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SWAMP/FISHERY CREEK FLOODPLAIN RISK MANAGEMENT STUDY

Issue 4

8 November 2013

rp02996-131106wjh_ja - Swamp-Fishery Creek FRMS.doc

Water Resources
Level 12, 141 Walker Street
North Sydney 2060 Australia
Tel: +61 2 8923 6812
Fax: +61 2 8923 6877
www.worleyparsons.com
WorleyParsons Services Pty Ltd
ABN 61 001 279 812

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Project: 301015-02996 - Swamp/Fishery Creek Floodplain Risk Management Study

REV	DESCRIPTION	AUTHOR	REVIEWER	WORLEY-PARSONS APPROVAL	DATE	CLIENT APPROVAL	DATE
0	Issued for Internal Review	JA / WJH JA / WH	WJH W Honour		11-04-2013		
1	Draft Report Issued for Client Review	JA / WJH JA / WH	WJH W Honour		20-05-2013		
2	Draft Report Issued for Exhibition	JA / WJH JA / WH	WJH W Honour		21-06-2013		
3	Revised Draft Report Issued for Exhibition	WJH W Honour	CRT C Thomas		31-07-2013		
4	Final Report	WJH W Honour	CRT C Thomas		8-11-2013		

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ACKNOWLEDGEMENTS

The following report was prepared by WorleyParsons Services Pty Ltd (*incorporating the former Patterson Britton & Partners*) on behalf of Cessnock City Council's Floodplain Risk Management Committee.

The Swamp/Fishery Creek Floodplain Risk Management Study (*FRMS*) has been funded jointly by Council and the Office of Environment and Heritage on a 1:2 subsidy basis, under the New South Wales Government's Floodplain Management Program.

It has been prepared by incorporating contributions from individuals from the local community and key stakeholders. Contributions from members of the Floodplain Risk Management Committee have been essential to the formation of management strategies that have been considered as part of the Study and are greatly appreciated.

The collegial manner in which input has been provided to the project from representatives of the NSW Office of Environment & Heritage (*formerly DECCW*) and Cessnock City Council has also been critical to its success.

FOREWORD

The State Government's Flood Policy is directed towards providing solutions to existing flooding problems in developed areas and ensuring that new development is compatible with the flood hazard and does not create additional flooding problems in other areas. Policy and practice are defined in the Government's Floodplain Development Manual (*2005*).

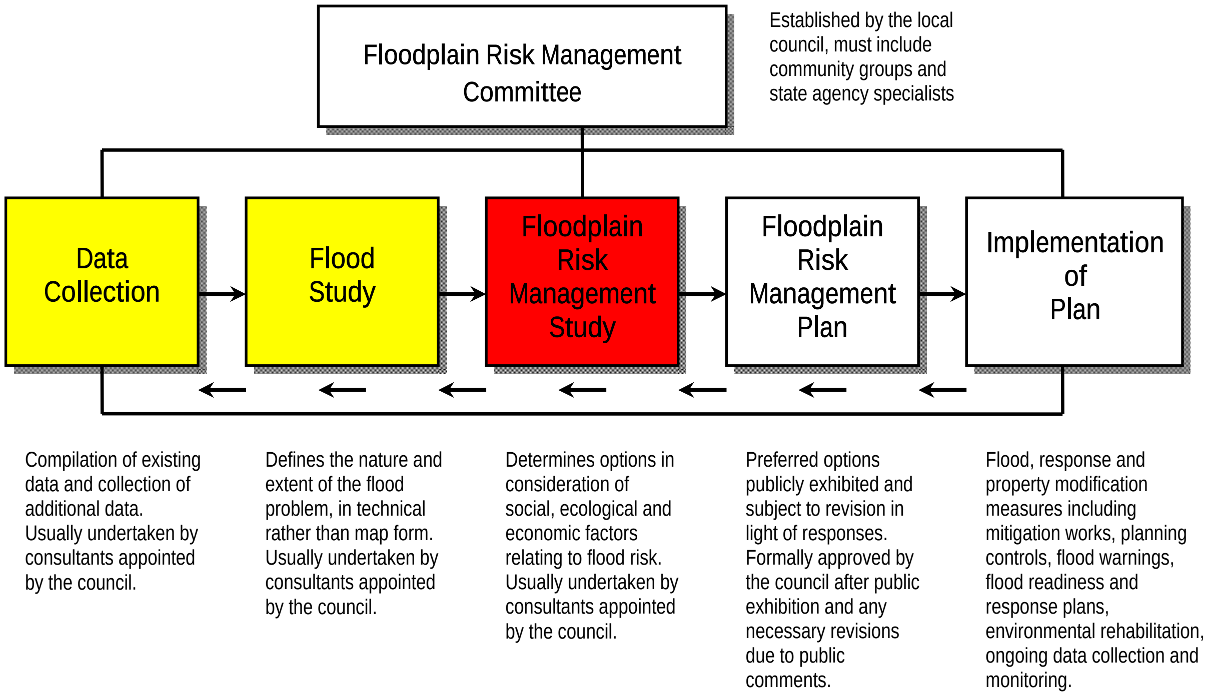
Under the Policy, the management of flood liable land remains the responsibility of Local Government. The State Government subsidises flood mitigation works to alleviate existing problems and provides specialist technical advice to assist Local Government in the discharge of their floodplain risk management responsibilities.

The Policy provides for technical and financial support by the State Government through the following four sequential stages:

Stages of Floodplain Risk Management

STAGE	DESCRIPTION
1. Flood Study	Determines the nature and extent of the flood problem.
2. Floodplain Risk Management Study	Evaluates management options for the floodplain in respect of both existing and proposed developments.
3. Floodplain Risk Management Plan	Involves formal adoption by Council of a plan of management for the floodplain.
4. Implementation of Plan	Results in construction of flood mitigation works to protect existing development and the application of environmental and planning controls to ensure that new development is compatible with the flood hazard.

A detailed description of the inter-relationship between these stages is provided overleaf. The link between the various outcomes of the studies involved in the floodplain risk management process and the implementation of measures (*both planning and structural*) to reduce flood damages is also shown.



Source: *'Floodplain Development Manual'(2005*)

1. INTRODUCTION

The Swamp/Fishery Creek and Wallis Creek catchments are situated inland from the central coast of New South Wales, about 30 kilometres due west of Newcastle. The two catchments lie adjacent to each other, with Fishery Creek flowing into Wallis Creek approximately seven kilometres upstream of the confluence of Wallis Creek and the Hunter River near Maitland (*refer* **Figure 1.1**).

Both catchments have a history of flooding, particularly in their lower reaches near Maitland. The lower reaches of both creeks are susceptible to flooding from the Hunter River, which can spill into adjoining floodplain areas during major events.

Although not generating the same runoff volume and peak discharges as the Hunter River, local catchment runoff can cause significant flooding in both the upper and central sections of Swamp Creek, including within the study area between Abermain and Loxford (*refer* **Figure 1.2**). Local catchment flooding of this nature can cause substantial damage to urban communities sited along the banks of the creeks, as was experienced by residents of Abermain and Weston during the February 1990 flood and more recently during the June 2007 event.

The focus of investigations for this Floodplain Risk Management Study has been local catchment flooding, as the study area upstream from Loxford is considered to be on the fringe of influence from Hunter River flooding.

The primary objective of the floodplain risk management process is for Council to formulate a Floodplain Risk Management Plan for the study area.

The Plan is to be based on a range of strategies and mitigation measures that address the existing, future and continuing flood problems, in accordance with the NSW Government's *Flood Prone Land Policy*. The primary objective of the Government's *Flood Prone Land Policy* is to reduce the impact of flooding on individual owners and occupiers of flood prone land, and to reduce private and public losses caused by flooding. In this regard, the Policy recognises:

- that flood prone land is a valuable resource that should not be sterilised by unnecessarily precluding its development; and,
- that if all applications for development on flood prone land are assessed according to rigid and prescriptive criteria, some proposals may be unjustifiably disallowed or restricted, and equally, quite inappropriate proposals could be approved (NSW Government, 2005).

Accordingly, it is appropriate, under the NSW Government's *Floodplain Management Program*, to consider options for reducing the flood damages that could be experienced by residents along Swamp Creek and to reduce the risk for loss of life. These options will provide appropriate solutions to mitigate the existing, future and continuing flood risk.

The associated assessment first involves consideration of the flood damages that residents and the broader community may experience as a consequence of the existing flood problem. These damages are a measure of the cost of flooding under existing conditions. As outlined above, the NSW Government's *Floodplain Management Program* is targeted toward determining measures that can be cost effectively implemented to reduce existing flood damages.

Typically, the community is engaged to comment on a range of potential flood damage reduction measures (*structural measures*) and potential planning controls (*non-structural measures*) that could reduce the impact of floods. These are tested to establish their relative benefit, which is usually measured in terms of the potential reduction in flood damages, or the potential for additional future development that can occur at no increased risk to the community. The measures are also costed and their respective costs compared to their net benefit, thereby allowing a benefit-cost ratio to be determined for each measure.

Measures with a high benefit-cost ratio are typically recommended for inclusion within a Floodplain Risk Management Plan, which is the fourth phase in the floodplain management process (*refer to flow chart in Foreword*).

Therefore, this Floodplain Risk Management Study sets out to:

- identify and evaluate management options for the floodplain in terms of their capacity to reduce existing and potential future flooding problems;
- provide information on flood behaviour and flood hazard, so that community aspirations for future land use can be assessed on a consistent basis;
- provide recommendations for emergency response management during local catchment flooding; and,
- provide a framework for revisions to planning instruments such as Local Environmental Plans (*LEPs*), so that land use controls are consistent with flood risk and flood hazard.

2. BACKGROUND

Maitland is protected from Hunter River flooding by the Lower Hunter Flood Mitigation Scheme which was constructed between 1956 and 1975. The flood mitigation scheme comprises levees, floodgates and storage areas, and has significantly altered riparian flow and flood behaviour around Maitland. The Scheme was constructed to reduce the frequency of flooding in and around Maitland.

Low lying land to the north of Maitland, such as around Louth Park and Wentworth and Dagworth Swamps, is used as a flood storage area, thereby attenuating peak flows in the Hunter River at Maitland. Hence, large areas of the Wallis and Fishery Creeks floodplains, particularly downstream of Dagworth Swamp on Wallis Creek, and downstream of Black Waterholes Creek on Fishery Creek, can be inundated during major Hunter River floods. As a result, absolute peak flood levels for the lower Wallis and Fishery Creeks systems are controlled by flood levels in the Hunter River near Maitland.

Further upstream, flooding occurs as local catchment response to high intensity short duration rainfall over the steep sided upper catchments of both tributaries.

In addition to flooding, there is concern that land degradation and inappropriate land-use practices are threatening the ecological and agricultural sustainability of the catchments. The exclusion of tidal flows by the Wallis Creek floodgates, located about 100 metres upstream from the Hunter River, combined with years of cumulative impacts of settlement and development, has resulted in environmental changes, many of which are not sustainable or acceptable in the long term.

In recognition of these changes and the potential for urban expansion and rural subdivision, a Total Catchment Management Committee was established under the auspices of the then Hunter Catchment Management Trust (*now the Central Rivers Catchment Management Board*). The aim of the TCM Committee was to chart a course towards a sustainable future for the Wallis and Swamp / Fishery Creek catchments.

The Committee, which had the support of Cessnock and Maitland City Councils, Landcare groups, local industry and the community, developed a Total Catchment Management Strategy for the Wallis and Fishery Creeks Catchments. The TCM Strategy was published in November 2000. It is understood that the Central Rivers CMA has been implementing recommended strategies since that date.

The TCM Strategy was underpinned by a number of Task Group Reports that addressed catchment characteristics that could be influenced by future development, or could in fact, influence development. These included:

- a Water Quality Task Group Report;
- an Ecology Task Group Report;

- a Planning Task Group Report; and,
- a Flood Study.

The flood study was prepared as part of supporting investigations for the *'Wallis and Swamp/Fishery Creeks Total Catchment Management Strategy'* (*November 2000*). It was based on the results of 1-Dimensional computer modelling of flood behaviour that was undertaken in the late 1990s. The 1-Dimensional flood model was developed from a combination of surveyed cross-sections of the floodplains and channels of Swamp/Fishery and Wallis Creeks. The results of that investigation established that measures to reduce urban and rural flood damages in the catchment needed to be an important outcome of the TCM Study process.

2.1 INVESTIGATIONS BY WORLEYPARSONS TO-DATE

Cessnock City Council subsequently engaged Patterson Britton & Partners (*now a part of WorleyParsons*) to extend the work undertaken for the original Flood Study and to update the report to ensure that it is consistent with the procedures that are typically employed in the preparation of flood studies undertaken under the State Government funded Floodplain Management Program.

Accordingly, Patterson Britton & Partners prepared an updated version of the Flood Study that incorporated additional investigations carried out for Cessnock City Council between 2004 and 2006. The primary objective for updating the Flood Study was to define flood characteristics along Wallis and Swamp Creeks, thereby providing Council with information on which building controls could be based. An updated version of the Wallis and Swamp/Fishery Creeks Flood Study was issued as a Final Draft in August 2006 (*Issue No.4, August 2006*).

In June 2007, the Central Coast of NSW experienced an East-Coast Low which generated high intensity rainfall across the lower Hunter Valley. This rainfall led to major flooding in coastal catchments including the Wallis and Swamp Creeks catchments. In recognition of the significance of the event and the damage that it caused, Cessnock City Council collected a range of flood data and requested that this be used to calibrate the flood model that had been developed for the Final Draft Flood Study.

Since that time, further investigations have been completed to expand upon the original 1-Dimensional HEC-RAS flood modelling to incorporate 2-Dimensional RMA-2 modelling for Wallis Creek and across the lower reaches of Fishery Creek. The results of this modelling were documented by WorleyParsons in the *Wallis and Swamp/Fishery Creeks Flood Study (2011)*, and associated reports outlined in the following.

2.1.1 Wallis and Swamp/Fishery Creeks Flood Study, WorleyParsons (2011)

The HEC-RAS and RMA-2 flood models were calibrated to the recorded data for the June 2007 event. Both flood models showed a good agreement with the majority of recorded flood marks.

The calibrated models were used to predict design flooding conditions for the 20%, 5%, 2% and 1% AEP events, as well as for the Probable Maximum Flood (*PMF*). Peak flood level, depth and velocity and flood extent mapping for each of these design events is documented in the Flood Study report.

The results of a climate change scenario were also documented in the Flood Study, which reflected a 10% increase in rainfall intensity across the study area. Given the distance of the study area from the coast, sea level rise impacts were negligible and therefore not considered.

2.1.2 Hunter Expressway Bridge Crossing of Wallis and Surveyors Creeks; Flood Impact Assessment, WorleyParsons (2010)

The impact of the proposed expressway crossing of Wallis Creek and Surveyors Creek on flood characteristics was investigated using hydrologic and hydraulic modelling based on the modelling for the Flood Study.

This investigation involved the application of localised survey data for Wallis Creek and Surveyors Creek that was supplied by the Hunter Expressway Alliance (*HEA*).

2.1.3 Abermain / Weston Floodplain Risk Management Study; Preliminary Options Assessment, WorleyParsons (2011)

Community consultation undertaken as part of previous investigations to complete the 2011 Flood Study identified the need to undertake an initial assessment of flood mitigation options involving clearing the creek channel of vegetation, concrete lining the channel, and excavation of the channel bed to provide additional conveyance capacity. The raising of the spillway at Hebburn Colliery Reservoir was also investigation for its potential to provide detention during a flood.

The preliminary assessment was undertaken using the HEC-RAS 1-Dimensional flood model for Swamp Creek and showed that notable flood level reductions could be achieved via particular options to clear the channel and excavate the bed. However, it was also identified that the most effective options (*i.e., channel excavation*) would likely involve significant construction costs. The Hebburn Reservoir option was shown to be ineffective in reducing downstream flows in Swamp Creek, which was due to the relative timing of peak flows from the upper catchment.

The report was publicly exhibited and a total of 10 completed questionnaires were returned by residents, in addition to a detailed submission. Several questionnaire responses were supportive of options to excavate the channel bed, and to also clear the channel of vegetation.

The submission that was received included further suggestions on the use of the Hebburn Reservoir for detention, and also identified the need to consider the existing detention measures incorporated within the recent Hunter Economic Zone site. The report and the submissions were both considered in the preparation of the Floodplain Risk Management Study.

2.2 PREVIOUS SWAMP CREEK INVESTIGATIONS

2.2.1 Swamp Creek Flood Study, Public Works Department (1992)

The '*Swamp Creek Flood Study*' (*1992*) provided estimates of peak flood levels and mean velocities along Swamp Creek from about 800 metres upstream of the William Street road bridge at Abermain, to Norton Road, Loxford. The study was based on a hydrologic model of the catchment upstream of Loxford and a linked hydraulic model extending as a single branch along the main channel of Swamp Creek between Abermain and Loxford.

The RAFTS rainfall-runoff flood routing software package was used to develop the hydrologic model for the catchment. The US Army Corps HEC–2 software package was used to develop a hydraulic model of the floodway between Abermain and Loxford. Peak discharges generated by the RAFTS model were used as boundary conditions for the HEC-2 hydraulic model. Design flood profiles were generated for the floodway for the design 1%, 2%, 5% and 10% AEP (*Annual Exceedance Probability*) events, as well as for an extreme flood.

In all, flood levels were predicted at 53 locations along the main channel corresponding to the locations of channel cross-sections that were surveyed for the study. No discussion of the results or the potential implications of the predicted flooding was made in the study report.

Although this 1992 study provides predicted peak floodwater levels for a substantial length of Swamp Creek, it should be recognised that the modelling was undertaken using the HEC-2 software, which applies steady state hydraulic theory, rather than the unsteady flow equations that are now favoured in hydraulic modelling.

2.2.2 Deep Creek Flood Study, Lawson & Treloar (2002)

The Deep Creek Flood Study included the assessment of flood characteristics along Deep Creek and South Deep Creek, tributaries of Swamp Creek that discharge to the creek approximately 1200 and 500 metres downstream from the Cessnock Road Bridge at Abermain, respectively.

The assessment involved XP-RAFTS hydrologic modelling of the local catchments and 1-Dimensional hydraulic modelling using MIKE-11 software.

2.3 HUNTER RIVER FLOOD INVESTIGATIONS

The following studies have been undertaken over the past 30 years in order to determine flood characteristics along the Hunter River in the vicinity of the confluence with Wallis Creek, which affect the hydraulic characteristics of Swamp/Fishery Creek:

- Lower Hunter River Flood Study (*Green Rocks to Newcastle*), Public Works Department (1994)
- Lower Hunter Valley Floodplain Management Study, Patterson Britton and Partners (1996)
- Lower Hunter Valley Floodplain Management Study, Webb, McKeown and Associates (1996)
- Maitland Flood Study, Webb, McKeown and Associates (1998)

Additional Hunter River studies and relevant information are outlined in the following sections.

2.3.1 Lower Hunter River Flood Study (Oakhampton to Green Rocks), Public Works Department (1996)

The *'Lower Hunter Valley (Oakhampton to Green Rocks) Flood Study'* (*1998*), covers the Lower Hunter floodplain and its tributaries between Oakhampton and Green Rocks (*downstream of Hinton*). This area also included floodplains that are considered the lower reaches of Wallis Creek, upstream from its junction with the Hunter at the Wallis Creek Floodgates.

