high ground on both the left and right banks of the creek. Lockyer Creek makes another bend and the creek channel then travels in a southerly direction again for approximately 700 metres. Near the south eastern corner of the quarry pit, Lockyer Creek makes another bend and then flows in an east-south-easterly direction for approximately 3 km before it reaches the confluence with Sandy Creek, near the centre of the town of Grantham.

The left bank of the flood plain is above an elevation of 125 metres above the Australian Height Datum (125 m AHD)[1] to the north of the quarry, which would constrain all but very large floods to the creek channel. To the eastern side of the quarry, the Lockyer Creek channel becomes less incised than it is upstream of this point, which implies that breakouts may be expected from the creek channel on to the left bank of Lockyer Creek.

The flash flood event that occurred on 10 January 2011 in Lockyer Creek at Grantham was a very large flood. During the early part of the flood event, flood flows would have been constrained to the course of the creek channel, as described above. As flows increased on the rising limb of the flood, flood flows broke out over the flood plain of the left bank of the creek opposite the quarry. The south eastern part of the quarry pit would have started to be inundated at the same time due to ingress of flood water from lower ground near the south eastern corner of the quarry.

[1] The Australian Height Datum is the standard datum used for expressing elevations above mean sea level in Australia. The datum was defined using mean sea level for the period 1966-1968 measured from thirty tide gauges located around Australia.

3 Hydraulic Modelling Method

3.1 Model Development

A hydraulic model was developed of Lockyer Creek and its floodplain by Sinclair Knight Merz for the Lockyer Valley Regional Council's Floodplain Management Study (Lockyer Valley Regional Council, 2011). The hydraulic model was constructed in the TUFLOW modelling software (BMT WBM, 2011). Lockyer Valley Regional Council authorised the use of the model by Sinclair Knight Merz to provide this report for the Queensland Floods Commission of Inquiry. TUFLOW is industry standard modelling software that represents movement of flood water using both one-dimensional (linear) and two-dimensional (grid) elements.

The hydraulic model constructed for the Lockyer Valley Floodplain Management Study extends along Lockyer Creek and its tributaries from upstream of the township of Murphy's Creek to the confluence of Lockyer Creek with the Brisbane River. However for the purposes of this report, a smaller model was extracted from the full Lockyer Valley model that extended from the crossing Lockyer Creek by the Warrego Highway at Helidon to where Gatton-Clifton and Gatton-Helidon Roads cross the floodplain of Lockyer Creek, approximately 2 km downstream of Grantham. Reducing the model extent in this way provided an accurate representation of flooding in Grantham and the potential influence of the quarry currently owned by Wagner Investments Pty Ltd on flooding whilst allowing the computational run times for the model to be considerably reduced.

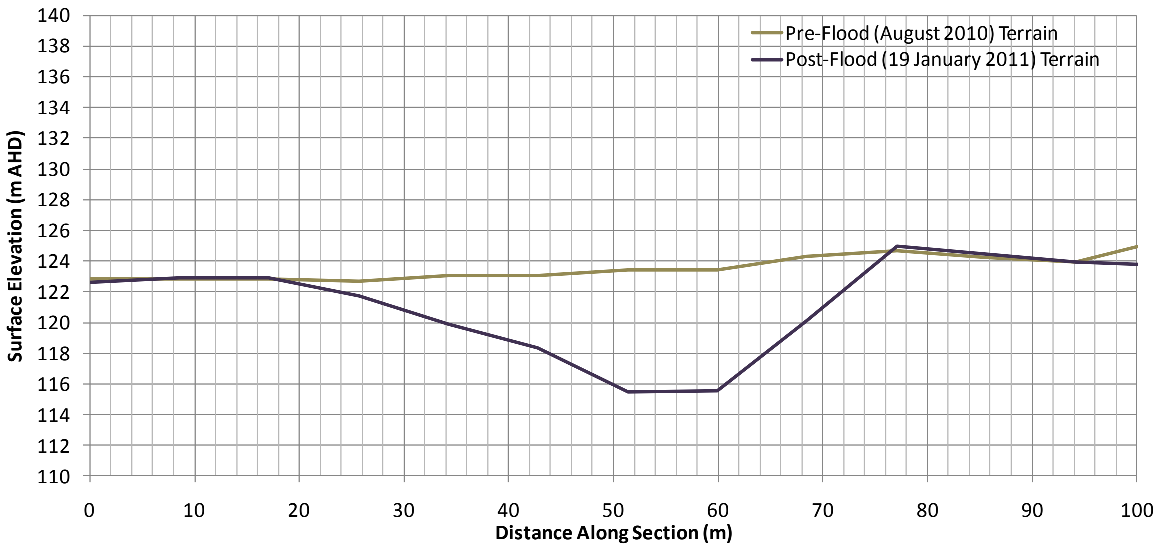
Three model scenarios were run for the purposes of preparing this report:

1) The flood hydrograph that occurred on 10 January 2011 was run through the model, using terrain data that was captured using light detection and ranging (LIDAR) survey of Lockyer Creek and it's floodplain in August 2010. This scenario includes the quarry in the terrain data and it also includes the 60 metre wide breach that occurred in the quarry wall during the event.
2) The flood hydrograph that occurred on 10 January 2011 was run through the model, using terrain data captured from aerial photography in May 1982 that represents the condition of the Lockyer Creek floodplain prior to quarrying works on the site that is now owned by Wagner Investments Pty Ltd.
3) The flood hydrograph that occurred on 10 January 2011 was run through the model, using terrain data captured by LIDAR survey of Lockyer Creek and it's floodplain in August 2010 but in this scenario the embankment on the upstream side of the quarry was not allowed to breach in the terrain data used for the model.

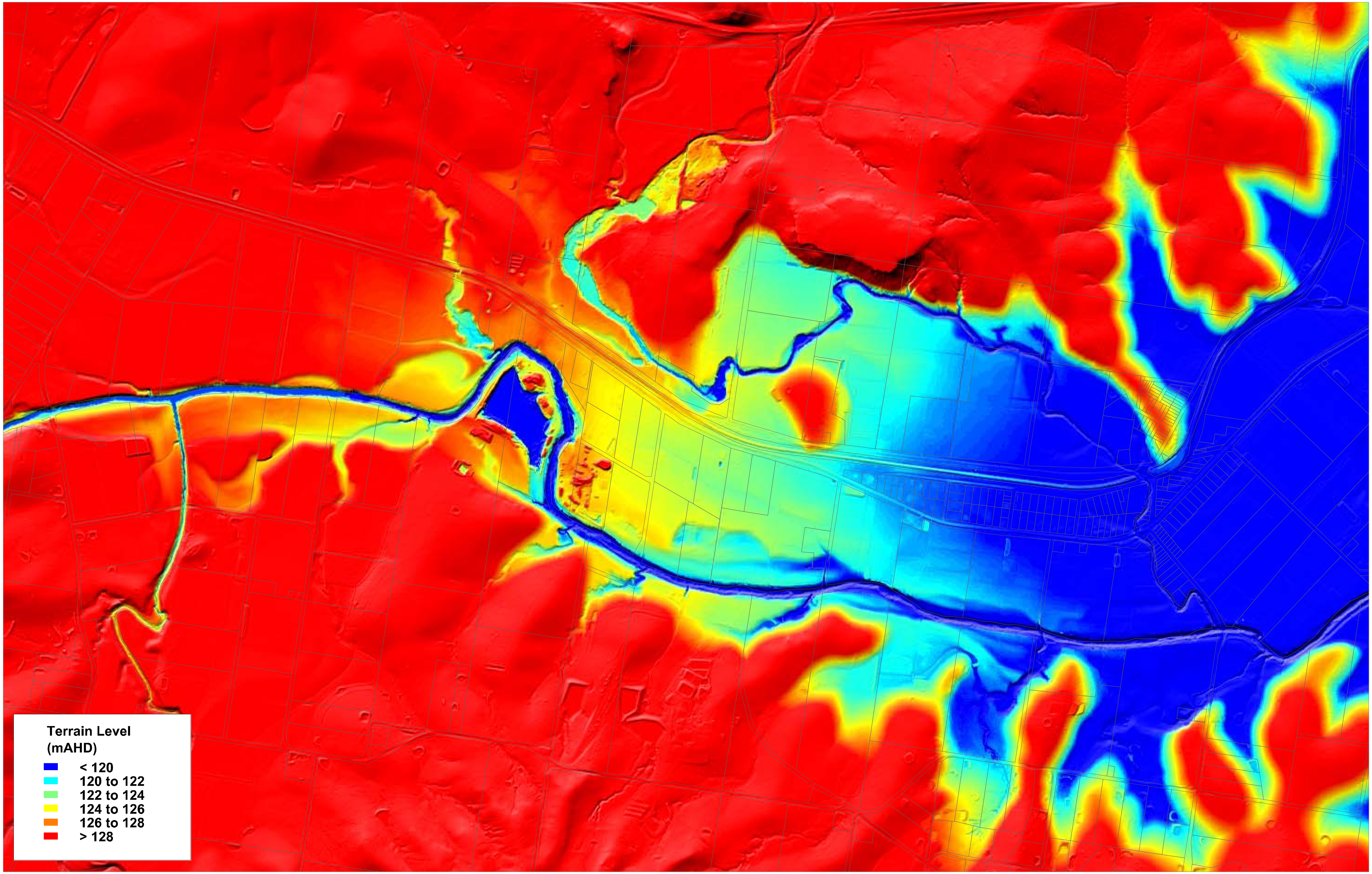
3.2 Terrain Data Inputs – Actual Terrain for Event

Terrain data for the event was captured by LIDAR survey of the Lockyer Creek floodplain in August 2010 and again on 19 January 2011, eight days after the flood. The LIDAR data from prior to the flood (August 2010) was used as the primary terrain data input for all of the model simulations (Queensland Department of Environment and Resource Management, 2010). Figure 3–2 and Figure 3–3 show the terrain data captured from each of these LIDAR surveys of the floodplain.

The most apparent difference between the two terrain surveys is that there was a breach in the embankment between the quarry pit and Lockyer Creek, near the north western corner of the quarry pit. This breach was approximately 55 metres wide and 8 metres deep, as shown in Figure 3–1. The breach in the embankment occurred during the 10 January 2011 flood. The simulation of the flood with the embankment breach was represented as a temporally varying terrain within the TUFLOW model. When the water level at the crest of the embankment reached a water level of 124.6 m AHD, ground levels within the model were reduced over a period of five minutes until the reached the levels detected in the post-flood LIDAR terrain data.



- **Figure 3–1 Cross section of terrain through the breach in the mound between the western side of the quarry and Lockyer Creek**



SINCLAIR KNIGHT MERZ

Datum: GDA94

Coordinate System: MGA Zone 56

0 0.5 1

Kilometres

N

Figure 3.2

Terrain
Pre breach
August 2010

Assessment OF Impact of Quarrying Operations on Flash Flooding in Grantham on 10 January 2011

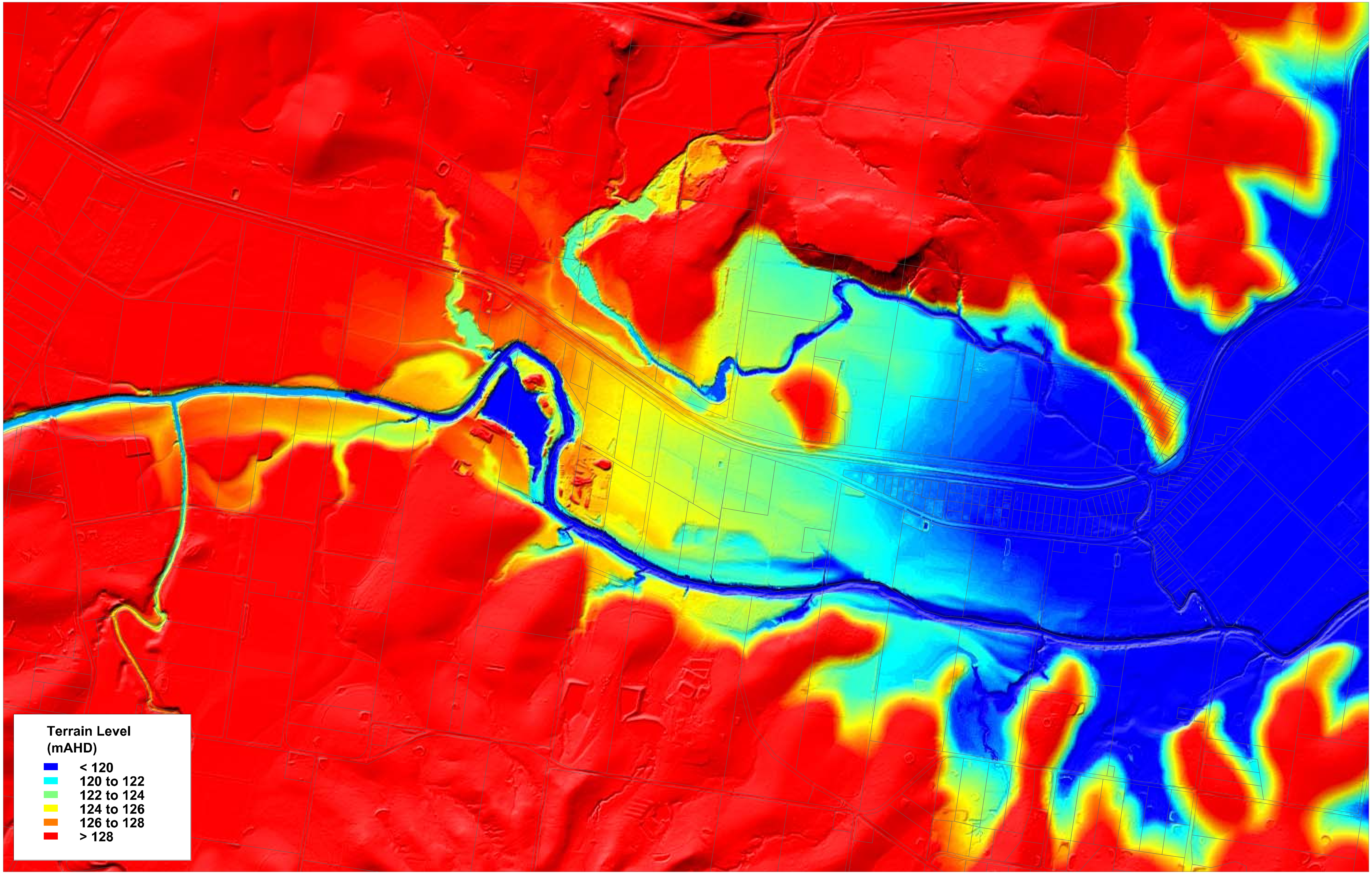


Figure 3.3

Terrain Post breach January 2011

Assessment OF Impact of Quarrying Operations on Flash Flooding in Grantham on 10 January 2011

3.3 Terrain Data Inputs – Pre-Quarry Terrain

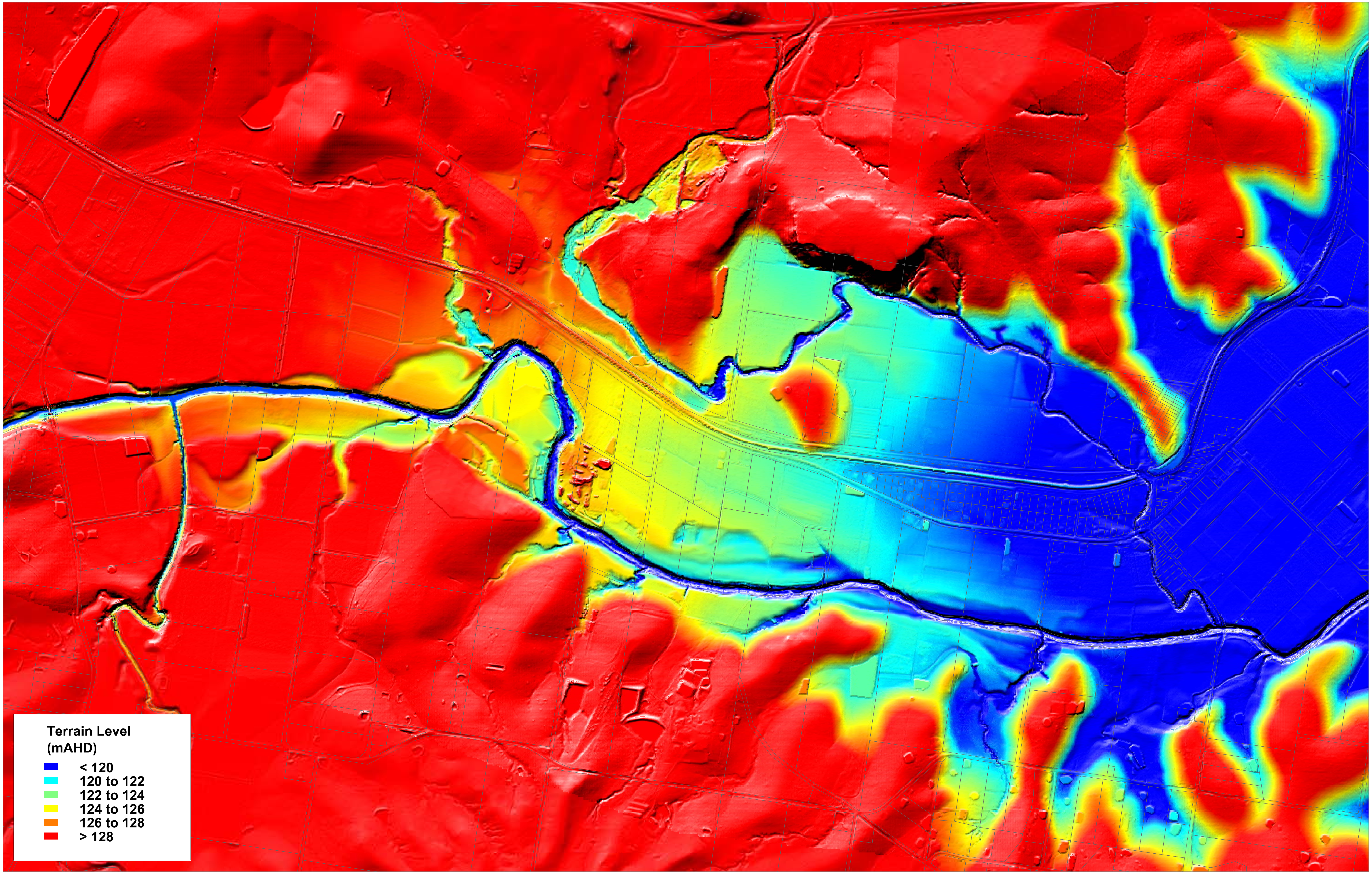
Aerial photography was flown over the Lockyer Valley area in May 1982 by the predecessor organisation to the Queensland Department of Environment and Resource Management. Electronic copies of these black and white aerial photographs were purchased from the Queensland Department of Environment and Resource Management. The photographs were taken on 13 May 1982 and they are referenced by the aerial photograph numbers QAP4014-012, QAP4014-013 and QAP4014-014.

Figure 3–4 shows an extract from the 1982 aerial photography that shows the area that later became the quarry currently owned by Wagner Investments Pty Ltd. It shows that quarrying operations had commenced in the northern part of the site, with evidence of removal of material and creation of mounds and material stockpiles on the northern part of the site. At the time of photography on 13 May 1982, ninety percent of the area that was later affected by quarrying operations was in its pre-quarrying state. It is apparent from the aerial imagery that the land that would later become the quarry was farm land before that time.

- **Figure 3–4 Aerial photograph of the area that later became the quarry currently owned by Wagner Investments Pty Ltd upstream of Grantham, captured 13 May 1982.**

The three aerial photograph images overlap in extent with one another. Stereophotogrammetry was used to create a digital terrain model from 13 May 1982 over the area that became the quarry currently owned by Wagner Investments Pty Ltd. The terrain model created from the 1982 aerial photography would provide an accurate representation of the terrain over the site that had not been quarried prior to 13 May 1982.

To represent the terrain on the site prior to the commencement of any quarrying operations, the terrain model determined from the 13 May 1982 aerial photography was modified to remove the quarrying that had occurred on the northern ten percent of the site prior to 13 May 1982. Ground levels on the site in the farm land areas surrounding the quarrying visible in the aerial photography were consistently around 124 m AHD. Terrain levels across the area affected by the quarry prior to 13 May 1982 were therefore modified to a constant elevation of 124 m AHD across that part of the site, as shown in Figure 3–5.



SINCLAIR KNIGHT MERZ
SKM

Datum: GDA94
Coordinate System: MGA Zone 56

0 0.5 1
Kilometres

N

Figure 3.5

Terrain
Pre quarry
1982

Assessment OF Impact of Quarrying Operations on Flash Flooding in Grantham on 10 January 2011

Gatton Shire Council provided Town Planning consent for extractive operations at the site on 22 July 1981(Wagner Investments Pty Ltd, 2011). Quarrying commenced at the site in the period between 22 July 1981 (date of town planning consent) and 13 May 1982 (date of aerial photography, which shows quarrying). Wagner Investments Pty Ltd purchased the quarry in 1994(Wagner Investments Pty Ltd, 2011).

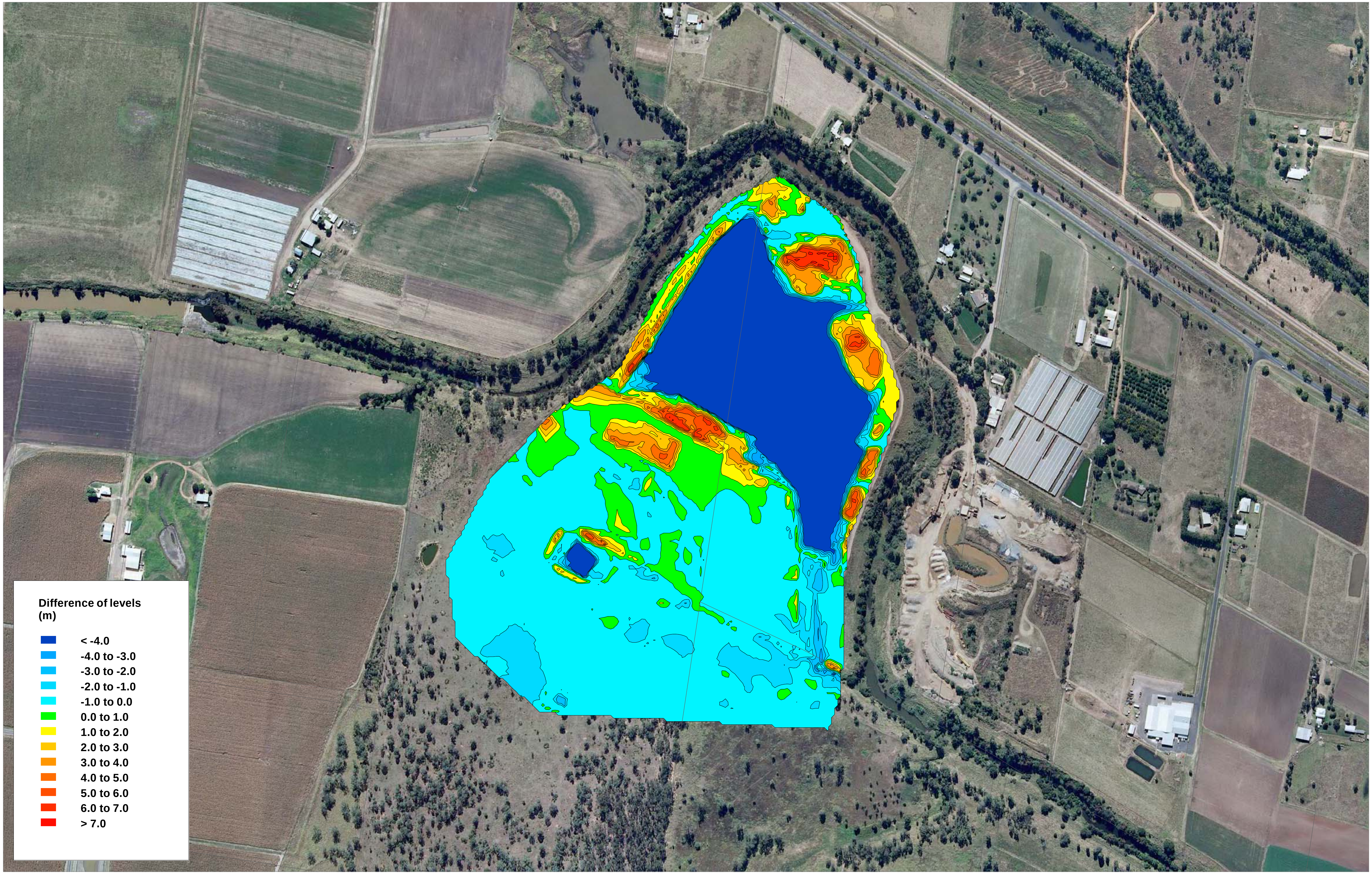
Figure 3–6 shows a the differences between the terrain between pre-quarry (derived from 1982 aerial photography) and just prior to the January 2011 flood event. It shows that material had been removed from the quarry pit and that the bed of the quarry pit is more than 4 metres (and up to 10 metres at its deepest point) lower than the ground surface that existed prior to quarrying. It also shows that material had been placed in embankments between the quarry pit and the bed and banks of Lockyer Creek. In particular, there was:

- a mound of material approximately 380 metres long and located between the right bank of Lockyer Creek and the western side of the quarry pit, with a crest profile as shown in Figure 3–7;
- a mound of material to the north east of the quarry pit that was approximately 100 metres by 80 metres in plan area before the flood and with a maximum level of 131.3 m AHD before the flood and
- five smaller mounds of material located between the eastern side of the quarry pit and Lockyer Creek.