The flood study used the MIKE-11 hydraulic modelling software package to generate design flood water surface profiles and mean velocities for a range of flood events. The primary objective of the study was to simulate flood behaviour in the Hunter River and across its floodplain for flood events generated by rainfall in the upper Hunter catchment. The lower reaches of Wallis and Fishery Creeks were included in the model to provide a definition of flood levels and velocities within the Louth Park and Dagworth Swamp areas, which act as backwater storages when floodwaters from the Hunter overtop the levee system upstream of Maitland.

The hydraulic model extends along Wallis Creek upstream from its confluence with the Hunter River to Dagworth Bridge, and along Fishery Creek upstream from its confluence with Wallis Creek to just downstream of Wentworth Swamps. Flood levels generated from the modelling are summarised in **Table 1.1**.

Table 1.1 PREDICTED PEAK FLOOD LEVELS FOR HUNTER RIVER FLOODS

LOCATION	1% AEP FLOOD (m AHD)	2% AEP FLOOD (m AHD)	5% AEP FLOOD (m AHD)
Wallis Creek Floodgates	10.0	9.6	9.4
Victoria Bridge	10.2	9.3	7.5
Long Bridge	10.4	9.3	8.0
Dagworth Bridge	10.3	9.3	7.5

Source: 'Lower Hunter Flood Study (Oakhampton to Green Rocks) – Supplementary Flood Study' (1998)

Although local catchment flooding (*i.e., flooding due to rainfall across the Wallis and Swamp/Fishery Creeks catchments only*) can be significant, the delineation of flood affected land in the lower sections of Wallis and Fishery Creeks is controlled by flooding from the Hunter River.

2.3.2 Hunter River Braxton to Green Rocks Flood Study, WMAWater (2010)

WMAWater was commissioned by Maitland City Council to undertake a flood study of the Lower Hunter River between Braxton and Green Rocks. The study area included the lower reaches of Swamp Creek and Wallis Creek.

TUFLOW modelling software was used to undertake hydraulic modelling for this study, while WBNM software was used for hydrologic modelling. Modern modelling techniques, as well as the most recent data, have been used in this study and therefore, it can be considered a reliable analysis of Hunter River flooding and associated tailwater levels that affect flooding along Swamp Creek and Wallis Creek.

The peak flood levels presented in **Table 1.2** have been extracted from tabulated data and flood mapping contained in the Flood Study.

Table 1.2 PREDICTED PEAK FLOOD LEVELS FOR HUNTER RIVER

LOCATION	DESIGN FLOOD LEVEL (m AHD)				
	0.5% AEP	1% AEP	2% AEP	5% AEP	10% AEP
Belmore Bridge (*Hunter River*)	11.9	11.7	11.5	11.1	10.6
Wallis Creek Floodgates	10.6	10.1	9.9	9.8	9.5
Victoria Bridge	10.7	9.7	7.7	-	-
Long Bridge	12.1	11.5	10.1	8.4	-
Dagworth Bridge	10.8	9.7	8.5	7.6	~ 4 (in Fishery Creek)

Source: 'Hunter River: Branxton to Green Rocks Flood Study' (2010)

The design flood mapping from the Study indicates the following:

- Mapping for the 0.5%, 1%, 2% and 5% AEP events shows there is significant discharge from the Hunter River down the Oakhampton Floodway, which passes to the west of Maitland.
- Significant ponding and storage occurs in the Wentworth and Dagworth Swamp areas to the south of Maitland due to this flow down the Floodway, and also potentially due to overtopping of the Wallis Creek floodgates in larger events (*i.e., the 0.5% AEP event*).
- In comparing the 5% and 10% AEP maps, it is obvious that in the 10% AEP flood the Oakhampton Floodway does not discharge to the Wentworth and Dagworth Swamp areas. There is some ponding across the area, but the associated flood level of about 4 mAHD is much lower than flooding in the Hunter River, which shows the Wallis Creek floodgates are effectively holding back the water from the Hunter River. It is understoond the ponding is the result of local runoff in the flood model.

It is noted from comparison of the levels contained in **Table 1.1** and **1.2** that the 2010 Flood Study predicted lower 1% AEP levels at Victoria Bridge and Dagworth Bridge. WMAWater attribute these differences to the different modelling approach (*i.e., 2-Dimensional versus 1-Dimensional hydraulic modelling*), and also the use of higher quality survey data (*e.g., LiDAR terrain data*).

3. THE FLOODING PROBLEM

The contemporary flooding problem in the Swamp/Fishery Creek floodplain can be broken up into three major components, namely:

- the existing flooding problem;
- the potential future flooding problem; and,
- the residual, or continuing flooding problem.

Measures to address these components are complicated by the social consequences of removing people from flood affected areas and the political and economic attractiveness of the floodplain lands due to their accessibility to existing infrastructure and their lower cost per hectare. Each component of the flooding problem is discussed in the following sections.

3.1 EXISTING FLOODING PROBLEM

The existing flooding problem relates to those areas where flood damages are likely to arise as a consequence of flooding. It concerns existing dwellings, industrial complexes and commercial premises that would be inundated during a flood, as well as all associated infrastructure within the floodplain, including roads, railways and utility services. In this context, the existing flooding problem is usually addressed by structural measures which aim to modify flood behaviour and thereby reduce flood damages.

A detailed review of the existing flooding problem is given in **Sections 4** and **5** of this report.

The development and assessment of options for mitigating the impact of flooding are outlined in **Section 9**.

3.2 FUTURE FLOODING PROBLEM

The potential *future* flooding problem refers to those areas of the floodplain that are likely to be proposed for future development or to be the subject of rezoning applications.

As land resources for development become increasingly scarce, pressures mount to allow development within floodplain areas where it might otherwise be avoided. The future flooding problem has potential to cause large scale flood damages in the Swamp Creek Floodplain and presents a potential risk to loss of life.

Council has a duty of care to ensure that its current planning instruments recognise the potential flood risk. Council also has a responsibility to ensure that a Floodplain Management Plan is in place and that this Plan, or an associated *Flood Policy*, can be used to support decisions to approve or reject development proposals on flood affected sections of the LGA.

The role of planning controls to manage the future problem is covered in **Section 11** of this report.

3.3 RESIDUAL FLOODING PROBLEM

Unless the Probable Maximum Flood (*PMF*) is adopted as the basis for determining structural and planning measures aimed at reducing flood damages, there will always be a residual or continuing flooding problem.

However, the adoption of the PMF as the 'planning flood' is not realistic or practical because it would sterilise a large area of land, thereby forcing development to areas of higher ground which may not historically be serviced or which could introduce unrealistically high infrastructure costs.

Hence, a lesser flood standard is adopted. Most Councils in NSW, including Cessnock City Council, have adopted the 100 year recurrence flood (*1% Annual Exceedence Probability*) level plus a freeboard of 0.5 m as the flood planning level. As a result, measures that are put in place to control flood damage will ultimately be overwhelmed by a flood that is larger than that adopted as the threshold for the planning control of land use, or as the limiting flood for the design of structural measures.

Accordingly, it is incumbent upon Council to consider the implications of floods greater than the adopted planning flood and to work with the State Emergency Service (*SES*) to develop a contingency plan for such events. Emergency response management is covered in **Section 10** of this report.

4. FLOOD MODELLING UPDATE

As discussed above, flood modelling for Swamp/Fishery Creek was undertaken as part of the *Wallis and Swamp/Fishery Creeks Flood Study* (*WorleyParsons, 2011*). It was completed using a combination of one and two dimensional flood modelling software. The extent of the area to which each model was applied was dependent on the availability of topographic data, whereby data limitations precluded the adoption of the more detailed two-dimensional modelling approach over the entire Wallis and Swamp/Fishery Creeks study area.

As an outcome of these data limitations, the HEC-RAS software (a *one-dimensional hydraulic modelling tool*) was adopted for flood modelling along Swamp/Fishery Creek in the vicinity of Abermain and Weston.

The section of Swamp/Fishery Creek downstream of Weston and sections of Wallis Creek up to Buchanan were modelled using RMA-2 software (a *two-dimensional hydraulic modelling tool*). Detailed LiDAR topographic survey was available for these extents of the study area and as such the development of a 2-Dimensional model was preferred. Figure 11 of the Flood Study (2011) shows the layout and extents of the HEC-RAS and RMA-2 models.

As part of initial work for the Swamp/Fishery Creek Floodplain Risk Management Study (*FRMS*), WorleyParsons was commissioned by Council to upgrade the existing HEC-RAS model in the vicinity of Abermain and Weston to a 2-Dimensional RMA-2 model using recently collected LiDAR survey data.

The modelling upgrade was to effectively comprise an extension of the existing RMA-2 model for lower Swamp/Fishery to also include sections upstream to Abermain. The upgrade would provide a more robust modelling base upon which to assess flood mitigation options as part of this study.

The following provides a summary of the investigation to extend the RMA-2 model, including details of the input data used, adopted boundary conditions and adopted model parameters. Update of the XP-RAFTS hydrologic model for the catchment was also required as part of the investigations.

4.1 DATA COLLECTION AND REVIEW

A range of existing data, such as the bathymetry of the creek and survey details of hydraulic structures, was readily available from the previous HEC-RAS flood modelling for incorporation into the RMA-2 model extension. As documented in the 2011 Flood Study, the HEC-RAS model was based on a total of 53 surveyed cross-sections along Swamp/Fishery Creek, as well as detailed survey of all bridge structures along Fishery Creek in the vicinity of Abermain and Weston; i.e., from the William Street Bridge in Abermain to the Government Road Bridge in Weston. The creek bathymetry and bridge details were used where possible in the development of the upgraded RMA-2 flood model.

The location and extent of the HEC-RAS cross-sections are shown in **Figure 4.1**. Topographic data of the floodplain in the vicinity of Abermain and Weston was previously limited to 2 metre and 10 metre surface contours, which is why a 2-Dimensional modelling approach had not been adopted until now. Although LiDAR data was made available by Maitland City Council for use in the Flood Study, the data was limited to Maitland City Council's LGA and as such did not extend as far upstream as Weston (*refer* **Figure 4.1**).

4.1.1 LiDAR Topographic Data

Additional LiDAR topographic data was acquired and provided to Council by Land and Property Information NSW (*LPI*). The LiDAR data was collected on 17th February 2012, via an aircraft flying at 2,000 metres above ground level. The typical vertical accuracy of the LiDAR is reported as +/- 0.3 metres.

The extent of the LiDAR data relative to the extent of the RMA-2 model extension is shown in **Figure 4.2**.

As shown, the recently acquired LiDAR data covers the floodplain areas within the FRMS study area and the extent of the upgraded RMA-2 model. The northern extent of the LiDAR data matches the southern limit of the LiDAR that was made available by Maitland City Council (*refer* **Figure 4.1**).

Although the LiDAR data was used primarily for the purpose of extending the RMA-2 flood model, the data also assisted with updates to the hydrologic modelling of the catchments draining to the study area. The updates included the refinement of catchment boundaries/sizes and the calculation of lag times and catchment slopes for some sub-catchments.

4.1.2 Hunter Economic Zone Detention Basins

Various plans, drawings and reports were received from Council detailing the civil and stormwater works for the Hunter Economic Zone (*HEZ*), located upstream from the Hebburn Dam which is on the southern side of Swamp Creek between Abermain and Weston. Of particular interest were the construction plans for the three stormwater detentions basis included in the HEZ plan.

However, on-site inspections revealed notable differences between the on-ground arrangement of these detention basins (*and their outlet structures*) and the layout shown in design drawings. As such, the configuration of these structures was principally defined on the basis of the layout observed at site and associated photographs provided by Council.

A Water Cycle Management Srategy has also been developed as part of the Hunter Economic Zone (HEZ) development. This plan is being implemented as the development progresses. At present, three basins have been constructed, along with numerous culverts and other stormwater infrastructure.

The intention of these basins is to maintain a similar hydrologic regime to the existing site whilst allowing the development of the catchment (*Parsons Brinckerhoff, 2004*). To achieve this objective the stormwater detention basins have been designed to ensure that the peak flows during major storms, with an Average Recurrence Interval (*ARI*) of between 10 and 100 years, do not increase above present levels. It is also a requirement of the development that flow rates from the HEZ site are not to be significantly increased during smaller rainfall events, with an ARI between 1 and 10 years.

4.2 HYDROLOGIC MODELLING

Updates to the existing XP-RAFTS hydrologic model of the Swamp Creek catchment were made in order to facilitate the extension of the RMA-2 flood model. Revisions were also made to reflect current catchment conditions, including the construction of the stormwater detention basins as part of the Hunter Economic Zone development.

The revised layout of the XP-RAFTS model in the vicinity of Abermain and Weston is shown in **Figure 4.3**. Sub-catchments that were updated as part of the FRMS are indicated on the figure (*refer yellow shaded sub-catchments*).

The HEZ basins were modelled through the inclusion of three additional sub-catchments each using the '*retarding basin*' option available in XP-RAFTS. This allowed the storage volume of each basin to be taken into consideration during the simulation of runoff-routing processes for the study area. These additional catchments were set-up to drain to Hebburn Dam prior to discharge into Swamp Creek (*refer* **Figure 4.3**).

The XP-RAFTS model was also updated to incorporate additional sub-catchment detail for Deep Creek and South Deep Creek, which are tributaries of Swamp Creek that enter at Abermain.

Further refinements were made to the XP-RAFTS model upstream of Abermain, as well as in the vicinity of Weston, in order to capture the runoff-routing behaviour more reliably. Re-calculation of catchment slopes and lag times was undertaken where sub-catchment boundaries were refined.

Despite the updates to individual sub-catchments, the overall catchment area draining to the study area has remained unchanged. This reflects the localised nature of the updates, which were focused on refining sub-catchment layouts and linkages.

Catchment properties were retained between the original catchment and the system of smaller sub-catchments. The exception to this was the proportion of impervious surfaces, which was apportioned between sub-catchments to best represent the makeup of the sub-catchments. The total pervious and impervious area was in most cases consistent between original catchment and the system of smaller sub-catchments.

As shown in **Figure 4.3**, some additional refinement was made to the sub-catchment layout upstream of Abermain and at Kurri Kurri. The previous sub-catchment definition in these areas was relatively coarse. To improve the routing calculations and linkage with the extended RMA-2 flood model, these sub-catchments were further divided into smaller sub-catchments.

The additional sub-catchment refinements allowed greater discretisation of where local catchment inflows could be input into the RMA-2 model. This allowed for a more reliable consideration of local catchment inflows compared to the previous HEC-RAS model.

4.3 RMA-2 MODEL EXTENSION

The model network for the extended RMA-2 model is shown in **Figure 4.4**. The figure inset shows the model extension relative to the wider Wallis and Swamp/Fishery Creek flood model.

As shown, the RMA-2 extension was configured to incorporate Hebburn Dam, Deep Creek and South Deep Creek. These waterways had not previously been modelled as part of the HEC-RAS Flood Study model.

4.3.1 Model Geometry

The elevations for the majority of model nodes were assigned based on the recently acquired LiDAR topographic data. The exceptions to this included nodes defining the Swamp/Fishery Creek channel as well as nodes defining road crest elevations and bridge structures. Comparison of channel bed elevations as defined by the LiDAR data with the HEC-RAS cross-sections indicated differences of up to 0.5 metres (*bed elevations defined by LiDAR were up to 0.5 metres higher*). This was largely expected because the LiDAR typically captures the low-flow water surface in the creek and cannot penetrate beneath this. The dense vegetation lining parts of the Swamp/Fishery Creek channel can also impact on LiDAR accuracy. Accordingly, adoption of the HEC-RAS elevations (*as surveyed*) was considered appropriate to define the in-channel bed elevations.

A sample comparison between HEC-RAS cross-sections and sections from the LiDAR data was carried out and is shown in **Appendix A** (*refer* **Figure A1**) for a location approximately 1 km upstream of the Kline Street Bridge. It was shown that creek widths and depths are similar between the surveyed HEC-RAS cross-section and the cross-section taken from the LiDAR. However, there is considerable variability between the LiDAR section and another LiDAR section taken 100 metres further upstream (*refer* **Figure A1**). The narrower of the two cross-sections shows a considerable reduction in the available flow area, which demonstrates that the creek channel is not uniformly shaped. In light of the HEC-RAS cross-section spacing of between 100 and 150 metres, it is considered that the HEC-RAS model reproduced only an approximation of the channel geometry along the creek.

The LiDAR terrain data, and hence RMA-2 model, provides a higher-resolution representation of the creek channel that incorporates these variations in the channel geometry, which is likely to impact on flood characteristics.

Checks were also carried out comparing cross-sections collected as part of the *Deep Creek Flood Study* (*2002*) with cross-sections from the LiDAR terrain data. This comparison is shown in **Appendix A** (*refer* **Figure A2**). Creek channel widths and depths are similar between the LiDAR terrain and the surveyed cross-section, although the LiDAR data does show a slightly reduced channel area. Similar to Swamp Creek, the LiDAR data showed considerable variability along the length of the channel, while the cross-sections surveyed for the 2002 Study are relatively coarse and do not capture this variation. Again the RMA-2 data gives a higher resolution representation of the creek channels.

Hebburn Dam was incorporated into the hydrodynamic model to capture the flood storage that it represents during very large floods, as well as to facilitate the preparation of reliable flood hazard mapping at this area. The elevation around the perimeter of the dam was calculated using the LiDAR data. Due to the difficulties LiDAR has with measuring elevations below water surfaces, bathymetry inside the dam was assumed to have a maximum elevation of 17 mAHD.

4.3.2 Channel and Floodplain Roughness Parameters

The roughness parameters adopted in the previous HEC-RAS model were adopted as an initial estimate of channel and floodplain roughness values for the RMA-2 model extension. The distribution of roughness was determined based on field observations of channel and floodplain vegetation density and also from available aerial photography. The greater network detail in the RMA-2 model allowed far greater discretisation of channel and floodplain roughness' than was possible using HEC-RAS.

Once the initial estimates of roughness values had been assigned, an iterative approach was used to progressively adjust the roughness values within acceptable guidelines. This was done in order to achieve a better fit between the flood level profile predicted using the updated RMA-2 model and the recorded flood marks from the June 2007 flood event. The adopted roughness parameters for each of the adopted RMA-2 element types are listed in **Table 4.1**.

Incorporated into the table is a comparison with the roughness parameters adopted in the original RMA-2 model for Wallis Creek. The values for Wallis Creek have limited appropriateness for floodplain areas along Swamp/Fishery Creek. This is particularly the case based on the higher density of creek vegetation and floodplain development in the vicinity of Abermain and Weston.