These mounds of material had crest elevations that were above the surface that had existed prior to commencement of quarrying operations.

As shown in Figure 3–6 and Figure 3–7, the mound along the western side of the quarry pit is between 3 and 5.5 metres higher than the pre-quarry terrain surface along its entire length of approximately 380 metres.

There is also an above ground power line that travels across the quarry site. The centre line of the power line runs approximately 20 metres to west of the mound on the western side of the quarry, between the mound and the right bank of this reach of Lockyer Creek. Ergon Energy installed the power line on the site in 1990 (Wagner Investments Pty Ltd, 2011). Property owners (including Wagner Investments Pty Ltd) are constrained from modifying the ground levels underneath the alignment of the power lines. Current guidance from Ergon Energy is that ground levels are not to be modified along a corridor that is 12 metres wide, with the corridor centred on the direct line between the centre of each power pole. It is likely that ground levels had already been built up by quarrying operations on the western side of the quarry between May 1982 and when the power line was installed in 1990. The terrain model also showed that ground levels in August 2010 were approximately 1 metre higher along the length of the top of this mound than along the alignment underneath the power line that is adjacent to the mound.



SINCLAIR KNIGHT MERZ
SKM

Datum: GDA94
Coordinate System: MGA Zone 56

0 125 250
Metres

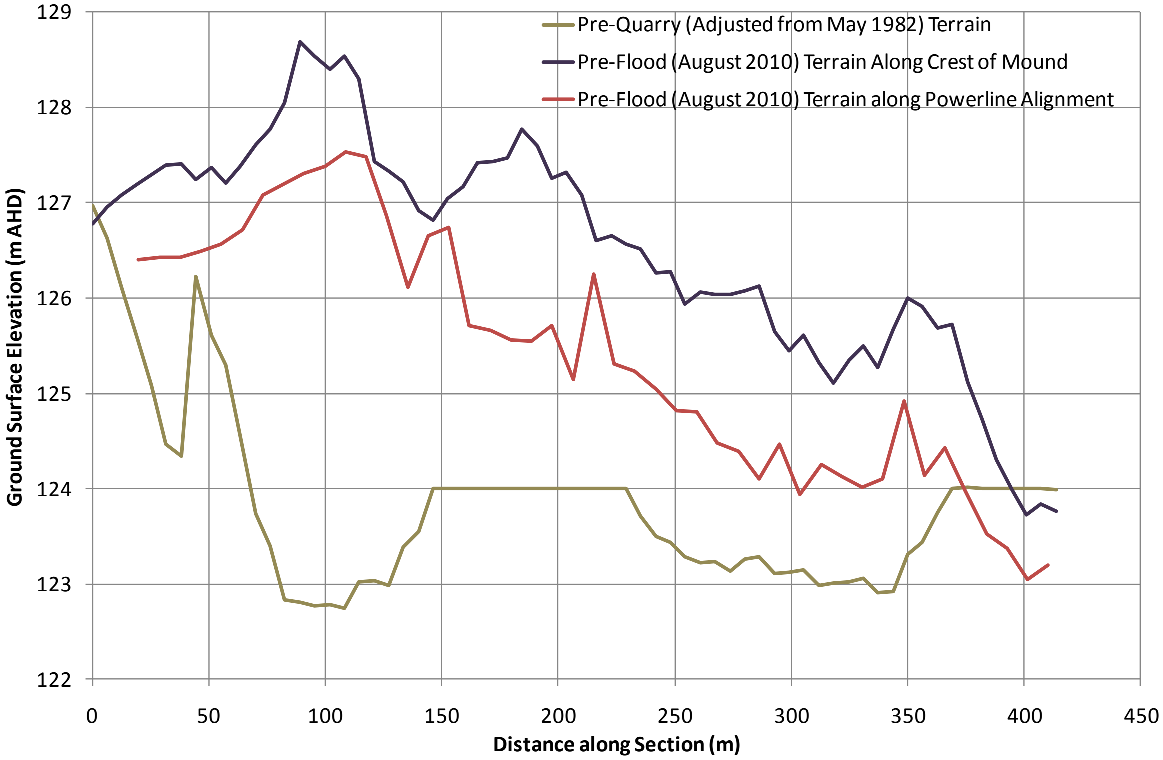
N

Figure 3.6

Terrain
Difference between 2010
pre breach and 1982 terrain

Assessment OF Impact of Quarrying Operations on Flash Flooding in Grantham on 10 January 2011

Dated 12 September 2011 I:\QENV2\Projects\QE06544\Spatial\MapInfo\WOR\Figures\Numbered\3-5 Terrain Differnce between pre breach and 1982 terrain.wor

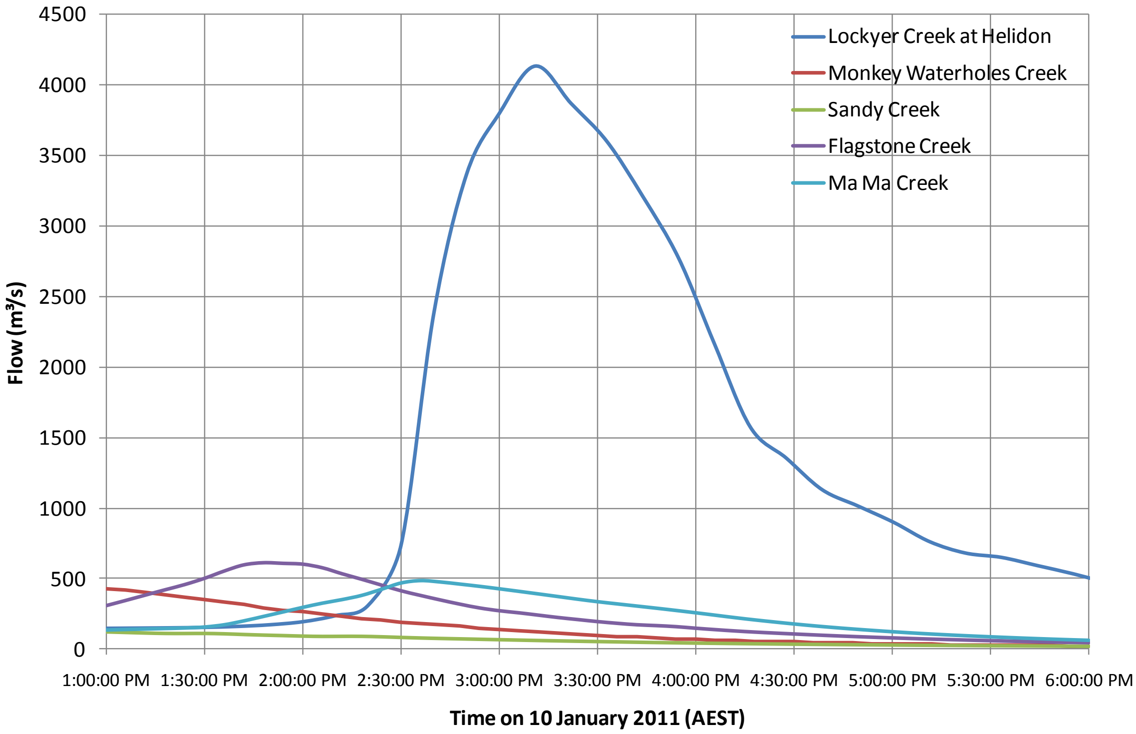


- **Figure 3–7 Ground surface elevation section along the crest of the mound of material between the western side of the quarry pit and Lockyer Creek from the Pre-Flood (August 2010) terrain data and the ground surface elevation along the same alignment from the pre-quarry terrain data**

3.4 Flow Hydrograph Inputs

Virtually all of the flow that occurred along Lockyer Creek at Grantham on 10 January 2011 originated from the part of the catchment upstream of Helidon. The streamflow gauge at Helidon captured the flood hydrograph at Helidon reliably for most of the event, with the height recorders at this location only failing for a brief period around the peak of the flood. The inflow hydrograph at the upstream extent of the model, which was the Warrego Highway crossing at Helidon, were represented by the gauged flow hydrograph at the Helidon streamflow gauge, as shown by the blue line in Figure 3–8.

Inflow hydrographs were also input to the TUFLOW model to represent inflows from Flagstone Creek, Sandy Creek, Monkey Waterholes Creek, Ma Ma Creek and the Lockyer Creek floodplain itself between Helidon and Grantham. Flow hydrograph inputs for these flows were estimated using the XP-RAFTS rainfall-runoff routing model of the Lockyer Creek catchment that was developed by Sinclair Knight Merz for the Lockyer Valley Regional Council's Floodplain Management Study (Lockyer Valley Regional Council, 2011). Rainfall intensities for the catchments of Flagstone, Sandy, Ma Ma and Monkey Waterholes creeks and on the Lockyer Creek floodplain downstream of Helidon were considerably lower than those recorded on the catchment upstream of Helidon. As shown in Figure 3–8, the peak flows simulated for these other four tributary catchments during the event were only a small fraction of the peak flow recorded at the Helidon streamflow gauge.



- **Figure 3–8 Inflow hydrographs used for all TUFLOW model simulations**

3.5 Downstream Boundary Condition

The downstream boundary of the TUFLOW model was represented by Gatton-Clifton Road and Gatton-Helidon Road, which is 2 km downstream of the centre of the town of Grantham. A constant water level of 114.2 m AHD was adopted across the downstream boundary of the model. Since ground levels in the town of Grantham and across the floodplain upstream of Grantham are above 120 m AHD, the downstream boundary would have minimal influence on the water levels and velocities simulated from the model for the town or any location upstream.

3.6 Roughness and Eddy Viscosity

Manning’s roughness values were set for different types of surfaces across the model. For most of the model domain, which included the channel of Lockyer Creek and grassed and cultivated areas of the floodplain, a Manning’s n value of 0.03 was adopted. Areas identified from aerial photograph imagery as low to medium density (shrub) vegetation were assigned a Manning’s n value of 0.06. Buildings that survived the January 2011 flood were assigned a very high Mannings'n value (2.0), which effectively provided a barrier to any flow over the two dimensional footprint of the building. Buildings that were destroyed by the January 2011 flood were represented with a variable Manning's n value that responded according to the depth of water at the location of the individual building. For the portion of the simulation prior to the simulated water depth at the location of the building being less than 1.5 m, a very high Manning's n value (2.0) was assigned. After the simulated depth exceeded 1.5 m at the location of each destroyed building, the simulation reduced the Manning's n value to 0.03 across the building extent to match the Manning's n that was adopted for grassed and cultivated areas in the simulation.

Eddy viscosity is used to compute energy losses due to turbulence that occurs at spatial scales that are smaller than the horizontal resolution of the model (i.e. at scales less than 10 metres for this model). Eddy viscosity was represented in the model using the Smagorinsky eddy viscosity formulation with the default value for TUFLOW models of 0.2 adopted as the value of the coefficient.

3.7 Representation of Railway Lines Roads and Structures

There was one bridge structure that was represented as a one-dimensional flow structure within the TUFLOW model. The Flagstone Creek Road crossing of Lockyer Creek was represented as a bridge structure, which had an opening width of 80 metres and a length (in the direction of flow) of 18 metres.

The small culvert bridge crossing by Grantham Winmill Road (Harris Street) of Lockyer Creek was not represented as a one-dimensional structure within the TUFLOW model. Instead, the crest of the road was represented in the terrain of the two-dimensional grid within the model. The culverts at this crossing would have insignificant capacity compared with the peak flow during the 10 January 2011 flood event and this would have had an insignificant effect on the results of the model simulations.

The railway bridge crossing of Sandy Creek, Ditchmans Road and Victor Street was modelled in the two dimensional model domain with the terrain in this area represented by the ground levels beneath the bridge. The railway bridge was not represented as a one-dimensional structure and therefore the influence on the flow of the timber bridge pylons and deck were not represented within the model. The influence of debris blockage against the railway bridge deck and pylons also was not directly represented in the model. The model simulation (for all scenarios) may slightly overestimate velocities and underestimate peak water depths in the immediate vicinity of the railway bridge but there would be limited effects on the accuracy of the simulation more than 200 metres away from the railway bridge.

The embankment portion of the railway line itself was represented in the two dimensional terrain data within the model. During the actual flood event water overtopping the railway line caused washing out of ballast from the railway line, which would have allowed more water to flow over the railway line onto the northern side of the floodplain and into the course of Sandy Creek north of the railway line. In all scenarios modelled with the TUFLOW model, the top of the railway embankment was maintained at a constant level during the whole simulation period. This simplification within the TUFLOW model may have kept simulated water levels in the TUFLOW model slightly higher on the southern side of the railway embankment at the peak of the flood event than if the crest of the railway embankment had been allowed to erode.