Table 4.1 ADOPTED RMA-2 ROUGHNESS VALUES

	ELEMENT TYPE	DESCRIPTION	MANNING'S COEFFICIENT
Element Types and Roughness Values Adopted for Wallis Creek	1	Open Channel	0.025
	2	Vegetated creek channel	0.032
	3	Swampy/Marshy Areas	0.040
	4	Floodplain with Trees	0.080
	5	Floodplain with Grass	0.040
	6	Floodplain with Crops	0.045
	7	Floodplain with urban development	0.030
	8	Bridges (with under deck flow) / Culverts	0.080
	9	Top of embankment / Roads (to control flow)	0.150
	10	Batter	0.060
Element Types and Roughness Values Adopted for Swamp/Fishery Creek	11	Roads (clear, acting as flow paths)	0.025
	12	Dense Trees (flow through branches)	0.090
	13	Light trees (largely clear flow paths)	0.040
	14	Urban development (moderate obstruction)	0.070
	15	Swamp/Fishery Creek (dense vegetation)	0.075
	16	Swamp/Fishery Creek (moderate vegetation)	0.055
	17	Swamp/Fishery Creek (low vegetation)	0.035
	18	Urban development (dense obstruction)	0.120
	19	Building (significant obstruction / only storage)	0.150

4.3.3 Downstream Boundary Conditions

The downstream boundary condition in the RMA-2 model was established as part of work for the 2011 Flood Study. The model network extends as far north as the Main Northern Railway at the Oakhampton Floodway, and the New England Highway to the east at Wallis Creek. The boundary condition has been established as a constant water level to reflect a nominated frequency of flooding for the Hunter River.

4.4 CALIBRATION OF XP-RAFTS HYDROLOGIC MODEL

Calibration of the updated XP-RAFTS hydrologic model and updated RMA-2 hydraulic model was undertaken to ensure the models were producing reliable results. The calibration process was similar to that adopted for the 2011 Flood Study, where calibration was undertaken to the recorded flood marks from the June 2007 historic flood.

As only minor changes were made to the XP-RAFTS model, the model was considered to be similar in structure to the previously calibrated model. No new catchments were introduced to the model, but rather the existing catchments for Deep Creek, South Deep Creek and those in the vicinity of Abermain, Weston and Kurri Kurri were divided into smaller sub-catchments (*refer catchments shaded yellow in* **Figure 4.3**). In that regard, the overall catchment area draining to Swamp/Fishery Creek remained unchanged.

No streamflow records exist along Swamp Creek in the vicinity of Abermain and Weston and so calibration of the XP-RAFTS model was only undertaken insofar as providing suitable inflow hydrographs for the RMA-2 model to calibrate against available flood marks. Aside from the very upstream boundary of the RMA-2 model, the inflows to the model are based on local catchment flows, which are essentially independent of the cumulative flow along the main creek channel.

However, in an attempt to validate the updated XP-RAFTS model, the cumulative flows for the both the June 2007 historic event and the design 100 year recurrence flood were compared between the original model and the updated FRMS model at various locations through the study area. The flows extracted from each of these models is summarised in **Table 4.2** and **Table 4.3**, respectively.

As shown in **Table 4.2** the updated XP-RAFTS model generates peak flows for the June 2007 event that are up to 27% greater than those documented in the Flood Study. This greatest difference occurs at XP-RAFTS model node f1.10 downstream of Weston, and appears to be the outcome of a gradually increasing difference in flows starting upstream of Abermain.

As shown in **Figure 4.3**, significant refinement of the XP-RAFTS sub-catchments was undertaken upstream of Abermain to ensure better functionality with the updated RMA-2 model. As an example, the XP-RAFTS catchments f1.05c, f1.05b, f1.05a and f1.05 were originally modelled as a single catchment in the Flood Study model. The refinement of the catchment into four smaller catchments has allowed greater discretisation in the adopted values of catchment slope and pervious and impervious roughness values. This factor, in combination with the increased representation of channelised routing between catchments, has an impact on the relative timing of peak flows from each local sub-catchment and is considered attributable to the increase in peak flows along the creek.

Table 4.2 FLOW COMPARISON FOR THE JUNE 2007 CALIBRATION EVENT

LOCATION	XP-RAFTS MODEL NODE	PEAK FLOW (m^3/s) ORIGINAL MODEL	PEAK FLOW (m^3/s) UPDATED MODEL	PERCENTAGE DIFFERENCE (%)
Upstream extent of RMA-2 model (*boundary inflow location*)	f1.04	194	194	0.0
Upstream of Abermain (*William St*)	f1.05	270	256	- 5.2
Downstream of Abermain	f1.07	328	342	+ 4.3
Upstream of Weston (*Kline St*)	f1.09	356	403	+ 13.2
Downstream of Weston	f1.10	361	458	+ 26.9
Hunter River Confluence	w1.11	1,028	1,099	+ 6.5

NOTE: Refer **Figure** 4.3 for locations of XP-RAFTS model nodes

Table 4.3 FLOW COMPARISON FOR THE DESIGN 1% AEP EVENT

LOCATION	XP-RAFTS MODEL NODE	PEAK FLOW (m^3/s) ORIGINAL MODEL	PEAK FLOW (m^3/s) UPDATED MODEL	PERCENTAGE DIFFERENCE (%)
Upstream extent of updated RMA-2 model	f1.04	165	165	0.0
Upstream of Abermain (*William St*)	f1.05	210	237	+ 12.8
Downstream of Abermain	f1.07	248	306	+ 23.4
Upstream of Weston (*Kline St*)	f1.09	295	359	+ 21.7
Downstream of Weston	f1.10	358	414	+ 15.6
Hunter River Confluence	w1.11	1065	1082	+ 1.6

NOTE: Refer **Figure** 4.3 for locations of XP-RAFTS model nodes

In many cases the increased delineation of sub-catchments has effectively allowed flows to reach catchment outfalls more rapidly; however, the total volume of flow remains similar. **Table 4.3** shows similar differences in flow for the design 1% AEP event, albeit the differences are slightly lower (*a maximum difference of 23.4%*).

The updated XP-RAFTS model is considered to better reflect the runoff-routing processes of sub-catchments along Swamp/Fishery Creek. In addition, because the RMA-2 modelling relies on local catchment inflows in areas downstream from the upstream boundary of the model, it is considered that the updated XP-RAFTS model is validated appropriately for the purpose of deriving input hydrographs for the RMA-2 model.

4.5 CALIBRATION OF RMA-2 HYDRAULIC MODEL

Calibration of the updated RMA-2 hydrodynamic model was undertaken for the June 2007 historic flood based on recorded flood marks in the vicinity of Abermain and Weston. In effect, the calibration of the RMA-2 model to the flood marks also validates the flows extracted from the XP-RAFTS model, for lack of any streamflow data on which to base the XP-RAFTS calibration.

The following provides a summary of the outcomes of the RMA-2 model calibration as well as details of the adopted channel and floodplain roughness parameters.

4.5.1 Calibration to June 2007 Flood Marks

The June 2007 historic flood was simulated using the updated RMA-2 model using June 2007 hydrographs extracted from the updated XP-RAFTS model. Peak flood level results along Swamp/Fishery Creek are shown in **Figure 4.5**, **Figure 4.6** and **Figure 4.7** as Water Surface Profile (*WSP*) plots. The locations and elevations of recorded flood marks as well as the June 2007 water surface profile derived from the previously calibrated HEC-RAS model are included on the figures. The corresponding mapping of depth and velocity is provided in **Figures 4.8 and 4.9**.

As shown in **Figure 4.6**, the calibrated RMA-2 WSP is in close agreement with the recorded flood marks in the vicinity of Abermain. Flood levels are generally within 250 mm of the recorded flood marks; many are within +/- 100 mm. An exception to this occurs upstream of William Street where the RMA-2 model could not be calibrated to match two of the eight flood marks located upstream of the bridge crossing. The two flood marks are considerably higher than those immediately upstream and downstream and as such could be considered to be outliers (*refer* **Figure 4.6**).

As shown in **Figure 4.7**, the June 2007 flood levels generated by RMA-2 are also in good agreement with the recorded flood marks in the vicinity of Weston. This is particularly the case near the Kline Street and Fourth Street bridge crossings where flood level marks are typically within 100 mm of the predicted flood levels. The RMA-2 model could not be calibrated to two flood level marks located immediately upstream of the Government Road bridge crossing. Considering the HEC-RAS model could also not be calibrated to these flood marks we believe they are likely to be erroneous or influenced by very localised factors and therefore, could be disregarded. A flood level mark immediately downstream of Government Road was calibrated to successfully using both the RMA-2 and HEC-RAS models (*refer* **Figure 4.7**).

As shown in **Figure 4.6**, few flood marks were initially recorded along the reach of Swamp/Fishery Creek two kilometres downstream from the confluence with South Deep Creek.

The RMA-2 model predicts an increase in flood levels of up to 1.0 metre across this area relative to the previous HEC-RAS model. The RMA-2 modelling results are considered more robust based on the ability of the 2D modelling to more reliably simulate the hydraulic losses that would occur as a result of the significant creek meanders.

According to the lack of comments from residents in this area, it is understood that no houses in this section of the creek received any direct inundation from floodwaters during the June 2007 flood. On 29th November 2012 Cessnock City Council contacted residents in this area in an attempt to collect further floodmarks (*that may or may not have led to property damage*). The occupant of 1 Abermain Street, was able to confirm that floodwaters came near to the pool at the rear of this property. This observation was in good agreement with the flood extent modelled by RMA-2 (*refer* **Figure 4.8**).

4.5.2 Comparison of Flood Levels Predicted by HEC-RAS and RMA-2

Also included on **Figure 4.5**, **Figure 4.6** and **Figure 4.7** are WSPs for the June 2007 flood and 100 year recurrence flood derived from the HEC-RAS Flood Study model. These WSPs were included in order to allow a direct comparison with those generated by the updated RMA-2 model.

Figure 4.6 and **Figure 4.7** indicate that the RMA-2 model typically predicts levels that are within 200 mm of those generated by the HEC-RAS model. With the exception of some localised differences. The only significant exception occurs over a two kilometre length of Swamp/Fishery Creek downstream from the confluence with South Deep Creek. Flood level differences along this section of Swamp/Fishery Creek typically range between 0.2 and 1.0 metres (*refer* **Figure 4.6**). These differences are attributed to a number of significant creek meanders which cause hydraulic losses, resulting in a higher build-up of floodwaters. These hydraulic losses would have been difficult to capture in HEC-RAS due to the limitations of the one-dimensional modelling approach. As shown in **Appendix A**, at certain locations cross-sections may have a reduced flow area due to the natural variation in the creek banks. The RMA-2 model is considered to more reliably reflect flooding conditions in these locations and therefore, the higher flood levels predicted by RMA-2 are considered appropriate. The recently collected flood extent information at 1 Abermain Street was able to confirm the higher flood levels through this section for the June 2007 flood event.

4.5.3 Comparison of Flood Levels Predicted by MIKE-11 and RMA-2 for Deep Creek and South Deep Creek

A comparison was made between the flood levels predicted using the RMA-2 model and those predicted by the MIKE-11 model as part of the previous Deep Creek Flood Study (*Lawson Treloar, 2002*). The results of this analysis are presented in **Table 4.4.**

Table 4.4 Comparison of RMA-2 and MIKE-11 Results for Deep Creek and South Deep Creek

	Distance From Upstream Extent	RMA-2 Model Result *(m AHD)*	MIKE-11 Model Result *(m AHD)*	Difference *(m)*
Deep Creek	0 m (Upstream extent of model)	33.3 m	33.5	-0.2
	1000 m	28.57	28.5	+0.07
	1600 m (Upstream of Frame Drive Crossing)	25.6	25.6	0.0
	2000 m	23.7	23.4	+0.3
	2800 m (Confluence with Swamp Creek)	20.8	20.6	+0.2
South Deep Creek	350 m	30.4	29.4	+1.0
	900 m (Upstream of Frame Drive)	25.3	25.5	-0.2
	1185 m (Downstream of Lismore Street)	22.4	22.5	-0.1
	1550 m (Confluence with Swamp Creek)	21.7	21.7	0.0

It should be noted that the two studies have used different software and modelling approaches, as well as different boundary conditions. Because of these differences, some variation between the results would be expected. However, the majority of the results for the 1% AEP flood level are within 200 mm, and those which are greater can be explained by features in the RMA-2 model terrain not included in the more coarsely sampled MIKE 11 model. As such, the two studies are considered to be generally in good agreement.

4.5.4 Summary

The June 2007 flood levels derived from the updated RMA-2 model were considered to be in good agreement with the majority of flood level marks available along Swamp/Fishery Creek in the vicinity of Abermain and Weston. As shown in **Figure 4.6** and **Figure 4.7**, the vast majority of flood marks were calibrated to within 200 mm; in many locations within 100 mm.

Comparison of the peak WSPs generated for the June 2007 flood and the 1% AEP flood based on the HEC-RAS and RMA-2 models indicates variations in levels typically less than 200 mm. This is considered to represent a good agreement with the HEC-RAS/flood study modelling results. Similarly, the agreement between the MIKE-11 model results for Deep Creek and South Deep Creek and the RMA-2 model results is considered satisfactory.

Some increases in levels of up to 1.0 metre in areas directly downstream of South Deep Creek are likely the result of the 2D modelling more reliably simulating the hydraulic losses that would occur as a result of the significant creek meanders. The increases in flood levels were confirmed to be appropriate according to anecdotal reports of the peak flood extent.

Accordingly, the updated RMA-2 model is considered suitable for the simulation of design flooding scenarios for incorporation into the Swamp/Fishery Creek FRMS.

Flood extent mapping for the June 2007 flood as derived from the RMA-2 modelling is shown in **Figure 4.8** and **Figure 4.9** for Abermain and Weston, respectively.

5. DESIGN FLOOD ASSESSMENT

Five design events were previously modelled as part of the Wallis and Swamp/Fishery Creek Flood Study (*WorleyParsons, 2011*).

The modelling update for the FRMS included the expansion of the previous set of simulations to also include the 0.5%, 10% and 50% AEP events.

Accordingly, the complete set of design events that have been modelled is as follows:

- 50% AEP (*i.e., a 2 year recurrence event*)
- 20% AEP (*5 year recurrence event*)
- 10% AEP (*10 year recurrence event*)
- 5% AEP (*20 year recurrence event*)
- 2% AEP (*50 year recurrence event*)
- 1% AEP (*100 year recurrence event*)
- 0.5% AEP (*200 year recurrence event*)
- The Probable Maximum Flood (*PMF*)

5.1 CATCHMENT HYDROLOGY

The updated XP-RAFTS hydrologic model described in **Section 4**, was used to prepare inflow hydrographs for the full range of design flooding scenarios. As shown in **Figure 4.3**, inflow hydrographs were exported from a total of eighteen XP-RAFTS model nodes for input into the updated RMA-2 model (*between Abermain and Wentworth Swamp*). Peak flows extracted from the XP-RAFTS model are presented in **Table 5.1**.

As with the previous XP-RAFTS modelling, design storm events, with the exception of the Probable Maximum Flood (PMF), were generated for Swamp / Fishery Creek based on Intensity-Frequency-Duration (*IFD*) data obtained from the Bureau of Meteorology.

Table 5.1 ADOPTED INFLOWS TO RMA-2 MODEL

XP-RAFTS NODE	Peak Flow (m³/s)							
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	PMF
F1.04	53.1	81.8	99.1	121.1	142.7	165.0	187.4	903.5
F1.05b	2.6	4.6	5.8	7.6	9.2	10.9	12.8	72.7
f1.05	3.5	5.3	6.3	7.8	9.0	10.4	12.0	58.6
F1.05c	5.8	10.5	13.6	17.8	22.1	26.2	12.8	180.4
F1.05d	10.9	19.0	23.5	29.7	29.7	41.9	48.2	267.5
F1.06	5.7	7.9	9.2	10.9	12.3	14.0	15.7	85.4
F1.06b	6.4	9.3	11.0	13.4	15.3	17.7	20.1	109.8
F4.00	2.1	3.0	3.6	4.4	5.0	5.8	6.6	29.4
F4.00b	24.1	36.1	43.2	52.9	61.2	70.9	81.2	417.3
F1.08	5.6	8.6	10.4	12.7	14.8	17.1	19.6	139.5
F5.00	18.8	29.6	35.8	44.1	51.6	60.2	69.1	348.2
F1.09	3.5	5.0	5.8	6.9	7.8	8.9	10.0	52.4
F1.10d	4.6	6.7	7.9	9.5	10.7	12.3	13.9	53.7
F1.10c	5.3	7.7	9.1	11.0	12.6	14.4	16.4	63.9
F1.10b	8.8	13.0	15.4	18.9	21.7	25.0	28.4	117.3
F1.10f	10.2	15.1	18.0	21.9	25.2	29.0	33.2	145.0
F1.10	8.6	12.6	15.0	18.3	21.1	24.4	27.8	124.1
F1.10e	19.8	29.6	35.4	43.0	49.7	57.4	65.4	299.3

Simulation of the PMF has been undertaken according to the Probable Maximum Precipitation (*PMP*), which has been estimated using standard techniques outlined in the General Short Duration Method (*2005*). The PMP has previously been calculated separately for both the Swamp/Fishery Creek and Wallis Creek catchments and is applied as such in the hydrologic modelling.

5.2 TAILWATER CONDITIONS

For design flooding scenarios a tailwater level of 4.0 mAHD was adopted at Dagworth Bridge and Victoria Bridge. In setting this level the objective was to consider a tailwater level that does not influence flood levels or characteristics in the study area of Abermain and Weston. This allows for a conservative estimate of the flood hazard and associated impacts due to the higher velocity of flow during local catchment flooding. In this regard, it is also most appropriate for the assessment of hydraulic impacts of potential flood mitigation options.

The tailwater level of 4.0 m AHD was established through consideration of the results of the *Hunter River Braxton to Green Rocks Flood Study* (*WMAwater, 2010*). This level corresponds to a 10% AEP flood in the Hunter River at Maitland. At this magnitude of event, there is not expected to be flow down the Oakhampton Floodway, and the flood gates at the confluence between Wallis Creek and the Hunter River are able to hold back the Hunter River floodwater. As such, this tailwater level represents a condition where the flood in Swamp Creek is coincident with a lower range flood in the Hunter River, or when it occurs on the rising limb of a large flood in the Hunter River.

It was noted that during the 1% AEP Hunter River flood there was significant ponding in the Wentworth and Dagworth Swamp areas, caused in part by significant flow down the Oakhampton floodway. This results in flooding of up to 9.7 m AHD. The 2% and 5% AEP events also cause some flooding in this area, though the level of flooding is lower. The 10% AEP flood and lesser events do not result in ponding in the Wentworth and Dagworth Swamps from flow through the Oakhampton Floodway.

Although the lesser 10% AEP tailwater level was adopted for a majority of the design simulations, it was considered appropriate to adopt the Hunter River 1% AEP flood level of 9.7 mAHD at Dagworth Bridge and Victoria Bridge as the tailwater condition when simulating the 1% AEP Swamp Creek flood for the purposes of determining Flood Planning Levels in Abermain and Weston.

5.3 DESIGN FLOOD CHARACTERISTICS

Flood surface profiles for the eight design events are shown in **Figures 5.1** to **5.3**. Flood level contours have also been produced for each design event and are presented in **Figures 5.4** to **5.19**.

Additional flood level profiles along Deep Creek and South Deep Creek for the 1% AEP design event are provided in **Appendix B**.