4 Assessment of Influence of Quarry on Flood Impacts for 10 January 2011 Flood Event

4.1 Model Scenarios and Results

The TUFLOW model was run for the following three scenarios for the 10 January 2011 flood event:

1) Using terrain data captured from aerial photography in May 1982 that represents the condition of the Lockyer Creek floodplain prior to quarrying works on the site that is now owned by Wagner Investments Pty Ltd.
2) Using terrain data that was captured using light detection and ranging (LIDAR) survey of Lockyer Creek and it's floodplain in August 2010. This scenario includes the quarry in the terrain data and it also includes the 60 metre wide breach that occurred in the quarry wall during the event.
3) Using terrain data captured by LIDAR survey of Lockyer Creek and it's floodplain in August 2010 but in this scenario the embankment on the upstream side of the quarry was not allowed to breach in the terrain data used for the model.

Results were extracted from the model as:

- Maps of the maximum value of depth recorded during the model simulation period at each 10 metre grid cell;
- Maps of the maximum value of depth averaged velocity recorded during the model simulation period at each 10 metre grid cell;
- Hydrographs of depth and depth-averaged water velocity during the model simulation period for a number of selected locations, as shown in Figure 4–1; and
- Hydrographs of flow through selected cross sections as shown in Figure 4–1 during the model simulation period.

Maximum water depths and velocities for each of the three simulations are shown in Figures 4-2 through to 4-7.

Figure 4–3 is the most useful for the purposes of validation of the performance of the TUFLOW model. Maximum water levels and depths simulated from the TUFLOW model were found to be within 0.3 metres of water levels surveyed from debris marks on buildings in Grantham after the January 2011 flood event. The extent of flooding for the pre-flood terrain including the quarry embankment collapse scenario is also consistent with sediment deposits that were evident from aerial photography captured after the January 2011 flood event.

Datum: GDA94
Coordinate System: MGA Zone 56

0 0.5 1

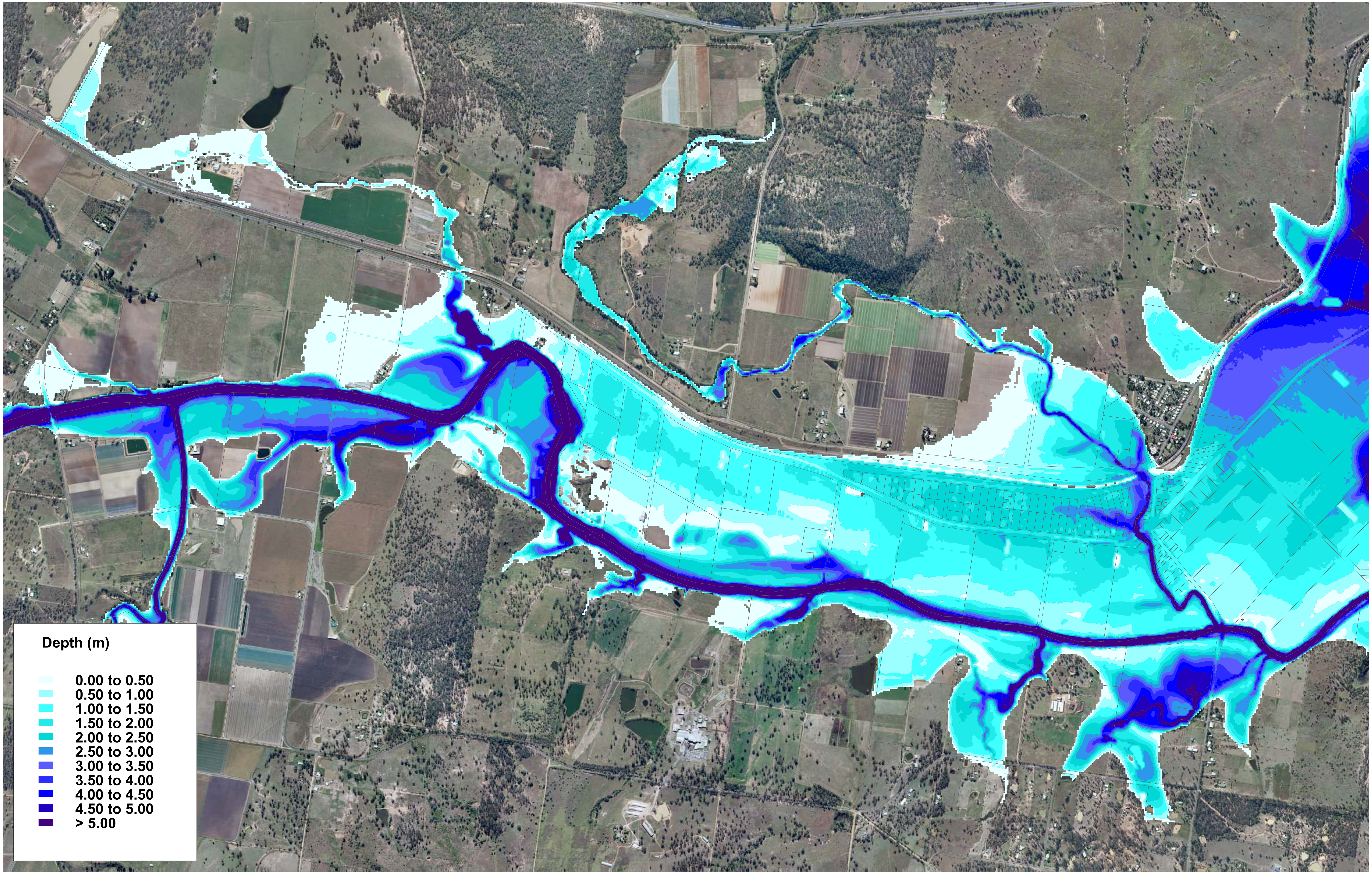
Kilometres

kilometres

N

SINCLAIR KNIGHT MERZ
SKM

Figure 4.1
Locations of Interest
Assessment OF Impact of Quarrying Operations on Flash Flooding in Grantham on 10 January 2011



SINCLAIR KNIGHT MERZ
SKM

Datum: GDA94
Coordinate System: MGA Zone 56

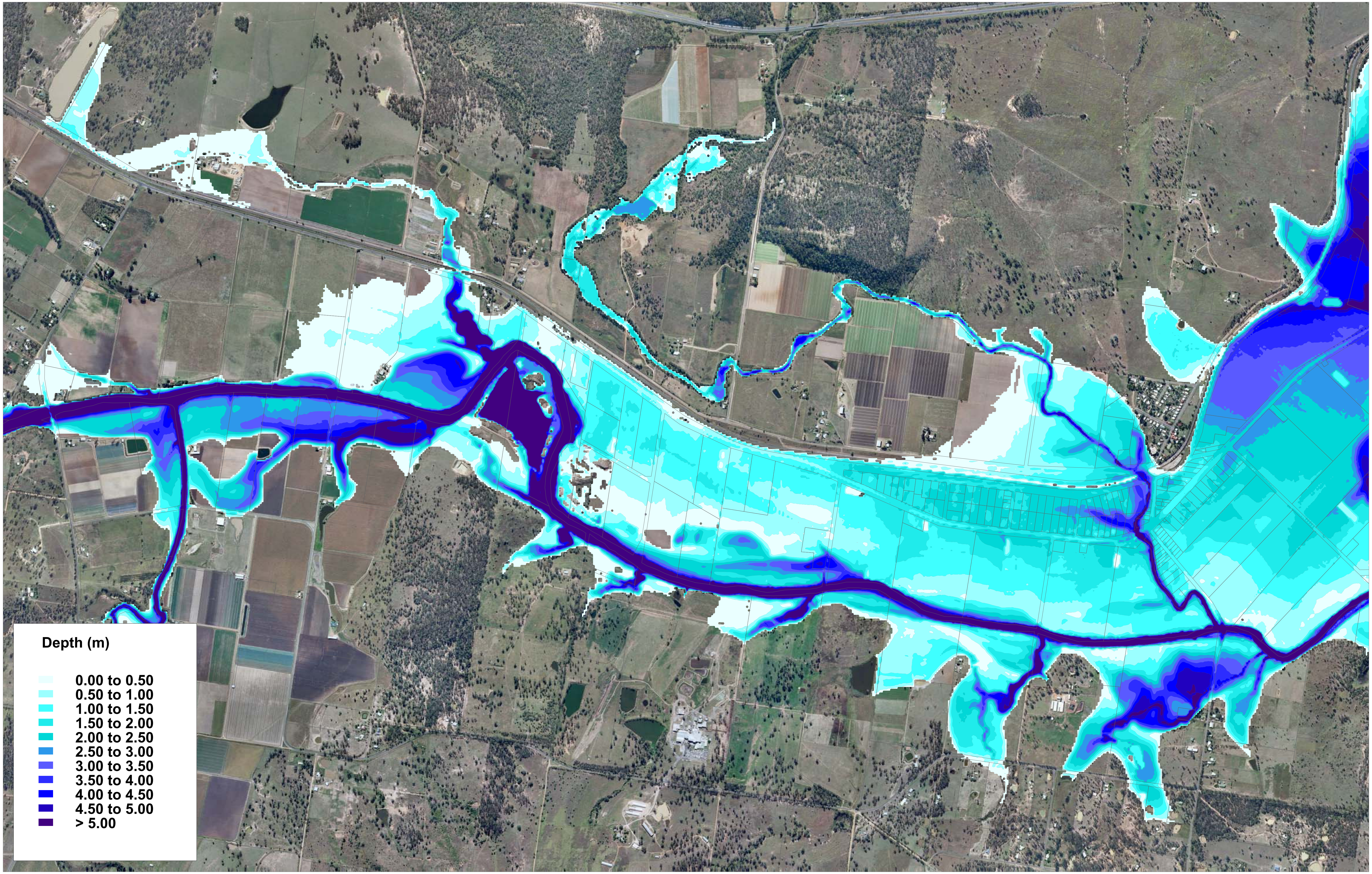
0 0.5 1
Kilometres

N

Figure 4.2

Peak Inundation Depth -Pre Quarry Terrain

Assessment OF Impact of Quarrying Operations on Flash Flooding in Grantham on 10 January 2011



SINCLAIR KNIGHT MERZ SKM

Datum: GDA94
Coordinate System: MGA Zone 56

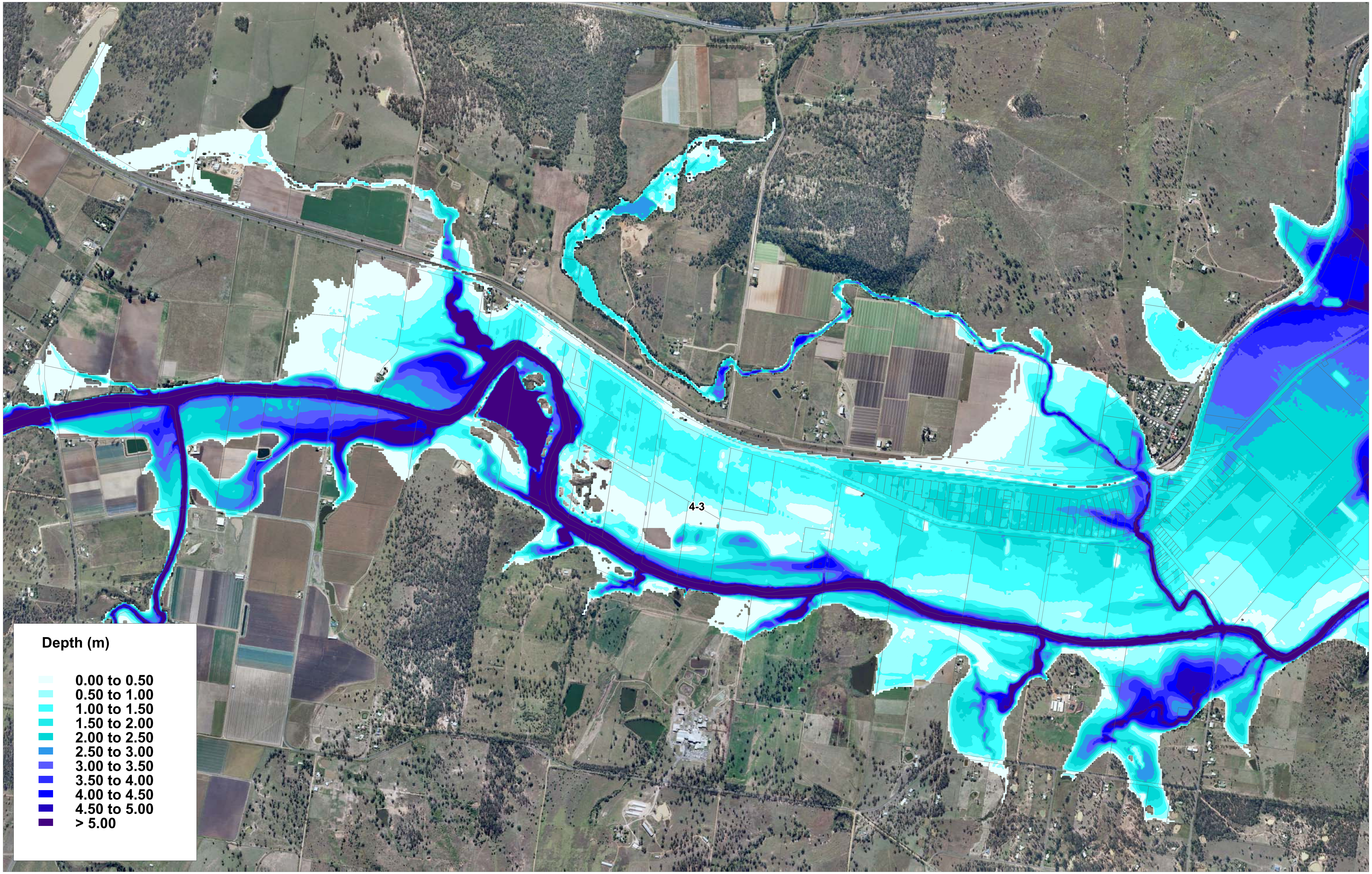
0 0.5 1
Kilometres

N

Figure 4.3

Peak Inundation Depth
Terrain as at January 2011
Quarry including embankment collapse