5.4 CLIMATE CHANGE ASSESSMENT

5.4.1 Effects of Climate Change

While the extent of potential climate change impacts are currently uncertain, the standard practice (*in non-tidal areas*) is to account for the anticipated effects of climate change by factoring an increase in rainfall intensity. The Office of Environment & Heritage (*OEH*) recommends that sensitivity testing be undertaken to reflect rainfall intensity increases of 10, 20 and 30% over the present day rainfall hyetographs. Hydrologic simulations were conducted to convert the increased rainfall into stream flows. The revised stream flows were then used to run climate change scenarios in the hydrodynamic model (*in this case, RMA-2*).

For Swamp Creek climate change sensitivity testing was undertaken for the 1% AEP flood. The 1% AEP rainfall hyetograph was modified to reflect an increase in intensity of 10, 20 and 30%, and this rainfall was simulated in the XP-RAFTS hydrologic model. The output hydrographs were then incorporated into the RMA-2 hydrodynamic model.

5.4.2 Climate Change Results

At Abermain a 10% increase in rainfall intensity will result in slightly less than a 10% (~8.5%) increase in peak 1% AEP flow rate, while a 20 and 30% increase will result in approximately a 20 and 30% increase in peak flow, respectively. At Weston, modelled flow rates under the Government Road Bridge showed that a 10% increase in rainfall intensity resulted in approximately a 10% increase in peak flow, while a 20 and 30% increase in rainfall intensity resulted in a 27 and 37% increase in the peak flows respectively.

Water surface profiles comparing the three climate change scenarios to the present-day 1% AEP conditions are presented in **Figures 5.20** and **5.21**. Mapping showing the increase in water levels as compared to the existing 1% AEP flood levels is shown in **Figures 5.22** to **5.27** for the 10, 20 and 30% increases in rainfall intensity.

Flood level increases associated with the increased flows were greatest upstream of structures such as the Cessnock Road Bridge and the Government Road Bridge. Downstream of these structures the water level increase was notably less. This is consistent with the effect that flow is being restricted by these structures, and thus water is ‘backing-up’ behind them.

5.5 BLOCKAGE SENSITIVITY TESTING

A sensitivity analysis was undertaken to examine the effect that debris accumulation at various structures would have on flood levels. Five key sites were identified as posing high flood risk as a consequence of blockage, as well as a high potential to accumulate debris that leads to blockage. The five nominated structures were:

- William Street Bridge (*Abermain*)
- Cessnock Road Bridge (*Abermain*)
- Kline Street Bridge (*Weston*)
- Fourth Street Bridge (*Weston*)
- Government Road Bridge (*Kurri Kurri*)

To test the effects of blockage at these structures, it was assumed that there was a 25 per cent reduction in the effective flow area under the structures. This was simulated by raising the bathymetry at these structures to reduce the available flow area.

The 10%, 5% and 1% AEP flood events were simulated to test the effect of blockage.

The results of the modelling are presented in **Figures 5.28** and **5.29** as a comparison of water surface profiles, while **Figure 5.30** to **5.35** as flood level difference maps. That is, the maps show the increase in water level that can be attributed to the 25 per cent blockage at the five structures.

As shown in the mapping, the effect of blockage at structures was generally localised, with water backing-up immediately upstream of the blocked structures. Downstream of the blocked structures water levels are typically unaltered.

Blockage at the Government Road Bridge has the greatest effect, with the increased levels from this structure extending upstream to the Fourth Street Bridge in the larger events (*for example, the 1% AEP event*). This is somewhat to be expected, as this section of Swamp Creek is relatively narrow and constricted, and floodwaters do not break-out into any off-channel storage or overbank flow paths.

6. FLOOD HAZARD ASSESSMENT

6.1 PROVISIONAL FLOOD HAZARD ASSESSMENT

Provisional flood hazard mapping was prepared for all the design flood events. Provisional hazards are classified in accordance with the hydraulic hazard categories presented in the NSW Floodplain Development Manual (DECCW, 2005). The mapping is based on the relationship between velocity and depth of floodwaters, and is related to the ability to wade or drive a car through the floodwaters. Maps of the provisional flood hazard for the 1% AEP event are shown in **Figures 6.1** and **6.2**. Mapping for the 5% and 0.5% AEP events and the Probable Maximum Flood (*PMF*) is included in **Appendix C**.

Provisional Flood Hazard mapping considers only the hydraulic characteristics of flooding, and does not include other factors such as the nature of development, evacuation routes and timing or other factors. As such, they can only be considered an indication of the hazard.

6.2 TRUE FLOOD HAZARD

Provisional flood hazard mapping considers only the hydraulic characteristics of flooding at any given location. According to the NSW Floodplain Development Manual (*DECCW, 2005*) the preparation of mapping for the true flood hazard also needs to consider other factors, including:

- The size of the flood;
- Effective warning time;
- Flood readiness of the community;
- The rate of rise of the flood waters;
- Duration of the flooding;
- Any evacuation problems that may be encountered;
- Effective flood access;
- The type of development present;

Flood hazard across the floodplain of Swamp Creek are complicated by the relatively rapid rise in the level of floodwaters at most locations in the study area. At Abermain during the 1% AEP event the peak flood level occurs 9 hours after water levels start to rise. Properties may receive initial inundation as early as 6 hours after the initial rise in floodwaters. As a result, there is little time to for people to prepare for flooding. Evacuation out of the floodplain is not a problem for most residents. However, in Abermain and Weston some evacuation routes may become blocked by floodwaters prior to any inundation of properties occurring.

The duration of flooding is relatively short, with floodwaters receding from most properties approximately 10 hours after the commencement of flooding during the 1% AEP event. As a result, any trapped residents will not be isolated for extended periods of time, and therefore will not need to be supplied with food or other provisions.

The mapping for true flood hazards was in most locations derived from the provisional flood hazard maps by removing islands of lower hazard or other areas which have become substantially surrounded by high hazard floodwaters. Additionally, there are a few properties for which evacuation could be potentially hindered by rising floodwaters. These areas were assigned a hazard corresponding to the highest hazard encountered along the most likely evacuation route.

For example, the property at 173 Harle Street, Abermain is situated in an area of Low or Transitional Hazard. However, evacuation back to Harle Street would encounter High Hazard floodwaters from relatively early in the flood event. Alternative evacuation routes to the west would involve travelling overland along unformed tracks and therefore are not considered "reasonable". As a result, this property and the surrounding area were assigned a High Hazard in the true hazard mapping.

Maps of the true flood hazard have been prepared for the 0.5%, 1% and 5% AEP events as well as the PMF. The mapping is presented in **Figures 6.3** to **6.10**.

It should be noted that many of the major roads across Swamp Creek will become blocked due to rising floodwaters, and evacuation to refuge centres may not be possible for all residents in the event of a major flood. However, this is unlikely to be a significant issue given the relatively short duration of the flooding. A more detailed description of the evacuation issues (*beyond the ability to move out of the immediate danger associated with the flood*) is provided as part of the classification of communities for emergency management (*refer* **Section 10**).

7. HYDRAULIC CATEGORY MAPPING

7.1 FLOODWAY DEFINITION

Floodways are those areas of a floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels and are areas that if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood level. By definition floodways are areas of high flow conveyance and can typically be identified by areas of high flow velocity.

The blocking of floodways typically results in significant impacts on flood characteristics such as increases in predicted peak flood level and changes in flow velocities. Therefore, it is important to define floodways in floodplain risk management so that areas where development is undesirable can be identified.

The floodway investigations for the Swamp Creek Floodplain Risk Management Study have considered several aspects of flooding and have included analytical assessment of all available hydraulic, topographic and cadastral data-sets.

A preliminary floodway extent was firstly determined based on an assessment of aerial photography, topographic data and flood modelling results for the 5%, 1%, 0.5% AEP events as well as the PMF. Specifically, the establishment of this extent or "line" considered the following:

- the location of flood storages that are readily identifiable from aerial photography;
- the location and potential impact of hydraulic controls and geomorphic features that could influence flood characteristics;
- mapping of contours of 'velocity-depth' product (*V x D*); and,
- mapping of the variation in peak flow velocity.

Because of the complex nature of flooding within the Swamp Creek system and the varied floodplain types encountered across the study area establishment of a standard set of criteria was not considered appropriate for the determination of all floodway extents. For example, definition of the floodway extent based on a single target value for velocity or velocity-depth product (*V x D*) would limit the reliability of the investigation findings.

Accordingly, to ensure the assessment of floodway extent was completed reliably, a set of interactive flood maps was produced for each of the selected design events showing the variation in V x D, peak flow velocities and peak flood depths during the flood. These maps were used to identify areas of the floodplain representing:

- High depth and high velocities; i.e., high V x D (*generally considered floodway*);

- High depth and low velocities (*generally considered flood storage*); and,
- Low depth and low velocity (*generally considered flood fringe*).

In this regard, a typical “first pass” assessment of floodway extents was undertaken to identify areas where the velocity-depth product is greater than 4.0 m^2/s and flow velocities are greater than 1 m/s. This set of criteria is accounts for the incised nature of Swamp Creek, which confines the majority of the flow to a relatively narrow, but deep and high velocity corridor. The alignment of significant flow paths across the floodplain (*i.e., potential flood runners*), as inferred by the velocity and V x D contour mapping, was also considered in determining the preliminary floodway extents.

The preliminary floodway extent was further verified by comparison with mapping of the width of the floodplain that would be required to convey 80% of the peak flow. Trial analyses for this project and similar floodplain risk management studies has shown a good correlation between the transitions in velocity-depth product contour mapping, geomorphic characteristics and the width of the floodplain that conveys about 80% of the flood flow. The width occupied by 80% of the flow was readily determined for any location within the lower reaches of the floodplain using the *Flow Extraction* tool within *waterRIDE™*.

Accordingly, the correlation observed in completing the floodway assessment for this project and other NSW Government funded floodplain management studies was applied to verify the preliminary floodway extents.

The floodway extents are shown in the hydraulic category mapping contained in **Figures 7.1** and **7.2** for the 1% AEP event. Hydraulic category maps for the 5% and 0.5% AEP flood events and the PMF are provided in **Appendix D**.

7.2 FLOOD STORAGE AND FLOOD FRINGE AREAS

Following determination of those areas of the floodplain categorised as floodway, investigations were focused towards identifying the remaining hydraulic categories; flood storage and flood fringe. As outlined in the NSW Floodplain Development Manual (*DIPNR 2005*) flood storage and flood fringe make up the remainder of the floodplain outside of the floodway corridor.

Flood storage areas are typically defined as those flood prone areas that afford significant temporary storage of floodwaters during a major flood. If filled or obstructed (*through the construction of levees or road embankments or building platforms*) the reduction in storage would be expected to result in a commensurate increase in flood levels in nearby areas.

The remaining flood prone areas not classified as floodway or flood storage are termed flood fringe. In order to determine the boundary between flood storage and flood fringe, the variation in peak flood depths in areas outside of the floodway extent were mapped to identify areas inundated to depths of approximately 0.3 metres. A depth of 0.3 metres was selected as the transitionary point between flood storage and flood fringe.

For the Swamp Creek floodplain, depths below 0.3 metres are generally considered to correspond to areas where negligible flow is conveyed, and represent a relatively small proportion of the available storage for floodwaters.

These areas, if filled, are unlikely to have any significant impact on flood levels and the pattern of floodwater distribution along the creek and across the floodplain.

Flood storage and flood fringe areas for the Swamp Creek floodplain are shown in the hydraulic category mapping contained in **Figures 7.1** and **7.2**, and in **Appendix D**.

8. FLOOD DAMAGES ANALYSIS

8.1 WHAT ARE FLOOD DAMAGES?

Flood damages are adverse impacts that private and public property owners experience as a consequence of flooding. They can be both tangible and intangible and are usually measured in terms of a dollar cost.

Tangible damages include direct damages such as the damage to property as a consequence of inundation (*e.g. the cost of replacing carpets*). Tangible damages can also be indirect damages such as the cost to the community of individuals being unable to get to work because they are isolated due to flooding. These costs can usually be measured and data has been gathered over many years to provide a reliable indication of the likely damage costs that can be incurred by residential, commercial and industrial property owners.

It is more difficult to quantify intangible damages. Intangible damages include less 'concrete' impacts such as the trauma felt by individuals as a result of a major flood and the associated health related impacts. Only limited data is available, but it has been stated that intangible damages could be as much or more than the tangible damage cost.

As part of a Floodplain Risk Management Study, it is necessary to determine the total damages that could be incurred as a consequence of flooding. If the total damage cost is significant, it can be argued that works or planning measures to reduce the cost can be justified. The justification process involves determining an estimate of the flood damage that could be expected to occur over the design life of the works. This damage cost is then compared to the damage cost if no works were undertaken. The difference defines the reduction in flood damage cost, or the net benefit. The net benefit of the works is compared against the cost of the works, thereby generating a benefit-cost ratio for the works.

If the benefit-cost ratio is sufficiently high (*i.e. ideally greater than 1*), it is likely that the works will attract State Government funding and could proceed.

8.2 FLOOD DAMAGE ASSESSMENT METHOD

8.2.1 Flood Damage Categories

Flood damage costs for Swamp Creek were determined based on consideration of the different types of land use within the floodplain. The predominant land uses are classified as:

- residential
- commercial; and,

- industrial.

Residential, commercial and industrial flood damages include damage to structures (*e.g. buildings, houses, factories, offices*) and damage to the items within those structures. They also include damages to outdoor facilities and associated infrastructure, and to the land on which the structures are sited.

Damage to infrastructure as a result of flooding includes losses associated with damage caused by inundation of roads, water supply and sewerage services, and damage to utilities such as electricity, gas and telecommunications systems.

Residential, commercial and industrial damages can be separated into direct and indirect damages. Direct damages are the result of the physical contact of floodwaters with the structure and may include the costs associated with repair, replacement or the loss in value of inundated items. Indirect damages represent all other costs not associated with physical damage to property and typically include the loss of income incurred by residents affected by flooding, as well as flood recovery items such as clean-up costs.

The approach developed to calculate flood damages for Swamp Creek is based upon the development of a representative damage curve for typical structures in the floodplain at Abermain or Weston. A damage curve is a numerical relationship that correlates the depth of flooding to the cost of damages that would result from that flooding. The cost of the damages associated with the flooding increases as the depth of flooding increases.

The approach employs the procedures outlined in the DECC (*now OEH*) Floodplain Risk Management Guideline titled, *Residential Flood Damages* (2007). It involves the application of the damage curves documented in the literature with flood data that has been updated as part of this study. Based on data collected by Council's surveyors, residential properties were classified as the following:

- single storey set directly on the ground;
- single storey building set on low piers;
- single storey on high set piers; and
- double storey building set directly on the ground.

As outlined in the Guideline, the data available on flood damages only applies to residential properties. Only a small number of commercial and industrial properties are located in the Swamp Creek floodplain. Commercial properties include shops, pubs and offices, while industrial premises include metal fabrication works and distribution warehouses.

An estimate of the direct damages associated with the inundation of commercial and industrial premises (*such as Weston Aluminium*) was based on recorded damage costs for similar premises reported in the literature. This literature includes a range of previous floodplain management studies and recorded data presented in intergovernmental reports. OEH has advised that this approach is suitable, provided that the damage curve data is updated to reflect current Average Weekly Earnings (*AWE*) and GST (*if applicable*).

The OEH guidelines for residential properties incorporate some allowance for indirect damages, such as clean-up costs and loss of rental income.

Indirect damages for commercial and industrial premises were assumed to be 50% of the corresponding direct damages which is based on values used previously in the background literature. This accounts for the significant impact of indirect influences, such as the slowdown that a business could experience due to employees being unable to get to work due to inundation of roads.

There is no specific data available to define the extent of the public and corporate infrastructure that could be damaged as a result of flooding. Additional infrastructure damages were applied to reflect 30% of the total direct and indirect the costs for residential, commercial and industrial properties. This is in keeping with approaches employed for other areas of NSW.

8.2.2 Stage–Damage Relationships

Stage-damage curves reflect the potential flood damage as a function of the depth of over floor flooding of a building, or the extent of inundation of the land on which the building is sited.

DECC's Floodplain Risk Management Guideline titled, *Residential Flood Damages* (2007), outlines the method for determining stage-damage curves for residential dwellings. This procedure is recommended as the basis for derivation of average annual damages and net present values of damages to enable the comparison of flood management options.

Standard stage-damage curves have also been developed from records of damages gathered from interviews with residents and landowners in flood affected communities. For example, Smith et al (1979) determined stage-damage relationships for different land use types based on data gathered during and following the Lismore floods in 1974. These curves were adopted for analysis of commercial and industrial damages.

The standard stage-damage curves for commercial and industrial properties were scaled to account for indirect damages. Infrastructure costs have been calculated separately.

The adopted stage-damage curves are included within **Appendix E**.

8.2.3 Average Annual Damage

The relative cost of the potential flood damages is typically expressed in terms of the Average Annual Damage (*AAD*). The AAD is the average damage per year that would occur from flooding over a very long period of time.

In understanding this concept, there may be periods where no floods occur or the floods that do occur are too small to cause significant damage. On the other hand, some floods will be large enough to cause extensive damage.

The average annual damage is equivalent to the total damage caused by all floods over a long period of time divided by the number of years in that period (*DECC, 2007*). It provides a measure for comparing the economic benefits of potential flood damage reduction options.

8.3 FLOOD DAMAGES ANALYSIS FOR ABERMAIN AND WESTON

In order to calculate the potential flood damages, it is necessary to have data that defines the floor levels of structures and infrastructure that could potentially be flooded and details of the type of structure; e.g., residential dwelling or commercial premises. This data can be used with peak flood levels generated from the flood modelling revised as part of this study to determine the depth of "over floor" flooding for each residential and commercial property.

Data defining the minimum floor elevations of residential and commercial buildings in Abermain and Weston was provided by Council (*refer* **Appendix I**). This data was used with peak flood levels generated from the flood modelling to determine the depth of over floor flooding at each structure (*if any*).

Estimates of the tangible flood damages associated with each of the 50%, 20%, 10%, 5%, 2%, 1% and 0.5% AEP floods and the Probable Maximum Flood (*PMF*) are outlined in **Table 8.1**.

The results indicate that the total damage bill is estimated to be $3,532,700 for the design 1% AEP event. This should be of similar scale to the flooding that occurred in June 2007; however, no data has been collected from home owners or insurers to verify this damages estimate.

Figures 8.1 to **8.8** in show the location of properties subject to damage during the 20%, 5% and 1% AEP events and in the PMF. The Average Annual Damage for Swamp Creek, incorporating all events up to the PMF, is estimated to be **$546,400**.

Table 8.1 EXISTING FLOOD DAMAGES

FLOOD EVENT	RESIDENTIAL		COMMERCIAL & INDUSTRIAL		INFRASTRUCTURE DAMAGES	TOTAL
	Number^	Damages	Number	Damages		
50% AEP	1 (0)	$10,500	0	$0	$3,100	$13,600
20% AEP	11 (3)	$408,000	0	$0	$122,400	$530,400
10% AEP	15 (6)	$672,700	0	$0	$201,800	$874,400
5% AEP	25 (11)	$1,281,200	0	$0	$384,400	$1,665,600
2% AEP	31 (17)	$1,849,300	0	$0	$554,800	$2,404,000
1% AEP	41 (26)	$2,717,500	0	$0	$815,300	$3,532,700
0.5% AEP	117 (61)	$7,282,000	2 (2)	$169,700	$2,235,500	$9,687,300
Probable Maximum Flood	442 (412)	$51,408,000	9 (9)	$4,011,400	$16,625,800	$72,045,300

^ *Number subject to over-floor inundation shown in parentheses*

As shown in **Table 8.1**, the damages associated with the PMF are significant (*approximately seven times higher than the 0.5% AEP event*). As a result, the PMF damages can 'skew' the interpretation of damages that might be experienced at different areas of the floodplain. Care should be taken in the development of flood damage reduction options for areas that only experience major damage in very extreme floods as these options are likely to have a very low benefit-cost and may be difficult to justify.

8.4 INTANGIBLE FLOOD DAMAGES

Intangible flood damages are those that are unable to be quantified in monetary terms. These damages are related to the physical and mental health of individuals, environmental concerns, the ability to undertake necessary evacuation measures and disruption to essential community services and operations.

Notwithstanding, emotional stress and mental illness can stem from a number of experiences associated with damage to family homes and businesses. These include:

- destruction of memorabilia (*i.e., family photos*);
- death of pets;

- financing the replacement of damaged property;
- living in temporary accommodation;
- children attending a different school;
- loss of business income and potential clients;
- loss of wages; and,
- anxiety experienced by young children.

This type of intangible damage to the well-being of residents could be significant in the event of a major flood. Accordingly, it is possible that the intangible damage cost could be as high or higher than the total tangible damage cost.

8.5 FLOOD DAMAGES UNDER POTENTIAL CLIMATE CHANGE SCENARIO

For comparison purposes, flood damages were also calculated considering the possible increases in rainfall intensity under a climate change scenario. Flood damages were calculated for the 1% AEP event with a 20% increase in rainfall intensities. The total damage bill for the 1% AEP flood is expected to increase to $4,149,200 due to climate change, which equates to an increase of 17%. A total of 68 residential properties receive damages under this scenario (*versus 41 properties damaged under present conditions*), as well as one commercial property (*versus no commercial properties*).

8.6 FLOOD DAMAGES UNDER BRIDGE BLOCKAGE SCENARIO

For comparison purposes, flood damages were also calculated considering the possible increases in flood levels under a bridge blockage scenario, as discussed above in **Section 5.5**.

Flood damages were calculated for the 10%, 5% and 1% AEP floods.

It was determined that in the 1% AEP event there would be an increase in damages to $4,025,200 which equates to an increase of 14%. The number of properties affected by over-floor flooding would be increased by only two.

There is expected to be greater impact on damages during the 5% and 10% AEP events, with damages increasing by 47% and 86%, respectively. The number of properties affected by over-floor flooding would be increased by five and three properties, respectively.

The most significant impact on properties occurs in Abermain, upstream from Cessnock Road and the railway bridge. This suggests that measures to improve the conveyance through this area may result in a damages reduction.

It was also noted that the significant increase in flood levels upstream of Government Road bridge (*refer* **Figures 5.31**, **5.33** *and* **5.35**) does not translate to a significant increase in property damages due to the limited creek-side development in this area.

9. ASSESSMENT OF OPTIONS TO REDUCE FLOOD DAMAGES

According to the *Floodplain Development Manual (2005*), floodplain risk management options are separated into the following categories:

- **Flood modification measures**. These are typically structural works, such as flood protection levees, flood detention basins or bypass floodways, which act to reduce flood damages.
- **Property modification measures**. These measures include flood planning controls for future development to ensure that land uses are compatible with flood risk. They can also include voluntary house raising and purchase, or flood-proofing of buildings, which can act to reduce flood damages.
- **Response modification measures**. These typically include emergency response management measures, flood predictions and warnings and community flood awareness and preparedness.

9.1 METHODOLOGY

A key objective of the Floodplain Risk Management Study is to identify and assess opportunities for reducing the impact of floods on communities located in Abermain, Weston and Loxford.

The damages assessment documented in **Section 8** established that the single occurrence of the design 1% AEP flood would lead to damages amounting to $3.53M. This damage cost does not account for intangibles, which have the potential to be as much again. Residential properties at Abermain and Weston would incur the greatest proportion of this damage cost.

The results of the analysis also indicate that the Average Annual Damage for all events up to the extreme flood is in the order of **$546,400**. That is, funds in the order of **$546,400** would need to be put aside each year on average, in order to cover the damage bills that could be incurred as a consequence of flooding.

In recognition of this, a range of potential flood management measures have been identified to reduce the flood damages and ameliorate associated flood risk to individuals. Some of these options have been the focus of preliminary assessments as outlined in **Section 2.1**. It was decided to revisit these options in light of the update to RMA-2 flood modelling across the study area.

A two stage process has been used in the assessment of structural flood damage reduction options, in which a wide range of options were initially tested (*Stage 1 Assessment*) using a Triple Bottom Line (*TBL*) approach. This included the assessment of hydraulic impacts according to flood modelling of the 20%, 5% and 1% AEP events to determine an indicative benefit-cost. The cost of options has been estimated according to basic concept designs and rates extracted from

Rawlinsons Construction Handbook (*Edition 30, 2012*), including allowances for design, construction management and contingencies.

The results of the assessment were applied to develop an Assessment Matrix, to provide the Committee with a means to assimilate the wide range of factors that require consideration before implementation of any option. Based on this comparison of options, the preferred options have been selected for further refinement and analysis for the full range of design floods as part of a Stage 2 Assessment.

9.2 STAGE 1 ASSESSMENT OF FLOOD MANAGEMENT OPTIONS

The potential flood damages reduction options that were investigated as part of the Stage 1 Assessment are listed in **Table 9.1**.

Table 9.1 POTENTIAL FLOOD DAMAGES REDUCTION OPTIONS

OPTION	DESCRIPTION
Option 1	Channel excavation to reduce existing bed levels by up to 1 metre
Option 2	Channel excavation to reduce existing bed levels by up to 2 metres
Option 3	Vegetation clearing to form a grass-lined channel, reducing channel roughness to reflect a Manning's 'n' value of 0.03
Option 4	Construction of a concrete-lined channel, reducing channel roughness to reflect a Manning's 'n' value of 0.015
Option 5	Undertaking works to improve the passage of floods under the Cessnock Road Bridge and the Rail Bridge at Abermain
Option 6	Construction of a levee along Swanson Street, West Esplanade and East Esplanade at Weston to protect houses in the vicinity of the Fourth Street Bridge
Option 7A	Raising of the Hebburn Colliery Reservoir weir level to provide increased detention
Options 7B and 7C	Upgrade of the Hebburn Colliery Reservoir to provide increased detention
Option 8	Construction of a flood mitigation dam upstream of Abermain
Option 9	Voluntary House Raising
Option 10	Voluntary House Purchase

Further details of the flood modelling undertaken to assess each option and the associated results are outlined in the following sections.

Flood modelling results for the options are presented as flood profiles in **Figures 9.1** and **9.2** for the 20% AEP flood, in **Figures 9.3** and **9.4** for the 5% AEP flood, and in **Figures 9.5** and **9.6** for the 1% AEP flood.

9.2.1 Channel Excavation – Options 1 and 2

Options 1 and 2 would involve excavation of the Swamp Creek channel bed by a depth of 1 or 2 metres, respectively, in the area between the creek banks. An indicative section of the channel works is shown in **Figure 9.7**. The proposed works would have a total length of approximately 9.5 km, stretching between Abermain and Loxford.

The entire study area was tested as part of these options due to the potential for adverse flood impacts to occur if works were limited to isolated sections of the creek. It is possible that the excavation of a particular section of creek may lead to a transfer of the flood problem to areas immediately downstream.

Hydraulic Assessment

Options 1 and 2 were assessed using the RMA-2 flood model by lowering model nodes within the channel bed levels by 1 or 2 metres. Other model nodes within the overbank areas were left unchanged.

The impact of Option 1 on design flood levels at Abermain and Weston is shown in **Table 9.2**, while the impact of Option 2 is shown in **Table 9.3**.

Table 9.2 PREDICTED DECREASES IN PEAK FLOOD LEVEL FOR OPTION 1

FLOOD EVENT	EXCAVATING THE EXISTING BED LEVELS BY UP TO 1 METRE DECREASE IN PEAK FLOOD LEVEL (*metres*)			
	ABERMAIN		WESTON	
	Typical	Maximum	Typical	Maximum
1% AEP Flood	0.3 – 0.5	0.7	0.6 – 0.7	0.8
5% AEP Flood	0.7 – 0.9	0.95	0.75 – 1.0	1.08
20% AEP Flood	0.75 – 0.85	0.88	0.85 – 1.0	1.08

As shown in the tables and in **Figures 9.5** and **9.6**, there is expected to be a significant reduction in 1% AEP flood levels as a result of the channel excavation. Option 2 results in the most reduction of all the tested options, especially in Abermain where the reduction is at least 0.8 metres greater than any other option.

Cost Estimates

The cost of implementing Option 1 is estimated to be $15.7M (*refer* **Appendix F**). The cost of implementing Option 2 is estimated to be $25.3M (*refer* **Appendix F**).

These costs are significant, which is reflective of the large volume of material that would be excavated from the channel bed, in addition to associated bridge modification works. Note that is has been assumed that the excavated material will be able to be used on any nearby construction projects and therefore, no allowance has been made for its disposal. If disposal costs were to be included, then the cost of the options would increase five-fold.

Table 9.3 PREDICTED DECREASES IN PEAK FLOOD LEVEL FOR OPTION 2

FLOOD EVENT	EXCAVATING THE EXISTING BED LEVELS BY UP TO 2 METRES DECREASE IN PEAK FLOOD LEVEL (*metres*)			
	ABERMAIN		WESTON	
	Typical	Maximum	Typical	Maximum
1% AEP Flood	1.0 – 1.4	1.5	1.1 – 1.5	1.65
5% AEP Flood	1.4 – 1.6	1.7	1.5 – 1.9	1.95
20% AEP Flood	1.75 – 1.85	1.94	1.8 – 2.0	2.1

It should be noted that these cost estimates include an allowance for cartage of the excavated material to up to 20 km from site, but also assume that there would be no other disposal costs. If an appropriate buyer of the material cannot be sourced, then the cost of disposal could increase the overall cost estimate by up to ten fold.

9.2.2 Vegetation Clearing – Option 3

This option would involve works to clear all significant vegetation from the creek bed and banks in order to lower channel "roughness" and provide increased flow conveyance.

The RMA-2 flood model was modified to reflect a roughness (*Manning's 'n'*) of 0.03 (*considered equivalent to maintained grass*) within the channel across an average width of about 40 metres and for the length of the study area (*about 9.5 km*).

Hydraulic Assessment

The impact of Option 3 on design flood levels at Abermain and Weston is summarised in **Table 9.4** below. As also shown in **Figures 9.5** and **9.6**, the greatest reduction in flood levels during the 1% AEP flood is expected in Weston.

Option 3 shows relatively little benefit in the 1% AEP event at Abermain compared to the reduction in levels expected at Weston. This is likely due to the steeper, more incised floodplain through Weston and the associated sensitivity to channel roughness.

Table 9.4 PREDICTED DECREASES IN PEAK FLOOD LEVEL FOR OPTION 3

FLOOD EVENT	VEGETATION CLEARING TO MAKE GRASS-LINED CHANNEL ('n' = 0.03) PREDICTED DECREASE IN PEAK FLOOD LEVEL (*metres*)			
	ABERMAIN		WESTON	
	Typical	Maximum	Typical	Maximum
1% AEP Flood	0.2 – 0.3	0.45	0.3 – 0.7	0.9
5% AEP Flood	0.45 – 0.5	0.58	0.3 – 0.7	0.85
20% AEP Flood	0.3 – 0.4	0.44	0.5 – 0.9	1.0

Cost Estimate

The cost of implementing Option 3 is estimated to be $4.0M (*refer* **Appendix F**). Although at least four times less costly than Options 1 and 2, this is still considered to be significant in terms of the funding that Council would need to raise.

9.2.3 Concrete-Lined Channel – Option 4

This option would involve works to clear all significant vegetation from the creek channel over a length of 9.5 km, followed by construction of a concrete-lined channel from bank-to-bank. The thickness of the concrete would be 70 mm.

The concrete lining would provide a reduced channel roughness with Manning's 'n' of 0.015. The RMA-2 flood model was modified to reflect this roughness and used to simulate the 1%, 5% and 20% AEP events.

Hydraulic Assessment

The impact of Option 4 on design flood levels at Abermain and Weston is shown in **Table 9.5**. As shown in **Figures 9.5** and **9.6**, Option 4 is expected to provide an increased benefit compared to that offered by Option 3 (*grass-lined channel*). This is directly reflective of the further reduction in channel roughness associated with Option 4.

Similar to Option 3, the greatest reduction in 1% AEP levels would be expected in Weston. For Option4 the benefit almost equals the benefit associated with Option 2 (*2m bed excavation*) in places.

Table 9.5 PREDICTED DECREASES IN PEAK FLOOD LEVEL FOR OPTION 4

FLOOD EVENT	CONCRETE-LINED CHANNEL ('n' = 0.015) PREDICTED DECREASE IN PEAK FLOOD LEVEL (*metres*)			
	ABERMAIN		WESTON	
	Typical	Maximum	Typical	Maximum
1% AEP Flood	0.25 – 0.35	0.55	0.6 – 1.0	1.35
5% AEP Flood	0.5 – 0.6	0.7	0.5 – 1.2	1.4
20% AEP Flood	1.75 – 1.85	0.6	0.6 – 1.4	1.6

Cost Estimate

The cost of implementing Option 4 is estimated to be $15.3M (*refer* **Appendix F**). These costs are significant, which is primarily a reflection of the cost of concreting such a large area.

9.2.4 Bridge Improvements at Abermain – Option 5

At Abermain there is a series of bridges and creek crossings which modelling has shown have an impact of flooding upstream of Cessnock Road. These structures are shown in **Figure 9.8** and comprise:

- The Cessnock Road Bridge;
- The rail bridge;
- A pedestrian bridge immediately downstream of Cessnock Road;
- A pedestrian Bridge approximately 18 metres upstream of Cessnock Road; and
- Three pipe and service crossings.

A number of these structures are at or below the 1% AEP flood level, or have piers that are within the floodway. Raising these structures or removing the piers, as illustrated in **Figure 9.8** will increase the capacity through this section of Swamp Creek, and reduce the amount that water backs-up south of the rail bridge.

Hydraulic Assessment

The impact of Option 5 on design flood levels at Abermain and Weston is shown in **Table 9.6**. As expected, there will be no benefit offered to sections of the creek downstream from the Cessnock Road Bridge. The reduction in flood levels is most significant between the William Street Bridge and the railway bridge during the 5% and 1% AEP events.

Cost Estimate

The cost of implementing Option 5 is estimated to be $3.4M (*refer* **Appendix F**), which comprises a cost of about $600,000 each for upgrading/replacing the Cessnock Road Bridge and railway bridge, and also for the combined cost of relocation of services crossings and the footbridges (*excluding demolition works and contingencies*).

Table 9.6 PREDICTED DECREASES IN PEAK FLOOD LEVEL FOR OPTION 5

FLOOD EVENT	BRIDGE IMPROVEMENTS AT ABERMAIN PREDICTED DECREASE IN PEAK FLOOD LEVEL (*metres*)			
	ABERMAIN		WESTON	
	Typical	Maximum	Typical	Maximum
1% AEP Flood	0.1 – 0.4	0.5	0.0	0.0
5% AEP Flood	0.0 – 0.3	0.38	0.0	0.0
20% AEP Flood	0.0 – 0.2	0.27	0.0	0.0

9.2.5 Levee System at Weston – Option 6

This option would involve the construction of a 460m section of levee on the western bank of Swamp Creek between Kline Street and near Sixth Street (*refer* **Figure 9.9**). This levee would be an average of 3 metres high and aim to provide flood protection to a cluster of houses situated adjacent to the floodway.

The Swanson Street roadway would need to be reinstated and integrated into the levee as part of the works, and the Fourth Street Bridge would require replacement.

The implementation of this levee would be expected to cause a localised increase in flood levels due to the constriction of flow to between the levees. Accordingly, a second smaller levee would be required on the eastern bank of the creek to offer protection to properties subject to damage on this side of the creek. This levee would be about 90 metres in length and have an average height of 2 metres (*refer* **Figure 9.9**).

Hydraulic Assessment

The impact of Option 6 on design flood levels at both Abermain and Weston is shown in **Table 9.7**.

Table 9.7 PREDICTED INCREASES IN PEAK FLOOD LEVEL FOR OPTION 6

FLOOD EVENT	LEVEE SYSTEM AT WESTON PREDICTED *INCREASE* IN PEAK FLOOD LEVEL (*metres*)			
	ABERMAIN		WESTON	
	Typical	Maximum	Typical	Maximum
1% AEP Flood	0.0	0.0	0.3	0.5
5% AEP Flood	0.00	0.02	0.3	0.4
20% AEP Flood	0.00	0.01	0.1	0.2

As to be expected, increases in flood levels are predicted to occur upstream of Fourth Street, with increases typically about 0.4m in the 1% AEP event upstream to Second Street. The upstream limit of flood level increases is Chinaman's Hollow.

Some upstream creek-side properties will be affected by the flood level increases, and one dwelling is expected to be adversely affected.

Cost Estimate

The cost of implementing Option 6 is estimated to be approximately $3.2M (*refer* **Appendix F**), which includes an allowance for replacement of the Fourth Street Bridge and works to reinstate Swanson Street along the inside of the levee between Kline and Fourth Streets.

9.2.6 Upgrade of Hebburn Reservoir – Options 7A, 7B and 7C

A series of upgrade options for Hebburn Reservoir have been considered, further to the investigations undertaken as part of the preliminary options assessment (*WorleyParsons, 2011*). The potential to simply raise the spillway crest level at Hebburn Dam was previously investigated.

However, not considered in previous investigations was the way in which the recently constructed stormwater detention basins in the Hunter Industrial Zone (*HEZ*) would interact with Hebburn Dam. Previously, without consideration of the HEZ basins, the reservoir weir crest could only be raised to 21.7 m AHD without causing general overtopping of the dam during the 1% AEP flood.

According to the revised hydrologic modelling of the catchment, the effect of the HEZ detention basins is to reduce the existing 1% AEP outflow from Hebburn Reservoir to about the magnitude of the 5% AEP event.

Option 7A

In light of the revised hydrology, it was determined that the weir crest level could be raised to a maximum level of 22 mAHD prior to causing general overtopping of the reservoir during the 1% AEP event. This option requires only minimal construction as it leaves the dam in its current form. The weir upgrade would comprise the installation of a row of gabion baskets along the top of the existing weir.

This option is labelled as Option 7A (*refer* **Figure 9.10**) and the associated hydrologic modelling results are included in **Table 9.8**.

As shown in the table, Option 7A is not expected to provide any reduction in the peak outflow from the reservoir, which is similar to the results of previous analyses. The peak flow in downstream sections of Swamp Creek is actually expected to increase due to the holding back of flow to better coincide with flow from the upper catchment upstream from Abermain.