Assessment OF Impact of Quarrying Operations on Flash Flooding in Grantham on 10 January 2011



SINCLAIR KNIGHT MERZ
SKM

Datum: GDA94
Coordinate System: MGA Zone 56

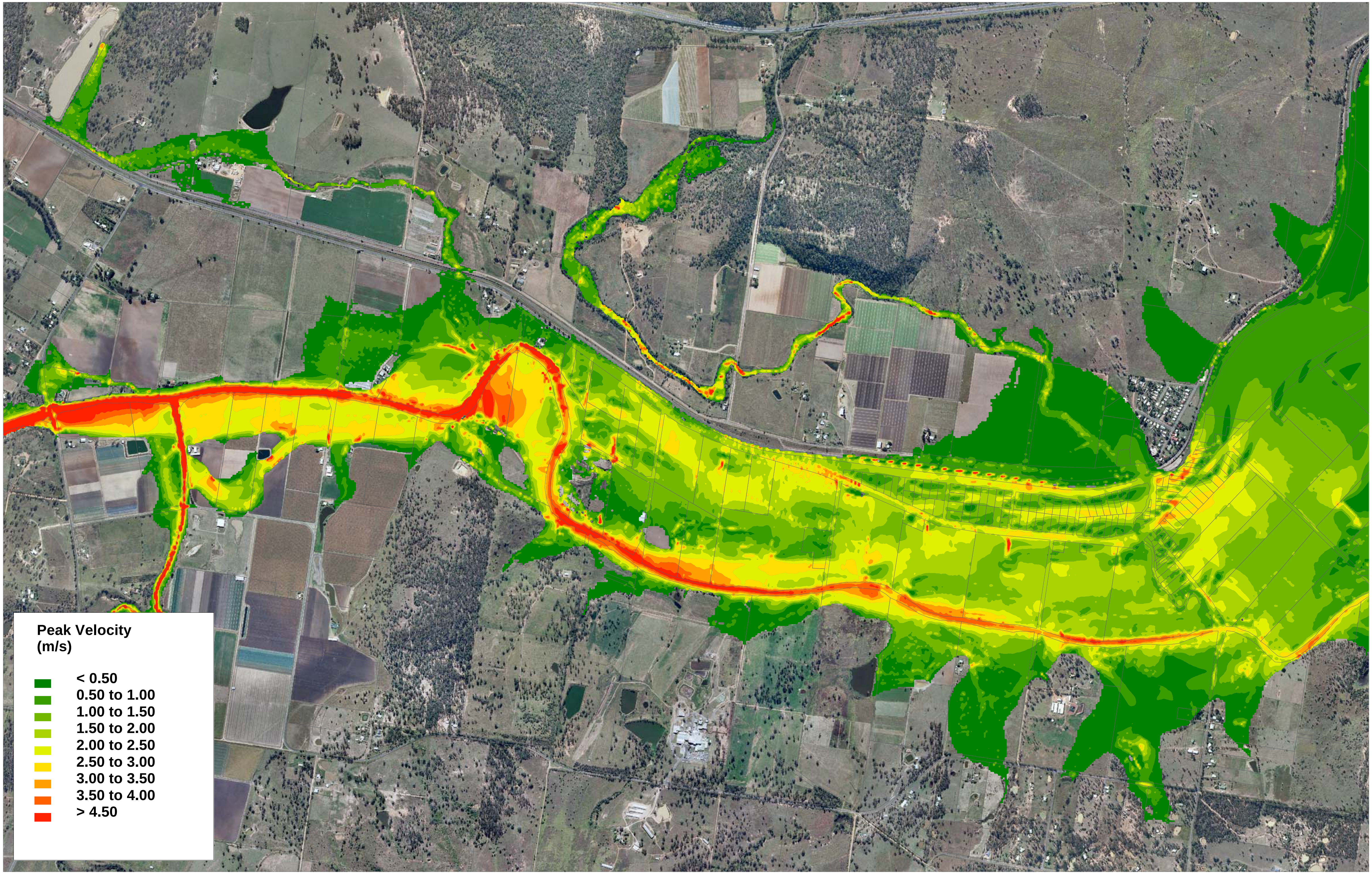
0 0.5 1
Kilometres

N

Figure 4.4

Peak Inundation Depth
Terrain as at January 2011
Without quarry embankment collapse

Assessment OF Impact of Quarrying Operations on Flash Flooding in Grantham on 10 January 2011



SINCLAIR KNIGHT MERZ
SKM

Datum: GDA94
Coordinate System: MGA Zone 56

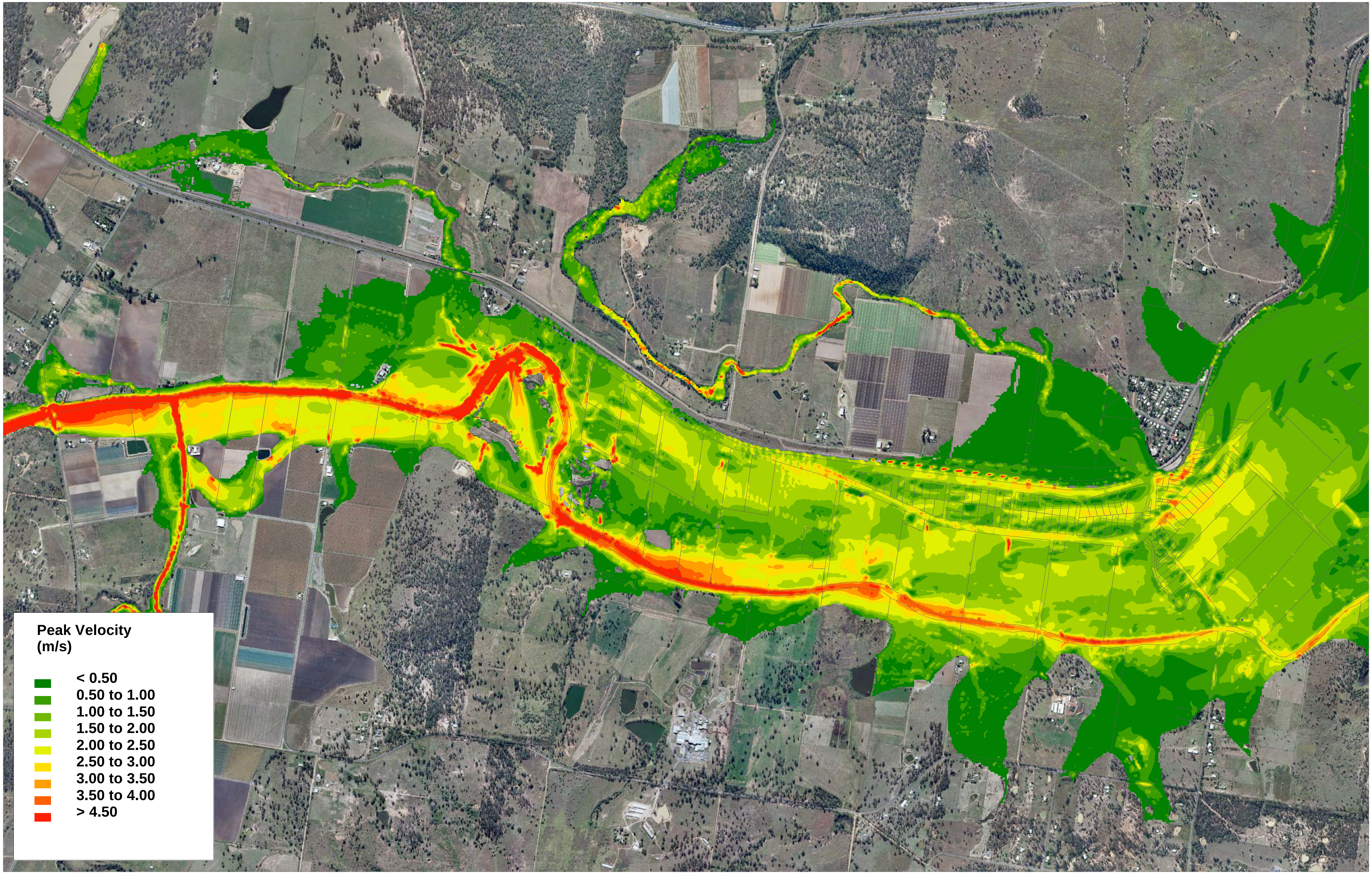
0 0.5 1
Kilometres

N

Figure 4.5

Peak Velocity
Pre Quarry Terrain

Assessment OF Impact of Quarrying Operations on Flash Flooding in Grantham on 10 January 2011



SINCLAIR KNIGHT MERZ

SKM

Datum: GDA94

Coordinate System: MGA Zone 56

0 0.5 1

Kilometres

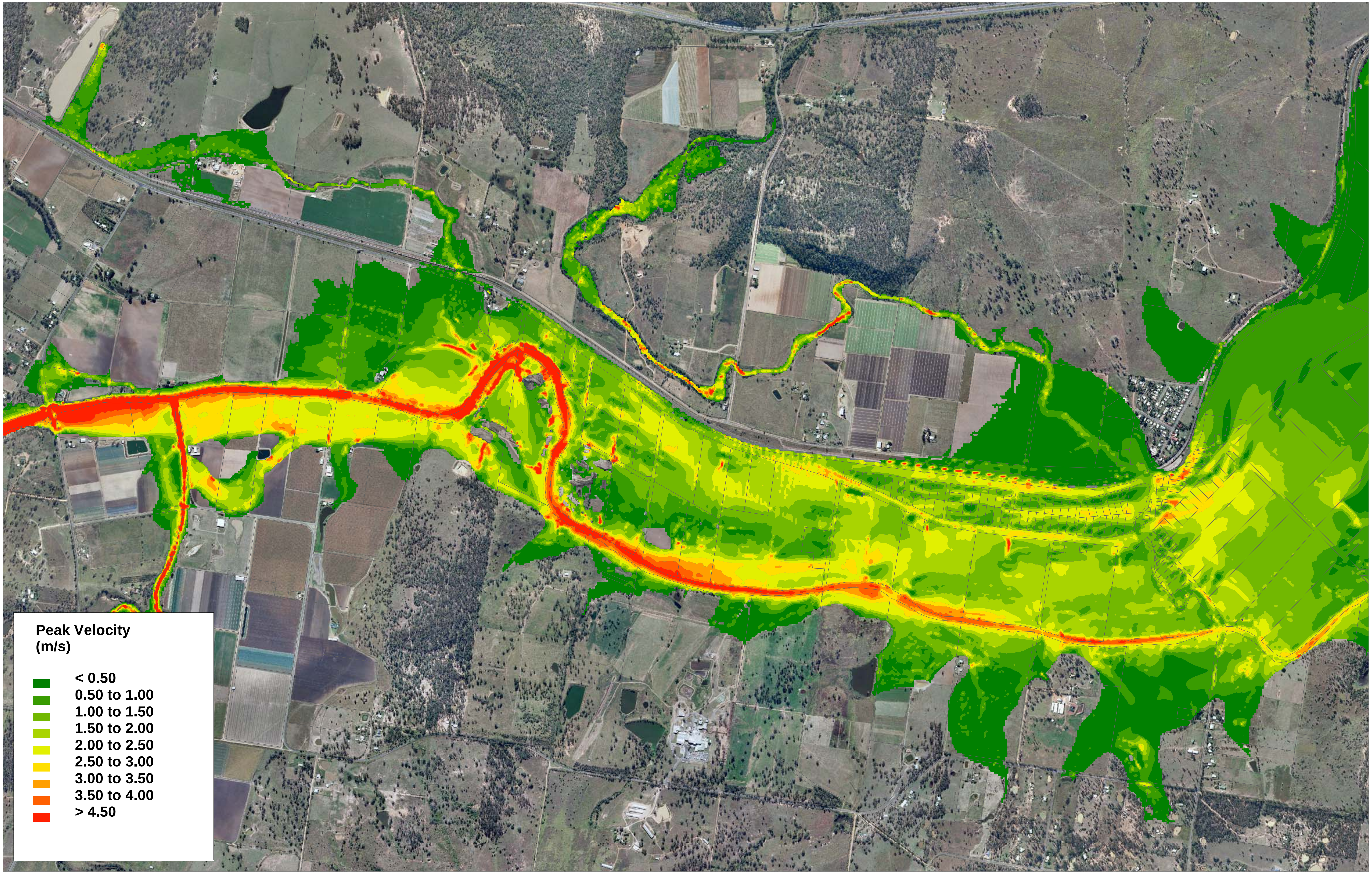
N

Figure 4.6

Peak Velocity
Terrain as at January 2011
Quarry including embankment collapse

Assessment OF Impact of Quarrying Operations on Flash Flooding in Grantham on 10 January 2011