Accordingly, two alternative concepts involving further works to augment the dam were also considered.

Option 7B

The first of these was to raise the spillway crest to 23.5 mAHD, which is sufficient to achieve a 10% reduction in peak flows during the 1% AEP event (*refer Option 7B in* **Table 9.8**). In this option the width of the existing weir and spillway would be retained. The initial intention was that this option would be carried out with only minimal variations to the dam structure, and thus could be achieved with minimal cost.

However, the raising of the spillway crest would cause the current dam to be overtopped and therefore, additional works would be required to increase the height of the dam embankment by about 1.4 metres. With an enlargement of the dam would come a requirement to adhere to strict dam safety criteria. In this case, the upgraded dam would need to be able to safely pass the Probable Maximum Flood (*PMF*) without overtopping that could lead to failure. In order to avoid this, the general dam embankment would need to be raised by up to 4 metres.

The concept design for Option 7B is provided in **Figure 9.11**, which has been configured using the available LiDAR data for the dam. The total length of the raised dam embankment would be some 600 metres.

Table 9.8 HEBBURN RESERVOIR UPGRADE OPTIONS – 1% AEP HYDROLOGY

Scenario	Weir Crest Level (*m AHD*)	Peak Weir Outflow (*m³/s*)	Reduction in Weir Outflow (*%*)	Peak Downstream Flow in Swamp Creek (*m³/s*)	Peak Reservoir Storage Level (*m AHD*)	Required Embankment Level ^ (*m AHD*)	Required Increase in Embankment Level (m)
Existing	21.6	58.5	-	340	22.9	23.8 (*existing*)	-
Option 7A	22.0	58.5	0	347	23.3	23.8	0
Option 7B	23.5	52.6	10	344	24.7 (*27.3 for PMF*)	25.2 (*27.8 for PMF*)	1.4 (*4.0 for PMF*)
Option 7C	25.2	29.2	50	321	25.3 (*26.9 for PMF*)	25.7 (*27.4 for PMF*)	1.9 (*3.6 for PMF*)

^ incorporating freeboard of 500mm above the 1% AEP peak storage level

As shown in **Table 9.8**, despite the reduction in outflow from the dam, the impact of Option 7B would be to hold back flow to coincide with flow from the upper Swamp Creek catchment, meaning the downstream flow in the creek would not be reduced.

Option 7C

A third option was investigated with the aim of eliminating spillway flow during events up to and including the 1% AEP flood, thereby providing the best chance to reduce downstream flooding.

As shown in **Figure 9.12**, this Option 7C would involve the installation of a low level outlet (*2.8m diameter pipe*) in conjunction with raising the dam embankment. The overflow spillway would be reconfigured and widened from 24 to 80 metres in order to reduce the height of stored floodwater in the PMF, thereby reducing the required height of the dam.

Option 7C would reduce the peak 1% AEP outflow from the dam by 50% (*refer* **Table 9.8**); outflow would only be via the low-flow pipes up to the 1% AEP event. In order to safely pass the PMF the dam embankment would need to be raised by up to 3.6 metres, which is slightly reduced but similar to Option 7B.

The impact of the 50% flow attenuation from the dam would be to reduce peak flows in downstream Swamp Creek by about 20 m^3/s (*refer* **Table 9.8**), which represents a decrease of only 6% and therefore, would not expect to result in significant flood mitigation benefits.

Hydraulic Assessment

The impact of Option 7A (*raising the weir crest level only*) on design flood levels at Abermain and Weston is shown in **Table 9.9**. Due to the increased peak flow in downstream sections of Swamp Creek, there is expected to be an *increase* in flood levels

Table 9.9 PREDICTED INCREASES IN PEAK FLOOD LEVEL FOR OPTION 7A

FLOOD EVENT	UPGRADE OF HEBBURN DAM PREDICTED *INCREASE* IN PEAK FLOOD LEVEL (*metres*)			
	ABERMAIN		WESTON	
	Typical	Maximum	Typical	Maximum
1% AEP Flood	0.0	0.0	0.02 – 0.03	0.04
5% AEP Flood	0.0	0.0	0.05 – 0.06	0.07
20% AEP Flood	0.0	0.0	0.03 – 0.04	0.05

Hydraulic testing of the alternative upgrade Options 7B and 7C has also been carried out, with results for the 1% AEP flood event presented in **Table 9.10**.

Table 9.10 PREDICTED CHANGE IN PEAK FLOOD LEVEL FOR OPTIONS 7B AND 7C DURING THE 1% AEP FLOOD

OPTION	UPGRADE OF HEBBURN RESERVOIR PREDICTED CHANGE IN PEAK FLOOD LEVEL (*metres*)			
	ABERMAIN		WESTON	
	Typical	Maximum	Typical	Maximum
OPTION 7	0.0	0.0	+0.03 to +0.04	+ 0.04
OPTION 7B	0.0	0.0	+0.01 to +0.02	+ 0.02
OPTION 7C	0.0	0.0	- 0.1 to - 0.13	- 0.14

The results reiterate the outcomes of the hydrologic analysis in that only Option 7C was capable of achieving any reduction in flood levels at Weston. Option 7B resulted in minor increases in the flood levels at Weston.

Cost Estimates

The cost of implementing Option 7A is estimated to be $160,000 (*refer* **Appendix F**), which is a relatively small cost because of the minimal works to raise the existing spillway/weir crest.

The costs associated with Option 7B and Option 7C are much higher considering the extensive works to upgrade not only the dam spillway but also the general dam embankment. These options are expected to cost $4.4M and $6.0M, respectively. Despite the reduced height of embankment for Option 7C (*as compared to Option 7B*), additional cost is expected in the construction of the much wider spillway (*compare* **Figures 9.11** *and* **9.12**).

9.2.7 Construction of a Flood Mitigation Dam – Option 8

The potential to construct a flood mitigation dam upstream from Abermain was investigated as a method for reducing peak flows and hence flood levels through the study area. A concept for the dam has been developed based on the target of achieving a 25% reduction in the peak 1% AEP flow at Abermain.

It should be made clear that the dam would not be a permanent water body; i.e., it would not hold water in normal dry-weather conditions. It would only store water temporarily during large flood events and therefore, act similarly to a dry detention basin.

Selection of the dam site required the following criteria to be met:

- The land use zoning be compatible with the construction of a flood mitigation dam;
- The physical constraints of the site be conducive to dam construction;
- The volume of storage behind the dam be as large as possible so as to capture the largest possible volume of flood water for the smallest possible rise in water level;
- The upstream catchment be large so as to capture the greatest proportion of the flood flows possible;
- The temporary inundation extents during significant flooding must not block evacuation routes or critical services; and
- The temporary inundation extents should not impact on private dwellings, and try to avoid additional inundation of private property.

A review of the upstream catchment areas revealed that it was not possible to meet all the above requirements for Swamp Creek. A site that achieved a majority of the above requirements was selected (*refer* **Figure 9.13**). However, it was not possible to avoid existing nature reserve areas and some impact on private property, when considering not only the dam footprint but also the temporary extent of inundation behind the dam during major flooding.

It should be noted that at this stage, a number of factors regarding the suitability of any particular site for dam construction are unknown. Most notably, the specific geotechnical conditions required for dam construction have not been investigated. In light of this, the selected location and design are indicative only, for the purposes of testing the concept of a flood mitigation dam.

The indicative concept for the dam is shown in **Figure 9.14** and incorporates the typical features that such a dam would require. A spillway crest level of 40 mAHD would be required to capture the peak flows during events up to the 1% AEP flood without overflow from the spillway. The outflow during events up to this magnitude would be restricted to twin 2.8 metre diameter concrete pipes through the base of the dam.

For the safety of the dam, a general embankment level of 42.5 mAHD would be required to ensure that the dam is not overtopped during the PMF, and that such flow can pass safely through the spillway. This embankment level is equivalent to a maximum height of 12 metres.

Hydraulic Assessment

The impact of the reduction in peak flows offered by the flood mitigation dam at Abermain and Weston is shown in **Table 9.11**. There is expected to be a notable decrease in flood levels through both areas in the 1% AEP event.

Figure 9.14 shows the extent of temporary inundation behind the dam during the 1% AEP flood, as well as during the Probable Maximum Flood. There is expected to be no impact to dwellings on private property during the 1% AEP event; however, it likely that two dwellings would be impacted during the PMF.

Cost Estimate

The cost of implementing Option 8 is estimated to be $15.7M (*refer* **Appendix F**). The majority of this cost is for the significant earthworks and spillway construction. Additional allowances have been made for environmental management and site access difficulties due to the location of the dam in nature reserve bushland.

Table 9.11 PREDICTED DECREASES IN PEAK FLOOD LEVELS FOR OPTION 8

FLOOD EVENT	FLOOD MITIGATION DAM UPSTREAM OF ABERMAIN PREDICTED DECREASE IN PEAK FLOOD LEVEL (*metres*)			
	ABERMAIN		WESTON	
	Typical	Maximum	Typical	Maximum
1% AEP Flood	0.25 – 0.4	0.53	0.3 – 0.4	0.4
5% AEP Flood	0.35 – 0.5	0.53	0.1 – 0.13	0.14
20% AEP Flood	0.06 – 0.08	0.09	0.2 – 0.25	0.27

9.2.8 Voluntary House Raising – Option 9

Due to the generally localised distribution of properties and dwellings affected by flooding along Swamp Creek, it is worthwhile to consider the potential to raise the floor levels of such dwellings.

A total of 20 houses were identified as being suitable for voluntary raising, which are shown in yellow in **Figures 9.15** and **9.16**. These dwellings were identified as being inundated to above the habitable floor level during the 1% AEP flood. It was also a requirement that the dwellings are not slab-on-ground construction. The floor level and construction information was provided by Council in the database of surveyed floor levels.

It was determined that the houses would need to be raised on average by 1.2 metres in order to lift the finished floor levels to 500 mm (*freeboard*) above existing 1% AEP flood levels.

Cost Estimate

The cost of house raising has been based on indicative per-house rates provided by contractors that specialise in house raising. A rate of $50,000 per house has been applied, in addition to temporary accommodation, removalist costs and contingencies, to estimate that this option would cost approximately $1.5M (*refer* **Appendix F**).

9.2.9 Voluntary House Purchase – Option 10

An alternative to raising those houses most affected by flooding would be to purchase the properties and demolish the houses.

A total of 26 properties were identified for voluntary purchase as those dwellings that are inundated to above the habitable floor level during the 1% AEP flood. This included dwellings that are slab-on-ground construction (*refer* **Figures 9.17** *and* **9.18**).

Subject to the willingness of land owners to sell their properties, it is expected that the acquisition of houses would be undertaken over an extended period of time (*i.e., at least 10 years*).

Cost Estimate

The cost of house purchasing has been based on the current median property price in Abermain. An allowance has also been applied for house demolition and basic remediation of the site. It is estimated that this option would cost approximately $14.1M (*refer* **Appendix F**).

9.3 BENEFIT COST ANALYSIS

A benefit-cost analysis was undertaken to assess the economic viability of implementing the proposed Stage 1 flood management options. The estimated cost of construction/implementation was compared with the predicted monetary benefit offered by each option in terms of the potential reduction in flood damages. An allowance for maintenance of structures has been also incorporated to provide a complete life-cycle cost for each option. Direct and indirect costs have been included in all damage cost estimates.

The Average Annual Damage (*AAD*) was determined for each scenario by summing the damages of the three simulated design events (*20%, 5% and 1% AEP floods*), which were factored by their probability of occurrence. The 'benefit' was calculated over a design life of 30 years as the present value of the reduction in AAD for each management option relative to the AAD that would be incurred under existing conditions. Each floodplain management option has been assessed to calculate an indicative benefit-cost ratio.

9.3.1 Reduction in Flood Damages

The assessment of flood damages for existing conditions has been outlined in **Section 8**.

The reduction in damages afforded by each option was calculated using the spatial analysis tools available in *water*RIDE^{TM}, which provides an indication of the relative benefits of each option. The damages costs for each option are provided in **Table 9.12**. The existing damages have been included for comparison.

Table 9.12 FLOOD DAMAGES FOR MITIGATION OPTIONS

OPTION	DESCRIPTION	FLOOD DAMAGES		
		20% AEP EVENT	5% AEP EVENT	1% AEP EVENT
-	*Existing Damages*	*$530,000*	*$1,670,000*	*$3,533,000*
1	Excavate Channel 1m Deep	$0	$400,000	$1,770,000
2	Excavate Channel 2m Deep	$0	$0	$590,000
3	Vegetation Clearing	$200,000	$820,000	$2,310,000
4	Concrete-lined Channel	$70,000	$560,000	$1,880,000
5	Bridge Upgrades at Abermain	$510,000	$1,560,000	$3,030,000
6	Levee System between Kline and Fourth Streets, Weston	$280,000	$1,040,000	$2,300,000
7A	Hebburn Reservoir Weir Upgrade	$540,000	$1,700,000	$3,580,000
7B	Hebburn Reservoir Upgrade	$520,000	$1,680,000	$3,540,000
7C	Hebburn Reservoir Upgrade	$500,000	$1,630,000	$3,390,000
8	Flood Mitigation Dam upstream from Abermain	$400,000	$1,030,000	$2,130,000
9	Voluntary House Raising	$130,000	$460,000	$1,840,000
10	Voluntary House Purchase	$0	$120,000	$600,000

As shown, Options 2 and 10 provide the greatest reduction in damages. The damages for Option 2 are reduced to zero during the 20% and 5% AEP floods. The damages listed in **red type** display an increase in damages from existing conditions. These are associated with the Hebburn Reservoir upgrade options that result in a minor increase in flood levels along Swamp Creek downstream from the reservoir.

In addition to assessing the reduction in flood damages, the reduction in the number of flood affected properties under each option has been determined. The number of properties affected by flooding provides a measure by which the intangible costs can be partially quantified. It also provides a measure of the demands that may be placed on the emergency services in the event of a flood. A summary of this assessment is provided in **Table 9.13**.

Table 9.13 NUMBER OF PROPERTIES AFFECTED

OPTION	DESCRIPTION	NUMBER OF PROPERTIES AFFECTED *(Number subject to over-floor inundation)*			
		20% AEP EVENT	5% AEP EVENT	1% AEP EVENT	PMF
-	*Existing Conditions*	11 *(3)*	25 *(11)*	41 *(26)*	451 *(421)*
1	Excavate Channel 1m Deep	0 *(0)*	10 *(2)*	25 *(12)*	451 *(421)*
2	Excavate Channel 2m Deep	0 *(0)*	0 *(0)*	14 *(3)*	451 *(421)*
3	Vegetation Clearing	5 *(1)*	16 *(5)*	30 *(18)*	451 *(421)*
4	Concrete-lined Channel	3 *(0)*	13 *(3)*	26 *(14)*	451 *(421)*
5	Bridge Upgrades at Abermain	10 *(3)*	23 *(11)*	37 *(21)*	451 *(421)*
6	Levee System between Kline and Fourth Streets, Weston	8 *(1)*	18 *(6)*	28 *(18)*	451 *(421)*
7A	Hebburn Reservoir Weir Upgrade	11 *(3)*	25 *(12)*	42 *(26)*	451 *(421)*
7B	Hebburn Reservoir Upgrade	11 *(3)*	25 *(12)*	41 *(26)*	451 *(421)*
7C	Hebburn Reservoir Upgrade	11 *(2)*	25 *(10)*	39 *(25)*	451 *(421)*
8	Flood Mitigation Dam upstream from Abermain	9 *(2)*	18 *(7)*	29 *(13)*	451 *(421)*
9	Voluntary House Raising	11 *(1)*	25 *(3)*	41 *(6)*	451 *(421)*
10	Voluntary House Purchase	0 *(0)*	4 *(0)*	15 *(0)*	425 *(395)*

It should be noted that the number of damaged houses includes those houses that received damage below the habitable floor level as well as above it.

Option 9 for shows no reduction in the number of houses that receive damages because no houses have been removed from the floodplain. Properties have, however, received a lower level of damage, and this is represented in the reduction in flood damages (*refer* **Table 9.12**).

It has been largely assumed (*and in most cases computed*) that there would be no reduction in the number of properties that would be affected in the PMF. The exception is Option 10, in which case houses would be removed from the floodplain.

All other options have been designed to reduce damages or the number of properties inundated in events up to the 1% AEP flood. For events greater than the 1% AEP flood, these measures are not able to provide a reduction in flood levels, and hence the number of properties damaged is unchanged.

9.3.2 Indicative Benefit-Cost Ratio

The estimate of the total costs over the life of the options has been brought back to a Net Present Value assuming a 7% real discount rate over 30 years.

Similarly, the expected annual reduction in flood damages afforded by the works was also brought back to a present value. The results of this analysis are presented in **Table 9.14**.

As shown in the table, aside from Options 3, 6 and 9, all other options would have a benefit-cost ratio that is significantly lower than 1.0 and therefore, would be unlikely to attract government funding.

Option 9 is the only option with a BCR greater than 1.0, which is due to the significant benefits and relatively small cost for house raising.

Table 9.14 INDICATIVE BENEFIT-COST RATIOS FOR OPTIONS

OPTION	DESCRIPTION	CAPITAL COST	PRESENT VALUE OF COSTS	PRESENT VALUE OF DAMAGES REDUCTION	BENEFIT-COST RATIO
1	Excavate Channel 1m Deep	$15.7m	$13.5m	$3.8m	0.28
2	Excavate Channel 2m Deep	$25.3m	$21.5m	$4.4m	0.20
3	Vegetation Clearing	$4.0m	$3.7m	$2.6m	0.70
4	Concrete-lined Channel	$15.3m	$13.0m	$3.3m	0.25
5	Bridge Upgrades at Abermain	$3.4m	$3.0m	$0.29m	0.10
6	Levee System between Kline and Fourth Streets, Weston	$3.2m	$2.8m	$2.0m	0.72
7A	Hebburn Reservoir Weir Upgrade	$0.16m	$0.15m	- $0.08m	- 0.53
7B	Hebburn Reservoir Upgrade	$4.4m	$3.8m	$0.02m	0.01
7C	Hebburn Reservoir Upgrade	$6.0m	$5.2m	$0.19m	0.04
8	Flood Mitigation Dam upstream from Abermain	$15.7m	$13.2m	$1.4m	0.11
9	Voluntary House Raising	$1.5m	$1.4m	$3.6m	2.6
10	Voluntary House Purchase	$14.1m	$10.8m	$4.5m	0.41

9.4 TRIPLE BOTTOM LINE ASSESSMENT

In addition to assessment of the economic benefit for each of the Stage 1 options, further assessment was undertaken to compare the options according to a range of additional criteria, including social and environmental factors.

The assessment criteria and their weighting are outlined in **Table 9.15**. As shown, separate consideration has been given to the impact of each option on flood behaviour. It is accepted that there is some overlap between the flood impact criteria and the criteria for economic, social and environmental assessment. For example, an impact on flooding is likely to affect the cost of flood damages and therefore impact on the benefit-cost ratio.

Notwithstanding, in light of the primary objectives of this floodplain risk management study and the relevance of the associated flood modelling results, it is considered appropriate to give this additional weighting to direct flood impacts and also the indirect consequences.