Dated 12 September 2011 I:\QENV2\Projects\QE06544\Spatial\MapInfo\WOR\Figures\Numbered\4-6 Velocity Terrain as at January 2011 - quarry including embankment collapse .wor



SINCLAIR KNIGHT MERZ
SKM

Datum: GDA94
Coordinate System: MGA Zone 56

0 0.5 1
Kilometres

N

Figure 4.7

Peak Velocity
Terrain as at January 2011
Without quarry embankment collapse

Assessment OF Impact of Quarrying Operations on Flash Flooding in Grantham on 10 January 2011

4.2 Comparison of Maps of Peak Water Levels and Maximum Velocities Between Scenarios

Figure 4–8 shows the differences in the peak water levels from the TUFLOW model for the 10 January 2011 flood event between the pre-quarry scenario and the event as it occurred with the quarry in place and the collapse of the quarry wall. Red and orange colours denote areas where peak levels in the flood were higher with the quarry than for the pre-quarry terrain and blue colours denote areas where peak levels in the flood were lower due to the quarry than would have been the case with the pre-quarry terrain. Figure 4–10 shows a similar plot of the differences in velocities between the two scenarios.

The embankments along the western side of the quarry caused additional resistance to flows on the upstream (Western) side of the quarry pit. This caused an increased proportion of the flow to be forced through a breakout in the floodplain to the south of the quarry pit and reduced flows carried by the main channel from those simulated with the pre-quarry terrain. As a result, water levels in Lockyer Creek and on the floodplain upstream of the quarry were considerably higher with the quarry than in the pre-quarry terrain. Increased flood levels occur along Lockyer Creek and its floodplain back from the quarry to the Flagstone Creek Road crossing, a distance of 2 km.

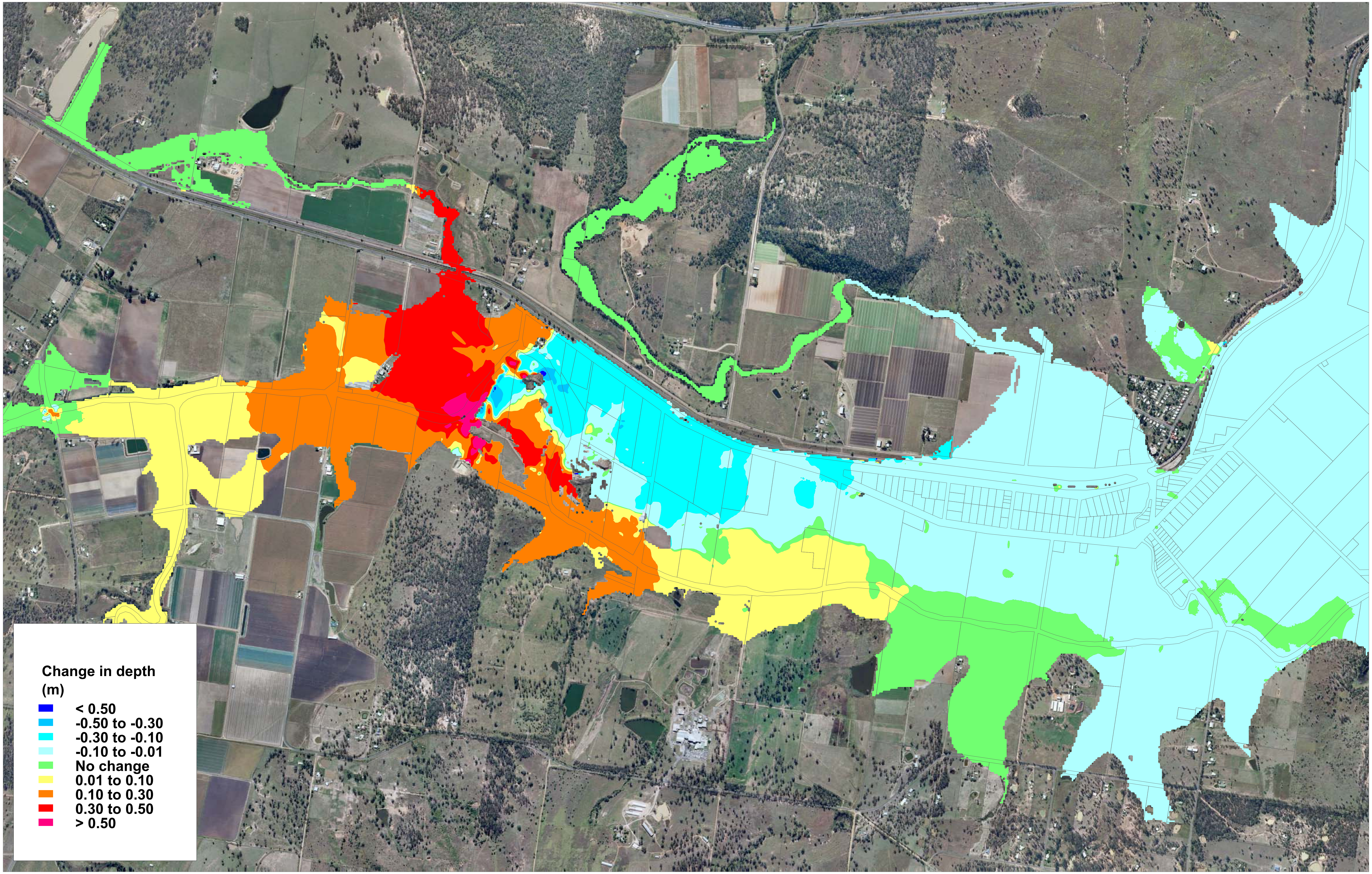
Peak flood levels and velocities through the town area were consistently lower for the simulation with the quarry in place than using the pre-quarry terrain. The quarry mitigated the impact of flooding through the town area of Grantham, with peak flood levels reduced by between 0.05 m and 0.1 m. The quarry had no impact on peak flood velocities through Grantham, with the maximum simulated velocities different by less than 0.01 m/s across the Grantham town area between the pre-quarry simulation and the simulation with the quarry in place and breach of the quarry embankment.

The breach in the quarry embankment allowed a stream of faster flowing water to travel directly through the pit during the January 2011 flood event. The TUFLOW model simulated that the breach in the mound would have commenced at 3:10 pm, at the time when this part of the embankment between Lockyer Creek and the quarry pit was first overtopped, although there is insufficient credible evidence to independently verify the time at which the breach in the embankment would have occurred. The flow path from the breach is evident as an area of velocities greater than 2 m/s in a line from the north western to south eastern corner of the quarry pit (see Figure 4–6).

Depths and velocities were also increased over the pre-quarry simulation along the main channel of Lockyer Creek from the south eastern corner of the quarry to 200 m downstream of Charles Road. The increase in depths and velocities in this area was due to the mound on the western side of the quarry forcing more water through the breakout to the south of the quarry and by the efficient flow pathway through the breach and across the quarry pit.

The TUFLOW model was also run for the hypothetical scenario that there was no breach in the embankment between the western side of the quarry pit and Lockyer Creek. Maps of differences in maximum simulated flood depths and velocities for this scenario are shown in Figure 4–9 and Figure 4–11.

The results for the hypothetical scenario that no breach had occurred in the embankment are very similar to the results that include the breach in the embankment that actually occurred. The map of changes in velocities (Figure 4–11) shows that if no breach had occurred in the embankment some of the flow that was directed through the breach and across the quarry pit would have diverted along the main channel of Lockyer Creek and through the breakout along the floodplain to the south of the quarry. The pattern of changes in flood levels through the town of Grantham and upstream of the quarry are very similar between the two January 2011 terrain scenarios, regardless of whether the embankment would have breached or not. The similarity in results between the two scenarios indicates that results for the town of Grantham are not sensitive to assumptions made about the timing of when the breach actually occurred.



SINCLAIR KNIGHT MERZ

SKM

Datum: GDA94

Coordinate System: MGA Zone 56

0 0.5 1

Kilometres

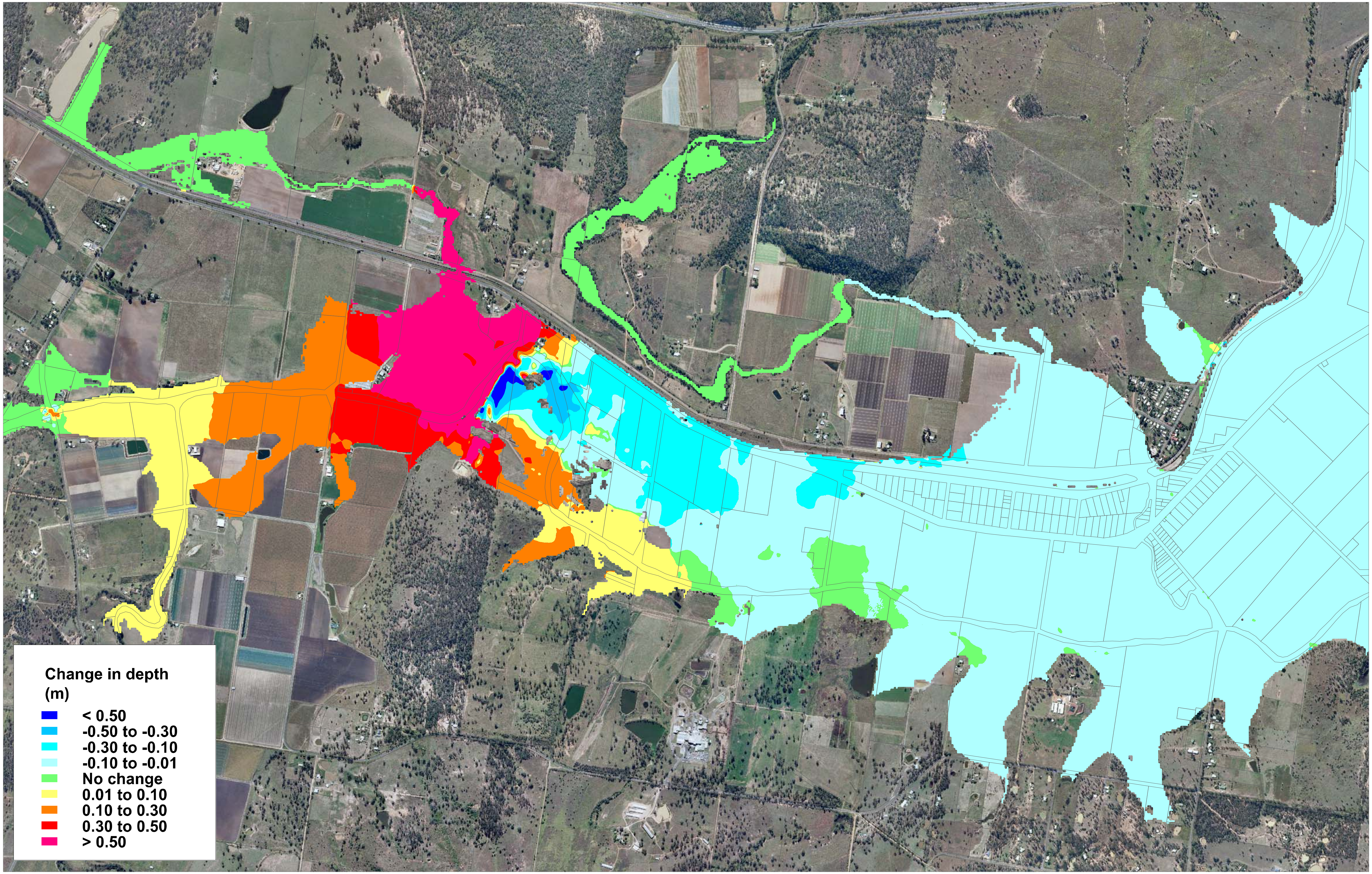
N

Figure 4.8

Changing in Water Surface Level
Terrain as at January 2011
Quarry including embankment collapse less
Pre Quarry Terrain