Table 9.15 TRIPLE-BOTTOM-LINE ASSESSMENT CRITERIA

EVALUATION CRITERIA	WEIGHTING	CONSIDERATIONS
Flood Impacts		
Impact on hydraulic behaviour	5	Impact on flood levels Impact on flood risk to residents
Reduction in flood damages	4	Present value of total flood damages benefit: >$4M=5, >$3M=4, >$2M=3, >$1M=2, >$0M=1, <$0M=0
Economic		
Benefit-Cost	4	Indicative benefit-cost ratio <0.2=0, <0.3=1, <0.5=2, <1= 3, >1=4, >1.5=5
Lifecycle cost of option	4	Present value of total costs (*including ongoing maintenance*) >$10M=0, >$5M=1, >$2M=2, >$1M=3, >$0.5M=4, <$0.5M=5
Social		
Impact on local community	4	Including temporary disruption to residents such as traffic, noise, dust in addition to ongoing impact on amenity
Likely community acceptance	3	Based on previous community feedback and anticipated feedback
Environmental		
Disruption to natural character of the area	3	Based on both construction impacts and ongoing impacts
Ecological impacts	4	Likely impact on existing flora and fauna

Each option was assigned a score of 0 to 5 against each criterion; 5 being the best score indicating the most beneficial impacts and zero being the lowest score or negative impacts. For the more qualitative criteria, such as ecological impacts and disruption to the natural character of the area, a median score of 2.5 was applied in the case of neutral impacts.

Where possible, the criteria were scored quantitatively; for example, the life cycle cost for each option was scored according to the present dollar value of the total life cycle costs.

Refer to **Appendix G** for the Triple-Bottom-Line assessments for each option, including justification and comments on scoring. The results are summarised overleaf.

Option – Raw Scores

TRIPLE BOTTOM LINE Evaluation Criteria	Weighting	1 Excavate channel by 1m	2 Excavate channel by 2m	3 Vegetation clearing	4 Concrete lining	5 Bridge upgrades in Abermain	6 Levee System in Weston	7A Hebburn Dam weir upgrade	7B Hebburn Dam upgrade	7C Hebburn Dam upgrade	8 Flood mitigation dam	9 Voluntary house raising	10 Voluntary house purchase
Flood Impacts													
Impact on hydraulic behaviour	5	4	5	4	4	3	1	0	1	3	2	1	2.5
Reduction in flood damages	4	4	5	3	4	1	3	0	0	1	2	4	5
Economic													
Benefit / Cost	4	1	1	3	1	0	3	0	0	0	0	5	2
Life cycle cost of option	4	0	0	2	0	2	2	5	2	1	0	3	0
Social													
Impact on local community	4	2	2	2.5	1	2	2	2	2	2	2	2.5	2
Likely community acceptance	3	2.5	2.5	4	1	2	2.5	1	1	1	2	2	2
Environmental													
Disruption to the natural character of the area	3	1	1	2	1	4	2	5	2	2	2	2	3
Ecological impacts	4	1	1	2	0	4	3	4	1	1	1	2.5	3

Option – Weighted Scores

TRIPLE BOTTOM LINE Evaluation Criteria	1 Excavate channel by 1m	2 Excavate channel by 2m	3 Vegetation clearing	4 Concrete lining	5 Bridge upgrades in Abermain	6 Levee System in Weston	7A Hebburn Dam weir upgrade	7B Hebburn Dam upgrade	7C Hebburn Dam upgrade	8 Flood mitigation dam	9 Voluntary house raising	10 Voluntary house purchase
Flood Impacts												
Impact on hydraulic behaviour	20	25	20	20	15	5	0	5	15	10	5	13
Reduction in flood damages	16	20	12	16	4	12	0	0	4	8	16	20
Economic												
Benefit / Cost	4	4	12	4	0	12	0	0	0	0	20	8
Life cycle cost of option	0	0	8	0	8	8	20	8	4	0	12	0
Social												
Impact on local community	8	8	10	4	8	8	8	8	8	8	10	8
Likely community acceptance	8	8	12	3	6	8	3	3	3	6	6	6
Environmental												
Disruption to the natural character of the area	3	3	6	3	12	6	15	6	6	6	6	9
Ecological impacts	4	4	8	0	16	12	16	4	4	4	10	12
TOTAL SCORE	63	72	88	50	69	71	62	34	44	42	85	76
RANK	7	4	1	9	6	5	8	12	10	11	2	3

The lowest scoring options were the Hebburn Reservoir options, the flood mitigation dam upstream from Abermain and the concrete-lined channel. The low scores were primarily a reflection on the high cost of the works, insufficient flood damages reduction or the potential environmental impacts.

Options 3, 9 and 10 were the highest scoring options. Accordingly, it was considered worthwhile to pursue these options further as part of Stage 2 investigations.

9.5 STAGE 2 ASSESSMENT OF FLOOD MANAGEMENT OPTIONS

Following the Stage 1 assessment consultation was undertaken with Council and OEH and it was agreed that the following structural options should be investigated further:

- Targeted vegetation clearing along Swamp Creek (*as further refinement of Option 3*). This option would be categorised as a flood modification option.
- Targeted voluntary house raising and purchase (*as further refinement of Options 9 and 10*). This option would be categorised as a property modification option.

9.5.1 Targeted Vegetation Clearing along Swamp Creek – Option S1

Despite ranking first in the Triple-Bottom-Line assessment and providing a significant reduction in flood damages, the significant cost of Option 3 (*vegetation clearing*) is likely to be prohibitive for Council.

As flood damages are concentrated at properties located in two clusters at Abermain and Weston (*refer* **Figures 8.5** *and* **8.6**), it was proposed to focus the vegetation clearing works on sections of the creek upstream from and in the vicinity of these properties.

Figure 9.19 highlights the two sections of Swamp Creek for which it is proposed to conduct targeted vegetation clearing; approximately 900 metres through Abermain and 1.6 km through Weston.

Hydraulic Assessment

The RMA-2 flood model was modified to reflect the targeted clearing works at Abermain and Weston. It was used to simulate the entire range of design flood events; between the 50% AEP event and the Probable Maximum Flood (*PMF*).

The model results were used to create difference mapping for flood levels and flow velocities for the 1% AEP event. The flood level difference mapping provided in **Figure 9.20** shows that Option S1 is expected to reduce 1% AEP flood levels by up to 0.4 metres in Abermain and 0.8 metres in Weston. The reduction in flood levels during the range of design floods is summarised in **Table 9.16**.

TABLE 9.16 DECREASES IN PEAK FLOOD LEVEL FOR OPTION S1

FLOOD EVENT	TARGETERD VEGETATION CLEARING PREDICTED DECREASE IN PEAK FLOOD LEVEL (*metres*)			
	ABERMAIN		WESTON	
	Typical	Maximum	Typical	Maximum
PMF	0.0 – 0.1	0.3	0.4 – 0.8	1.15
0.5% AEP	0.0 – 0.2	0.4	0.35 – 0.7	0.92
1% AEP	0.15 – 0.25	0.4	0.25 – 0.6	0.81
2% AEP	0.1 – 0.25	0.37	0.25 – 0.5	0.76
5% AEP	0.15 – 0.25	0.4	0.2 – 0.5	0.77
10% AEP	0.2 – 0.3	0.5	0.25 – 0.6	0.85
20% AEP	0.25 – 0.35	0.55	0.35 – 0.85	1.0
50% AEP	0.25 – 0.4	0.53	0.2 – 0.5	0.67

In comparison with the model results for Option 3 (*refer* **Table 9.4**), the flood level reductions for Option S1 are not as great, but the difference is only about 100mm, which is a decent result considering the significantly reduced scale of the clearing works.

The velocity difference mapping provided in **Figure 9.21** shows that this option has the effect of reducing 1% AEP flow velocities in some overbank areas through Abermain and Weston, with a commensurate increase in velocities within the channel.

Benefit-Cost Analysis

The capital cost of implementing Option S1 is estimated to be $1.3M (*refer* **Appendix F**), which represents more than a 60% reduction in cost over Option 3 (*channel clearing across the entire study area*). Despite the reduced cost, it may still be difficult for Council to raise this scale of funding for the works.

Refer to **Appendix H** for the Benefit-Cost analysis for Option S1, which incorporates the damages analysis for the range of design flood events listed in **Table 9.16**. The analysis incorporates a yearly maintenance cost of $30,000 to account for on-going clearing works and weed management activities.

The calculated Benefit-Cost Ratio of 1.39 shows that the reduction in flood damages is expected to outweigh the lifecycle cost of the works. Accordingly, it considered worthwhile to proceed with these works from a financial perspective (*subject to obtaining funding*).

Option S1 was review against the Triple-Bottom-Line criteria outlined in Section 9.4. It was determined that Option S1 would attract a score of more than 100, which is higher than any other option tested as part of the Stage 1 assessment.

Environmental Impacts

This option will result in the removal of a significant amount of vegetation along the creek channel, including within the bed and banks. A majority of the reed beds within the channel bed would likely be retained. During large flows these reeds typically fold over, effectively reducing their impact on flooding.

The residual vegetation comprises a combination of exotic species and native plants and trees. The exotic species include bamboo, camphor laurel, and privet amongst others.

The Hunter Central Rivers Catchment Management Authority (*CMA*) and members of the Floodplain Risk Management Committee have indicated concern over the removal of native trees and vegetation along the creek. Included in this vegetation are areas of Endangered Ecological Communities (*EECs*), which are shown in **Figure 9.19**.

As shown, the Swamp Creek channel through Abermain is recorded to be occupied by the *Kurri Sand Swamp Woodland* EEC and also *Riparian Apple – Grey Gum Dune Forest*. Pockets of the channel in Weston are also occupied by these particular ecological communities and also the *Cabbage Gum Floodplain Woodland*. It should be noted that the *Riparian Apple – Grey Gum Dune Forest* and the *Cabbage Gum Floodplain Woodland* are both included within the *River-Flat Eucalypt Forest on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner Bioregions* EEC.

It is expected that the proposed vegetation clearing works will have some impact on the existing EECs in these locations. The greatest potential impact will be in Abermain (*refer* **Figure 9.19**). However, it has been determined that the area of *Kurri Sand Swamp Woodland* that would be impacted by the works represents less than 1% of the total *Kurri Sand Swamp Woodland* area in the Abermain, Weston and Kurri Kurri regions. In relation to the immediate Abermain area, the area impacted by the works would be less than 3% of the total existing *Kurri Sand Swamp Woodland*.

Given the alignment of the vegetation corridor along the creek, the connectivity of vegetation from south to north is likely to be impacted.

It is recommended that future investigations to prepare designs and work methods for the proposed clearing works appropriately consider the impact on native vegetation and in particular, the existing areas of EECs. As a first step, it is recommended that the extent and condition of the EECs within the proposed work areas.

It is also recommended that an ecological assessment be undertaken for the works, which would incorporate flora and fauna surveys and assessments. This may involve the preparation of a Review of Environmental Factors (*REF*) and/or referral to the Office of Environment & Heritage (*OEH*), NSW Office of Water (*NOW*), NSW Fisheries and the HCRCMA.

It is also possible that threatened flora species may be present in the area of the proposed works. Threatened species nearby include Heath Wrinklewort, which has been recorded near the creek line in bushland at the unformed section of Church Street in Abermain. Earp's Dirty Gum is another threatened species which has been recorded in Kurri Sand Swamp Woodland to the west of Grey Gum Drive. The proposed works do not encroach into these specific areas; however, the REF would need to include information searches using the Atlas of NSW Wildlife/ Bionet (*for State listed species*) and the Environment Protection and Biodiversity Conservation Act (*EPBC*) Protected Matters Search Tool (*for Commonwealth listed species*).

It is suggested that an 'offset' arrangement or similar could be implemented as part of any removal of EECs. This would involve planting of the same EEC species in areas that are currently non-vegetated or consist of non-native species. Efforts should be made in the first instance to provide new sections of EEC in areas that will improve existing connectivity or create alternate connectivity between pockets of vegetation.

An additional cost of approximately $420,000 has been identified in the cost estimate for Option S1 (*refer* **Appendix F**) to cover potential vegetation 'offset' works, should they be required. This includes an allowance to acquire land (*or an easement*) and the costs of planting native species assuming an offset ratio of 2:1 (*i.e., double the lost area*). In this case the total cost of Option S1 would increase to approximately $1.9M. The resultant Benefit-Cost Ratio would be 1.15, which shows that, despite the increased cost, the works would still be worthwhile from an economic viewpoint.

Future maintenance of weeds along the creek will also need to be considered, which is often an issue following the clearing of native vegetation. It is proposed that native grasses be planted across cleared areas.

Potential for Bank Erosion

As discussed and shown in **Figure 9.21**, the removal of vegetation from the creek is predicted to increase flow velocities along the creek channel. Combined with the removal of vegetation and associated root matter, this has the potential to create bank stability and erosion issues.

Conversely, it should also be noted that there is potential for existing trees to become unstable and fall into the creek during flooding, which could act to exacerbate erosion as root systems are removed from the bank.

Accordingly, the potential for erosion and bank collapse will need to be addressed as part of the future design for the vegetation removal works. At this stage, a substantial cost allowance (*approximately 30%*) has been made for surface treatment of the cleared areas with soil stabilisation measures and native grasses, which would act to minimise future erosion. As part of the future design work, it may be that alternative measures are preferred and employed.

Summary

It is recommended that Option S1 be implemented as part of the Floodplain Risk Management Plan for Swamp Creek. Implementation will firstly involve detailed environmental assessments and further design work, prior to commencement of any works.

9.5.2 Targeted Voluntary House Raising and Purchase – Option S2

Options 9 and 10 identified properties that are subject to over-floor inundation during the 1% AEP flood and therefore, may be suitable candidates for voluntary house raising or purchase.

Further review of these options and the flooding conditions at the associated properties identified the following issues:

Voluntary House Raising

- The raising of houses above the 1% AEP flood level may increase the potential for residents to become trapped in their homes should floodwaters rise rapidly and without warning (*e.g., in the middle of the night*). By the time that floodwaters reach the raised floor level and alert residents of the danger, any effective evacuation route would have been cut-off.

- This type of increased flood risk to residents would manifest in flood events larger than the 1% AEP event and be most applicable in areas subject to high hazard flows where wading to higher ground is unsafe. These are the typical conditions in the vicinity of a majority of the houses that have been identified for voluntary raising.

Voluntary House Purchase

- As discussed above for Option 10, it is expected that the acquisition of properties subject to over-floor inundation during the 1% AEP will cost more than $14M, which is unlikely to be affordable within Council's budget, even with State funding and even over several years.

The development of Option S2 required consideration of these issues in order to refine the selection of properties that are suitable for voluntary raising or purchase. In consultation with Council and OEH, the following selection criteria were developed:

- Similar to Options 9 and 10, the considered dwellings are all subject to over-floor damages in the 1% AEP flood.

- Dwellings that are located in areas of high flow conveyance (*where the velocity-depth product is greater than 1.0* m^2/s) are expected to receive significant structural damage during a 1% AEP flood. According to Appendix L of the Floodplain Development Manual (*2005*), this is a guide as to when light structures may be impacted by floodwaters. Such dwellings were selected as candidates for voluntary purchase (*refer to properties in green on* **Figures 9.22** *and* **9.23**).

- The residual properties that are located <u>outside</u> of high hazard areas are considered suitable for voluntary house raising. These houses need to be of suitable construction to allow for house raising (*i.e., not slab-on-ground*). Refer to properties in yellow on **Figures 9.22** and **9.23**.

- The residual properties that are located <u>within</u> high hazard areas are not considered appropriate for house raising due to the potential for isolation and increased safety risk to residents, as discussed above (*refer to properties in red on* **Figures 9.22** *and* **9.23**).

As shown in **Figures 9.22** and **9.23**, according to these criteria, a total of five properties would be candidates for voluntary purchase and 10 properties for voluntary raising. This is significantly less than the 20 and 26 properties originally identified for voluntary raising and purchase, respectively.

It should be recognised that the use of the adopted property selection criteria will result in no benefit to several of the most at-risk properties located in high hazard areas, as shown by the properties in red in **Figures 9.22** and **9.23**.

For example, there are three properties in Fourth Street, Weston, that will remain in high hazard areas, while three properties closer to the creek would be targeted for purchase and one property located directly behind them would be a suitable candidate for raising. Accordingly, a situation of inequity between landowners will be created should offers for purchase or raising be accepted by the relevant candidates.

On the other hand, it should also be recognised that some residents are unlikely to accept offers for purchase or raising, which can also lead to inequity between landowners, resulting in various levels of flood protection for residents.

Benefit-Cost Analysis

The cost of implementing Option S2 is estimated to be $3.6M (*refer* **Appendix F**), which is more than double the cost of house raising alone (*Option 9*) but only one quarter of the cost of house purchase (*Option 10*).

Refer to **Appendix H** for the Benefit-Cost analysis for Option S2. As shown, the costs are expected to outweigh the flood damages benefits, thereby resulting in a Benefit-Cost Ratio of only 0.46.

If Council was to only target the purchasing of the five houses most severely impacted by flooding, this would result in only a minor reduction in the overall cost of the option, which would be offset by an increase in damages and therefore result in a similar Benefit-Cost Ratio overall.

Conversely, if Council was to only target the 10 houses recommended for raising, then the cost of the works would decrease significantly, but so will the dollar value of the damages reduction, again resulting in a similar Benefit-Cost Ratio overall.

Summary

It is not considered worthwhile to pursue any voluntary raising or purchase of flood-affected properties for the following reasons:

- The raising of houses in high hazard areas to above the 1% AEP flood level may increase the potential for residents to become trapped in their homes should floodwaters rise rapidly and without warning (*e.g., in the middle of the night*). However, an inequity will be created between landowners if such houses are excluded from the proposed house raising activities.
- Some residents are unlikely to accept offers for purchase or raising, which can also lead to inequity between landowners, resulting in various levels of flood protection for residents.
- The costs of raising and/or purchase of suitable dwellings are likely to outweigh the flood damages reduction, thereby resulting in a Benefit-Cost-Ratio of less than 0.5.
- The cost of voluntary purchase of the most severely impacted dwellings is likely to be prohibitive to Council (*approx. $3M*).

10. FLOOD EMERGENCY RESPONSE MANAGEMENT

10.1 GENERAL

The NSW State Emergency Service (*SES*) is the legislated Combat Agency for floods and it is responsible for coordinating other agencies involved with emergency management.

To allow SES to manage the emergency response to flood risk and undertake evacuation planning the SES, along with NSW Office of Environment and Heritage (*OEH*) (*formerly the Department of Environment, Climate Change and Water*), have developed guideline documents which detail their desired outcomes from the Floodplain Risk Management process. These guidelines are titled:

- *'SES Requirements from the Floodplain Risk Management Process'* (*2007*); and,
- *'Flood Emergency Response Planning Classification of Communities'* (*2007*).

Given the potential for loss of life or damage to property during flooding and in light of the emergency response guidelines, it is considered appropriate to assess the risk to the potentially flood affected communities of Abermain and Weston. This requires the updating of flood risk management procedures in light of the guidelines and recent flood modelling results (*where appropriate*), identification of those who are at risk from flooding and the assessment of measures that could be implemented to reduce the exposure of the community to flood risk.