Assessment OF Impact of Quarrying Operations on Flash Flooding in Grantham on 10 January 2011

Dated 12 September 2011 I:\QENV2\Projects\QE06544\Spatial\MapInfo\WOR\Figures\Numbered\4-8 Change in Water Surface Level Terrain as at January 2011 - quarry including embankment collapse less Pre Quarry Terrain.wor



SINCLAIR KNIGHT MERZ
SKM

Datum: GDA94
Coordinate System: MGA Zone 56

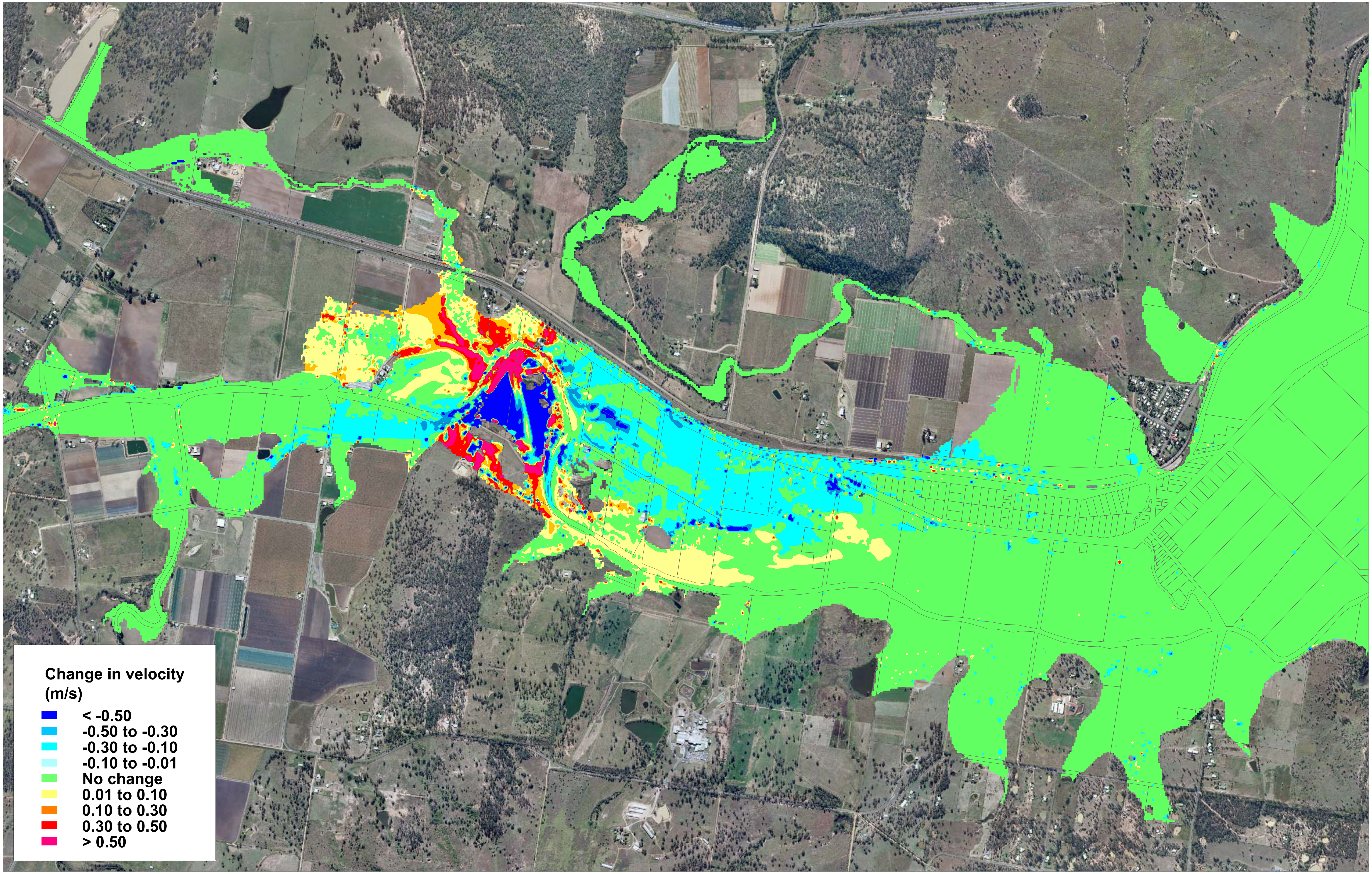
0 0.5 1
Kilometres

N

Figure 4.9

Change in Water Surface Level
Terrain as at January 2011
Without quarry embankment collapse
less Pre Quarry Terrain

Assessment OF Impact of Quarrying Operations on Flash Flooding in Grantham on 10 January 2011



SINCLAIR KNIGHT MERZ
SKM

Datum: GDA94
Coordinate System: MGA Zone 56

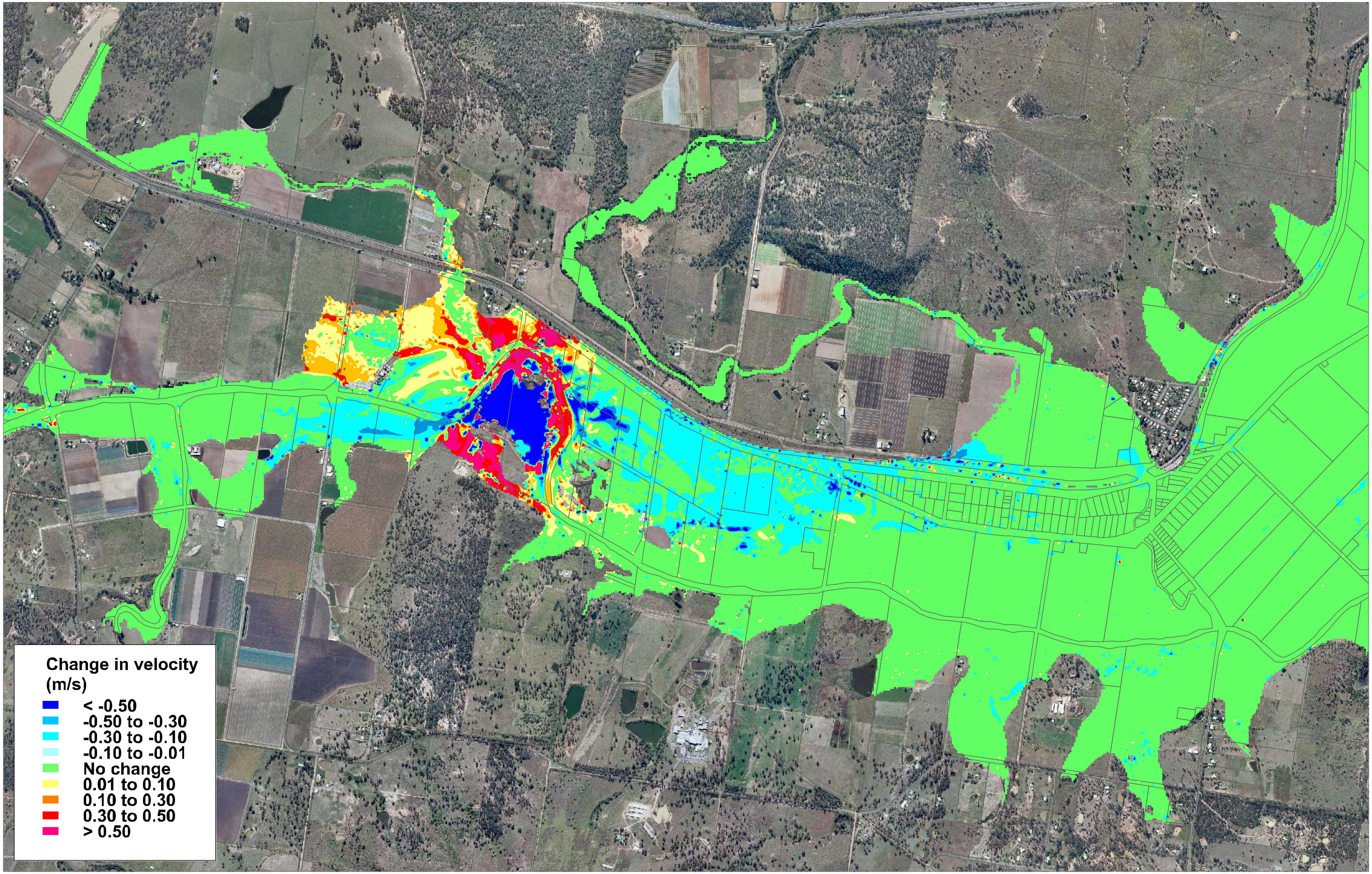
0 0.5 1
Kilometres

N

Figure 4.10

Change in Velocity
Terrain as at January 2011
Quarry including embankment collapse
less Pre Quarry Terrain

Assessment OF Impact of Quarrying Operations on Flash Flooding in Grantham on 10 January 2011



SINCLAIR KNIGHT MERZ SKM

Datum: GDA94
Coordinate System: MGA Zone 56

0 0.5 1
Kilometres

N

Figure 4.11

Change in Velocity
Terrain as at January 2011
Without quarry embankment collapse
less Pre Quarry Terrain

Assessment OF Impact of Quarrying Operations on Flash Flooding in Grantham on 10 January 2011

Dated 12 September 2011 I:\QENV2\Projects\QE06544\Spatial\MapInfo\WOR\Figures\Numbered\4-11 Change in Velocity Terrain as at January 2011 but without quarry embankment collapse less Pre Quarry Terrain.wor

4.3 Comparison of Hydrographs of Velocity and Water Level at Selected Locations

The maps shown above provide a comparison of the maximum velocity and water level across the whole area of interest in Grantham but they may mask insights about changes in timing of the flood event due to differences in terrain. Hydrographs of level and velocity at selected locations were extracted from the model result to demonstrate how changes in the timing of the flood event would have been affected by differences in terrain.

Figure 4–12 shows hydrograph of water level at six locations (with locations as denoted in Figure 4–1). At location A, just upstream of where the breach occurred in the quarry wall, the hydrographs demonstrate that the embankment on the western side of the quarry pit constrained flows along Lockyer Creek and caused flood levels at this location to be 0.3 m higher with the quarry incorporated and breaching than in the pre-quarry terrain scenario. The shape of the hydrographs are similar with the peak occurring at 3:55 pm in both scenarios. The simulated breach of the quarry wall at 3:05 pm is evident in the water level hydrograph at location A as the two scenarios with the January 2011 terrain (with and without breach) diverge at this time, consistent with the model simulating flow through the breach.

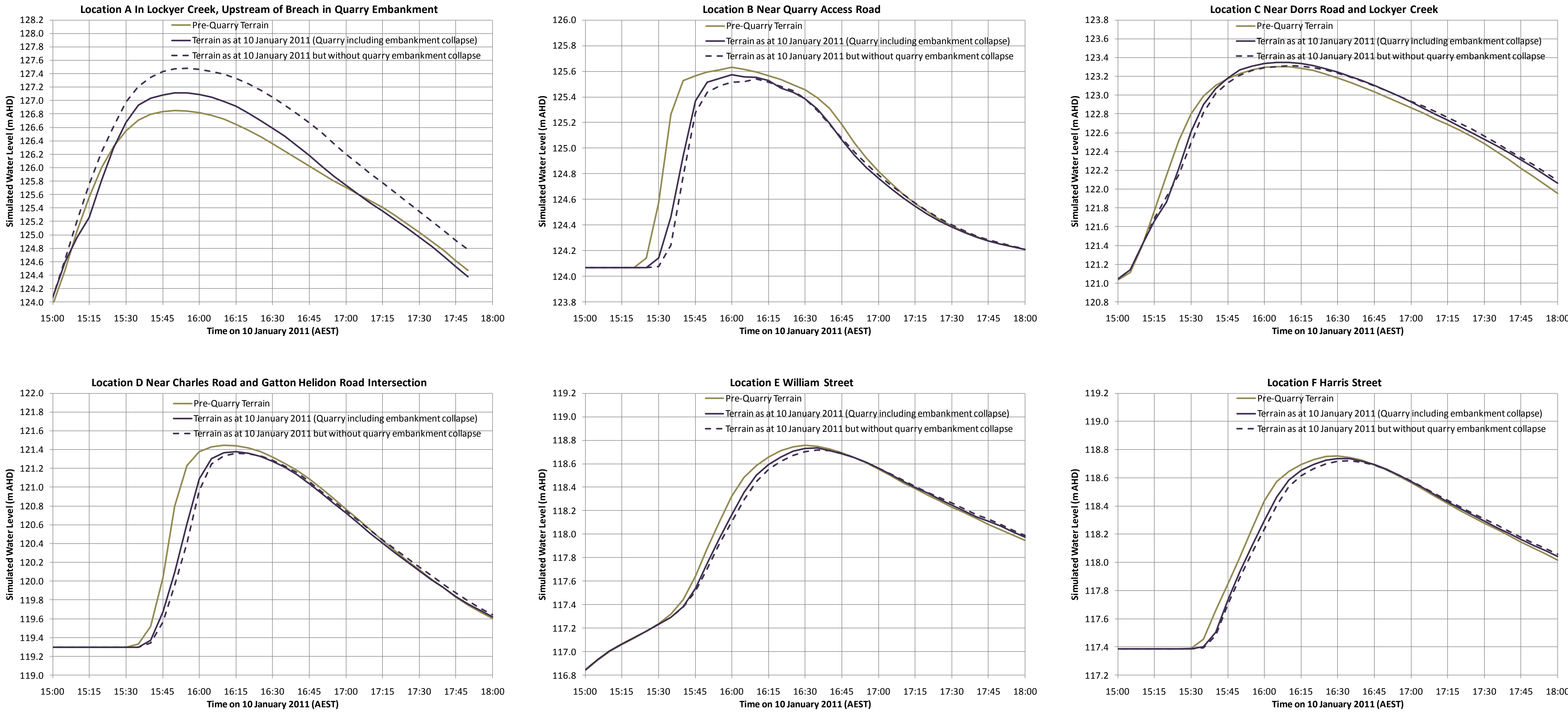
The water level hydrograph at location B, which is in the breakout across the left bank of Lockyer Creek opposite the north eastern side of the quarry, shows that with the quarry in place flows were attenuated such that the rising limb is delayed by 10 minutes when compared to the pre-quarry terrain simulation. Water levels peak in both simulations at 4:00 pm but the peak with the quarry in place and embankment breach are 0.06 m lower than with the pre-quarry terrain.

The water level hydrographs at Location C, near where Lockyer Creek breaks out onto the left bank of the floodplain near Dorrs Road, show a 5 minute delay for most of the rising limb for the scenarios with the quarry included but the additional flow forced through the quarry pit and through the breakout to the south of the quarry causes the water levels to peak 0.04 m above the levels that were simulated with the pre-quarry terrain at this location.

Water levels in the town of Grantham were delayed by the presence of the quarry, which caused more of the flood water to travel along the longer route of the main Lockyer Creek channel than would have been the case if the quarry had not been in place and water had broken out through location B and toward the railway line. The rising limb of water level hydrographs at locations in the town of Grantham (locations D, E and F) was delayed by 5 minutes due to the quarry and peak water levels were 0.09, 0.04 and 0.02 m lower than in the pre-quarry simulation at Charles Road and Gatton-Helidon Road intersection, William Street and Harris Street respectively. The hypothetical scenarios, without simulation of breach of the quarry embankment, show very similar results to the scenario with the breach but with marginally more attenuation of the rising limb and the peak of the flood in Grantham town.

The water velocity hydrographs shown in Figure 4–13 show a consistent analysis of the event to the flood level hydrographs at five selected locations. The quarry causes attenuation of the flood event, so that the hydrograph of velocities for the location B (breakout onto the right bank opposite the north eastern side of the quarry) and for the three locations in Grantham town (locations D, E and F) are attenuated and have slightly lower peaks than in the pre-quarry scenario.

Under all three scenarios and for all six locations shown in this section, the hydrographs of water level and depth are sufficiently high during this flood that conditions would be extremely dangerous for any person or animal at those locations. Velocities and depths are sufficiently large in all of the simulations that cars would be moved and buildings destroyed, which did indeed occur on 10 January 2011.



■ **Figure 4–12 Hydrographs of Simulated Flood Water Levels at Six Locations for the 10 January 2011 Flood Event**

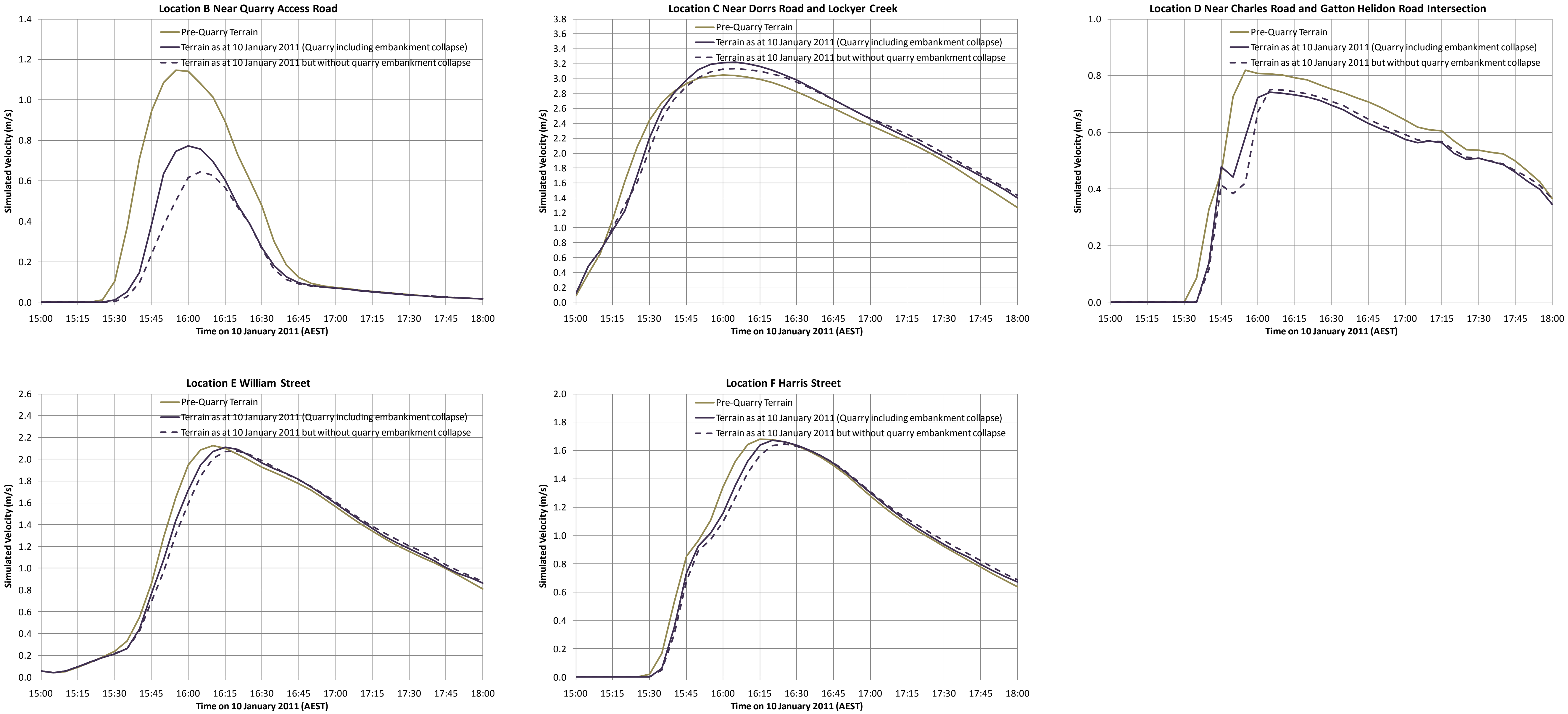


Figure 4–13 Hydrographs of Simulated Velocity at Five Locations for the 10 January 2011 Flood Event

5 Conclusions

Quarrying activities undertaken by Wagner Investments Pty Ltd affected flood levels in Grantham during the 10 January 2011 flood event. Modelling of the 10 January 2011 flood event using the hydraulic model TUFLOW showed that peak flood levels and velocities through the town area were consistently lower for the simulation with the quarry in place than using the pre-quarry terrain. The quarry mitigated the impact of flooding through the town area of Grantham, with peak flood levels reduced by between 0.04 m and 0.1 m. The quarry had no impact on peak flood velocities through Grantham, with the maximum simulated velocities different by less than 0.01 m/s across the Grantham town area between the pre-quarry simulation and the simulation with the quarry in place and breach of the quarry embankment.

The water level hydrograph at location B, which is in the breakout across the left bank of Lockyer Creek opposite the north eastern side of the quarry, shows that with the quarry in place flows were attenuated such that the rising limb is delayed by 10 minutes when compared to the pre-quarry terrain simulation. Water levels peak in both simulations at 4:00 pm but the peak with the quarry in place and embankment breach are 0.06 m lower than with the pre-quarry terrain.

Water levels in the town of Grantham were delayed by the presence of the quarry, which caused more of the flood water to travel along the longer route of the main Lockyer Creek channel than would have been the case if the quarry had not been in place and water had broken out through location B and toward the railway line. The rising limb of water level hydrographs at locations in the town of Grantham was delayed by 5 minutes due to the quarry.

The embankments along the western side of the quarry caused additional resistance to flows on the upstream (Western) side of the quarry pit. This caused an increased proportion of the flow to be forced through a breakout in the floodplain to the south of the quarry pit and reduced flows carried by the main channel from those simulated with the pre-quarry terrain. As a result, flow depths increased along Lockyer Creek and it’s floodplain from the Flagstone Creek Road crossing to the western side of the quarry pit. Depths and velocities were also increased over the pre-quarry simulation along the main channel of Lockyer Creek from the south eastern corner of the quarry to 200 m downstream of Charles Road.

The breach in the quarry embankment allowed a stream of faster flowing water to travel directly through the pit during the January 2011 flood event. The TUFLOW model simulated that the breach in the mound would have commenced at 3:10 pm, at the time when this part of the embankment between Lockyer Creek and the quarry pit was first overtopped, although there is insufficient credible evidence to independently verify the time at which the breach in the embankment would have occurred.

The results for the hypothetical scenario that no breach had occurred in the embankment are very similar to the results that include the breach in the embankment that actually occurred. If no breach had occurred in the embankment some of the flow that was directed through the breach and across the quarry pit would have diverted along the main channel of Lockyer Creek and through the breakout along the floodplain to the south of the quarry. The pattern of changes in flood levels through the town of Grantham and upstream of the quarry are very similar between the two January 2011 terrain scenarios, regardless of whether the embankment would have breached or not. The similarity in results between the two scenarios indicates that results for the town of Grantham are not sensitive to assumptions made about the timing of when the breach actually occurred.

The report has been prepared to analyse the impact of the 10 January 2011 flood event and only simulated hydrographs for this event have been produced. Flood behaviour in the area covered by this study may be different in a future specific flood event, particularly an event that is smaller or larger in the magnitude of the flood peak than that observed on 10 January 2011. No attempt was made in this report to speculate about flood behaviour for a theoretical design flood event with a particular annual exceedance probability.

6 References

Australian Government Bureau of Meteorology. (2011e). *Provision of Preliminary Meteorological and Hydrological Information: Background Briefing for the Queensland Floods Commission of Inquiry.* Submission to Commission of Inquiry.

BMT WBM. (2011). *TUFLOW Flood and Tide Simulation Software*. Retrieved September 12, 2011, from Build 2010-10-AD: http://www.tuflow.com/

Insurance Council of Austalia Hydrology Panel. (2011b). *Flooding in the Brisbane River Catchment, January 2011: Volume 4, Flooding in the Lockyer Valley Regional Council LGA.* Insurance Council of Australia.

Insurance Council of Australia Hydrology Panel. (2011a). *Flooding in the Brisbane River Catchment, January 2011: Volume 1: Overview.*

Lockyer Valley Regional Council. (2011). *Lockyer Creek Flood Risk Management Study*. Retrieved September 12, 2011, from Lockyer Valley Regional Council: http://www.lockyervalley.qld.gov.au/roads-stormwater/lockyer-creek-flood-risk-management-study

Queensland Department of Environment and Resource Management. (2010, August). Light Detection and Ranging Terrain Data for the Lockyer Valley. Brisbane.

Queensland Floods Commission of Inquiry. (2011). *Interim Report.* Brisbane.

Sinclair Knight Merz. (2011). *Hydrological Advice to Commission of Inquiry Regarding 2010/11 Queensland Floods, Toowoomba and Lockyer Valley Flash Flood Events of 10 and 11 January 2011*. Brisbane: Sinclair Knight Merz.

Wagner Investments Pty Ltd. (2011). *Submission to Queensland Floods Commission of Inquiry.*