It is envisaged that the information contained in this report will be of assistance to the SES in the verification and refinement of existing flood emergency response procedures or the development of additional protocols, if required.

10.2 CESSNOCK CITY LOCAL FLOOD PLAN (2009)

The SES and Cessnock City Council have prepared a Local Flood Plan (*2009*) as a sub-plan of the Cessnock City Local Disaster Plan (*DisPlan*). The Local Flood Plan (*LFP*) has been reviewed as part of this study to establish the existing flood emergency response protocols relevant to the Swamp Creek study area.

Based on this review, it has been determined that the LFP addresses two separate mechanisms of flooding; local catchment flooding and also Hunter River backwater flooding. The latter is covered in detail in Annex F through J of the LFP, which also considers the potential for flooding in the event of failure of the Glennies Creek Dam, located in the upstream catchment of the Hunter River.

10.2.1 Hunter River Flooding Evacuation Arrangements

In Annex F of the LFP the Cessnock City Council Area is divided into three sectors for the purposes of evacuation during extreme flooding from the Hunter River.

The study area along Swamp Creek between Abermain and Loxford is best represented by the *Loxford – Weston – Cliftleigh* sector (*refer* **Figure 10.1**). However, it is noted that the township of Abermain does not fall within this sector boundary or within any other sector.

The focus on Hunter River backwater flooding is understood to be the reason why areas upstream from the Weston Peace Park (*Chinamans Hollow*) are not covered in the detailed flood evacuation arrangements contained in the LFP.

The LFP indicates that up to 150 people may be directly affected in this area by backwater flooding in the event of failure of the Glennies Creek Dam. The SES estimates that floodwaters could reach the area within about 10 hours of dam failure.

The proposed evacuation centre for this sector would be Kurri Kurri High School, located in Stanford Street, Kurri Kurri.

According to the number of door-knockers available (*six*) and the ground to cover, it is expected that the evacuation operation would take about 5 hours to complete, indicating that sufficient warning should be available in the event of dam failure.

Although not stated in the LFP, it is also likely that sufficient warning would also be provided in the event of general (*non-dam-break*) Hunter River flooding and backing up to the Weston area.

10.2.2 Local Catchment Flooding Emergency Response

The LFP indicates that in most floods, no evacuations would be required. It is understood that this is referring to local catchment flooding scenarios, which are relatively short duration and primarily affect areas immediately adjacent to the creeks and watercourses.

Notwithstanding this, the LFP does contain various pieces of information that are specific to local flooding in the Swamp Creek study area between Abermain and Loxford:

- The June 2007 flood had the following impacts:
  - Abermain – 13 properties with over-floor flooding
  - Weston – 4 properties with over-floor flooding.
- The location of evacuation centres will be subject to decisions made by the SES Local Controller during a flood, but may include (*refer* **Figure 10.2**):
  - Abermain Bowling and Recreation Club at the corner of Armidale and Goulburn Streets, Abermain.
  - Weston Workers Club at Government Road, Weston.

- Road closure may occur at Cessnock Road between Abermain and Neath (*just west of the study area*), which would be the result of flash flooding along a small tributary of Swamp Creek. Closure may last for a few hours and would prevent travel from Abermain to Cessnock.

- A single river gauge exists on Swamp Creek at Abermain, but is understood to be a manual gauge monitored by a SES Local Reader.

- Rain gauges exist at Elrington and Neath in the catchment of Swamp Creek, but it is envisaged that these are simple daily read gauges, or monitored by a SES Local Reader on an as-needs basis.

10.2.3 Consultation

WorleyParsons spoke to Michael Slowgrove in August 2012, who is the NSW Ministry for Police & Emergency Services Emergency Management Officer for the Hunter / Central Coast Emergency Management District

Mr Slowgrove advised that while a register of disaster recovery centres has been prepared as part of the Cessnock City Council's DisPlan (*as outlined above for Abermain and Weston*), if evacuation was assessed as being required, then the location of the recovery centre would be determined by the nature of the emergency and through consultation with the SES and other agencies, such as the NSW Roads and Maritime Services.

10.3 APPROACH TO INVESTIGATIONS

The focus of investigations to review flood emergency response protocols for the Swamp Creek study area has been on local catchment flooding, rather than flooding from the Hunter River, which has been covered in some detail in the existing *Cessnock City Local Flood Plan* (*2009*).

The following approach has been employed for the investigations:

- Review the nature of flooding along Swamp Creek, including the rate of rise of floodwaters and anticipated flood hazards.

- Use this information to determine the likely warning time available for flood evacuation.

- Determine the typical duration of local catchment flooding.

- Assess the frequency at which key roads and evacuation routes will be cut (*e.g., would this occur during a 1% AEP event*).

- Use the above information to classify areas of the Swamp Creek floodplain using the SES system for classification of communities for flood emergency response planning.

- Identify measures to improve emergency response management.

10.4 INUNDATION MAPPING

The flood inundation maps prepared as part of this study using the RMA-2 flood model provide a range of useful information for emergency management, including flood depths, levels, velocities, flood hazard and the location of affected properties for a range of flood events.

In addition to informing the following assessment of emergency response considerations, it is envisaged that this mapping could be used directly by SES and Council operational staff to inform decisions during a flood. This would help to target flood responses to where they are most effective.

Furthermore, the set of inundation maps could also be compiled into a waterRIDE software package for use by SES and Council, which would allow the flood model results to be more closely interrogated, including step-by-step visualisation of the progress of flooding through the study area to identify the most critical areas in need of urgent attention.

10.5 FLOOD WARNING

According to the results of the RMA-2 flood modelling for the range of design events, it has been determined that floodwaters will start to overtop the banks of Swamp Creek and inundate the surrounding properties approximately 10 hours after the start of rainfall in the upstream catchment. The warning time may be reduced in the case of the simulated Probable Maximum Flood (*PMF*), which assumes a standard 6 hour storm duration.

It is therefore considered that there is only limited opportunity to provide advanced warning of local catchment flooding.

In general, flood warnings are provided to the community by SES according to rainfall and river data, which is provided by the Bureau of Meteorology (*BOM*). The BOM provides catchment-wide *Flood Watches*, which give an early warning of developing weather systems which could lead to flooding, and *Flood Warnings*, which include river height readings and height-time predictions. The BOM also provides severe weather warnings and warnings of flash flooding for fast response catchments.

On receipt of a flood warning, the SES Operations Controller will determine the requirements for evacuation. If evacuation is considered to be required, the warning messages are disseminated via TV and radio stations, door knocking, public address systems, telephone, two-way radio and SES Flood Bulletins.

At present there are no suitable water level gauges in Swamp Creek from which advanced flood warnings may be issued. It would only be possible to issue flood warnings from recorded rainfall or observations of the creek made by the community and the SES.

As discussed above, the Local Flood Plan (*2009*) indicates that a *Local Reader* monitors a river gauge located on Swamp Creek at Abermain. It is understood that this is not a formal gauge or automated data recorder. The LFP indicates that other *Local Readers* monitor rain gauges at Elrington and Neath in the Swamp Creek catchment.

Accordingly, the existing flood warning systems in place by SES are essentially manually operated and therefore, rely on the presence and efforts of SES volunteers during heavy rainfall / flooding. This further limits the provision of advanced flood warnings, particularly during the middle of the night when SES volunteers may not be aware of the flooding, or otherwise experience difficulties in taking rainfall or river level readings.

10.6 DURATION OF FLOODING

The results of the RMA-2 modelling indicate that the typical duration of local catchment flooding across overbank areas would be between 10 and 15 hours. It is accepted that periods of prolonged rainfall and hence inundation could occur, but an inundation period of this order is considered typical for this size catchment.

This relatively short duration of flooding indicates that any residents evacuating from creek-side properties, that are otherwise cut-off from the designated evacuation centres at Abermain Bowling Club and Weston Workers Club, would not remain isolated for an extended period of time.

Accordingly, the evacuated residents are unlikely to need any on-going assistance from the SES which can often be required in cases of extended isolation, such as food drops or air/water rescue. Local refuge at nearby higher ground is always available.

If residents are unable to return to damaged properties following a flood, then it would not be long before floodwaters recede further and access routes are again open to allow travel to flood recovery centres.

10.7 FLOOD-FREE ACCESS

The flood evacuation centres at Abermain Bowling Club and Weston Workers Club, as nominated in the Local Flood Plan, are shown in **Figure 10.2**.

The mapping in **Figure 10.2** also indicates the estimated frequency of flooding that will cause key crossings of the creek to be cut to the passage of vehicles. It is envisaged that this would assist the SES Emergency Operation Group and other government agencies make decisions about appropriate evacuation routes.

The crossings that will most frequently become cut by floodwaters are as follows:

- Fourth Street Bridge in Weston becomes inaccessible in events larger than 20% AEP event (*1 in 5 year event*).
- Elizabeth Street at the eastern subway beneath the railway in Abermain becomes inaccessible in events larger than 20% AEP event.

- Kline Street Bridge in Weston becomes inaccessible in events larger than 10% AEP event (*1 in 10 year event*).
- Cessnock Road at Chinamans Hollow (*Weston Peace Park*) becomes inaccessible in events larger than the 5% AEP event (*1 in 20 year event*).
- William Street Bridge in Abermain becomes inaccessible in events larger than 5% AEP event.
- Mitchell Avenue in Weston is cut-off at the crossing of a small tributary of Swamp Creek in events larger than the 5% AEP event.

Other crossings that are expected to be cut during larger events are as follows:

- Cessnock Road at Abermain will not become cut until the 0.5% AEP event is reached (*1 in 200 year event*).
- The Government Road Bridge will remain accessible in the 0.5% AEP event, but will be cut during the PMF.
- Frame Drive at South Deep Creek will remain accessible during the PMF.
- Charles Street to the south-west of Abermain will remain accessible in the 0.5% AEP event, but will be cut during the PMF.

According to the results of the RMA-2 flood modelling, Cessnock Road on the way to Neath is expected to remain flood-free during the PMF (*refer* **Figure 10.2**), which is contrary to the information contained in the Local Flood Plan. It is envisaged that the inundation reported in the LFP could be from very localised flash flooding across the road from the small catchment to the west of the road, which is not specifically captured in the flood model.

10.8 FLOOD MANAGEMENT COMMUNITIES

The SES guidelines highlight the need to identify Flood Management Communities. The delineation of communities within the SES' wider Operational Areas allows emergency response to be tailored for areas with differing degrees of vulnerability. Classification provides an indication of the relative vulnerability of communities located on the floodplain and helps identify the information required by SES to manage the risk. Community risk may be influenced by such factors as flood behaviour, topography and the provision of safe access and egress routes.

Figure 10.3 (*refer overleaf*) shows the process that is employed to identify Flood Management Communities.

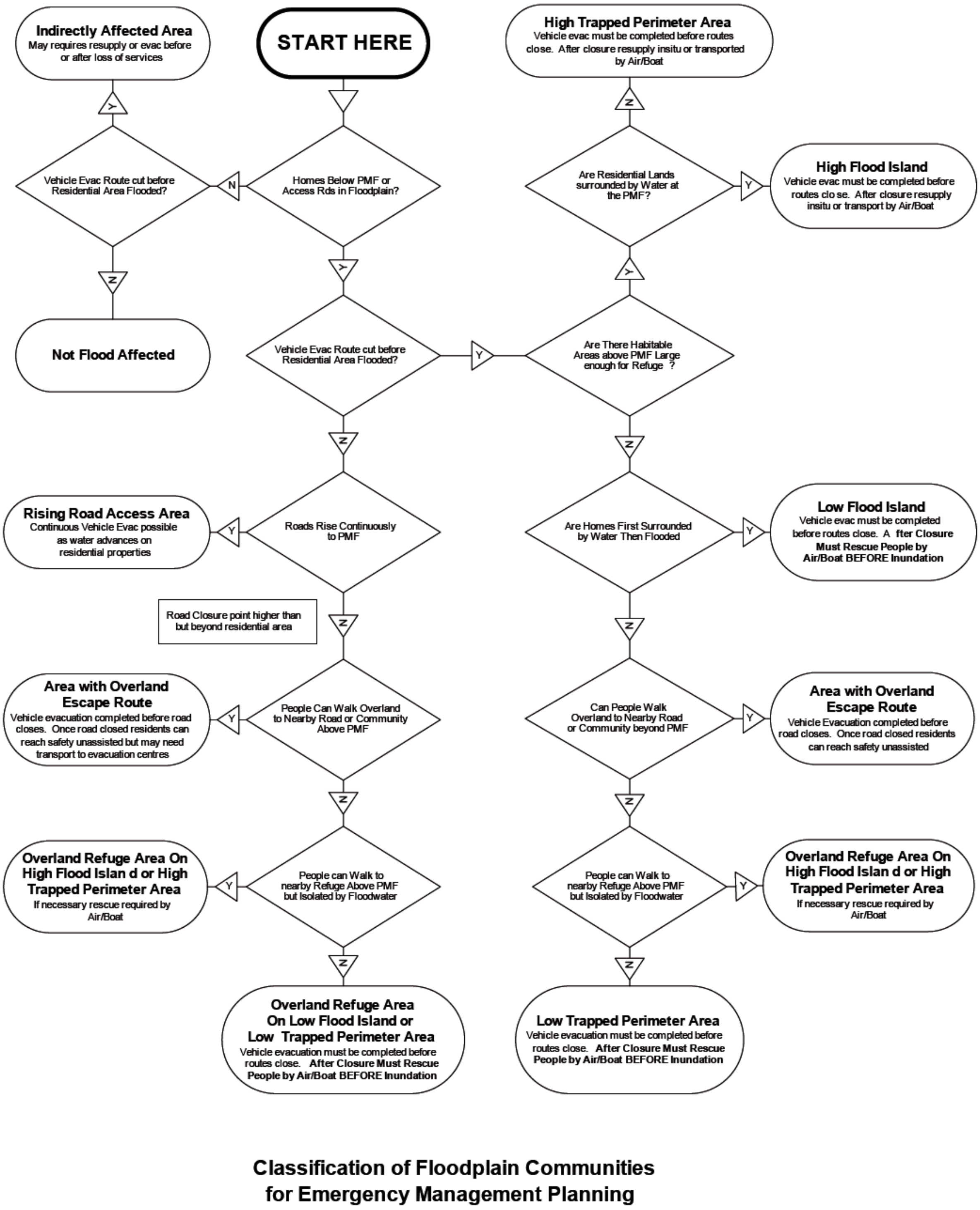


Figure 10.3 SES PROCESS FOR CLASSIFICATION OF COMMUNITIES FOR FLOOD EMERGENCY RESPONSE PLANNING

10.8.1 Classification of Communities for Flood Emergency Response Planning

The SES classifies communities according to the impact that flooding has on them. The primary purpose for doing this is to assist SES in the planning and implementation of response strategies. Flood impacts relate to where the normal functioning of services is altered due to a flood, either directly or indirectly, and relates specifically to the operational issues of evacuation, resupply and rescue.

Flood Islands

Flood Islands are inhabited areas of high ground within a floodplain which are linked to the flood-free valley sides by only one access / egress route. If the road is cut by floodwaters, the community becomes an island, and access to the area may only be gained by boat or aircraft. Flood islands are classified according to what can happen after the evacuation route is cut as and are typically separated into:

- High Flood Islands;
- Low Flood Islands.

A High Flood Island includes sufficient land located at a level higher than the limit of flooding (*i.e., above the PMF*) to provide refuge to occupants. During flood events properties may be inundated and the community isolated, however, as there is an opportunity for occupants to retreat to high ground, the direct risk to life is limited. If it will not be possible to provide adequate support during the period of isolation, evacuation will have to take place before isolation occurs.

The highest point of a Low Flood Island is lower than the limit of flooding (*i.e., below the PMF*) or does not provide sufficient land above the limit of flooding to provide refuge to the occupants of the area. During flood events properties may be inundated and the community isolated. If floodwater continues to rise after it is isolated, the island will eventually be completely covered. People left stranded on the island may drown.

Trapped Perimeter Areas

Trapped Perimeter Areas are inhabited areas located at the fringe of the floodplain where the only practical road or overland access is through flood prone land and unavailable during a flood event.

The ability to retreat to higher ground does not exist due to topography or impassable structures. Trapped perimeter areas are classified according to what can happen after the evacuation route is cut as follows.

High Trapped Perimeter Areas include sufficient land located at a level higher than the limit of flooding (*i.e., above the PMF*) to provide refuge to occupants. During flood events properties may be inundated and the community isolated, however, as there is an opportunity for occupants to retreat to high ground, the direct risk to life is limited. If it will not be possible to provide adequate support during the period of isolation, evacuation will have to take place before isolation occurs.

Low Trapped Perimeter Areas is lower than the limit of flooding (*i.e., below the PMF*) or does not provide sufficient land above the limit of flooding to provide refuge to the occupants people of the area. During a flood event the area is isolated by floodwater and property may be inundated. If floodwater continues to rise after it is isolated, the area will eventually be completely covered. People trapped in the area may drown.

Areas Able to be Evacuated

These are inhabited areas on flood prone ridges jutting into the floodplain or on the valley side that are able to be evacuated. However, their categorisation depends upon the type of evacuation access available, as follows.

Areas with Overland Escape Route are those areas where access roads to flood free land cross lower lying flood prone land. Evacuation can take place by road only until access roads are closed by floodwater. Escape from rising floodwater is possible but by walking overland to higher ground. Anyone not able to walk out must be reached by using boats and aircraft. If people cannot get out before inundation, rescue will most likely be from rooftops.

Areas with Rising Road Access are those areas where access roads rising steadily uphill and away from the rising floodwaters. The community cannot be completely isolated before inundation reaches its maximum extent, even in the PMF. Evacuation can take place by vehicle or on foot along the road as floodwater advances. People should not be trapped unless they delay their evacuation from their homes. For example people living in two storey homes may initially decide to stay but reconsider after water surrounds them.

These communities contain low-lying areas from which people will be progressively evacuated to higher ground as the level of inundation increases. This inundation could be caused either by direct flooding from the river system or by localised flooding from creeks.

Indirectly Affected Areas

These are areas outside of the limit of flooding and therefore will not be inundated nor will they lose road access.

However, they may be indirectly affected as a result of flood damaged infrastructure or due to the loss of transport links, electricity supply, water supply, sewage or telecommunications services and they may therefore require resupply or in the worst case, evacuation.

Overland Refuge Areas

These are areas that other areas of the floodplain may be evacuated to, at least temporarily, but which are isolated from the edge of the floodplain by floodwaters and are therefore effectively flood islands or trapped perimeter areas. They should be categorised accordingly and these categories used to determine their vulnerability.

Note that Flood Management Communities identified as Overland Refuge Areas on Low Flood Island have been classified according to the SES Flow Chart for Flood Emergency Response Classification (*refer* **Figure 10.3**). These are areas where vehicular evacuation routes are inundated before residential areas of the Community.

10.8.2 Flood Management Communities for Swamp Creek

Mapping of Flood Management Communities within the Swamp Creek study area is provided in **Figure 10.2**.

As shown, most of the study area can be classified as either '*High Trapped Perimeter'* areas or '*Rising Road Access'* areas.

For areas in Abermain to the west of Swamp Creek and north of Cessnock Road, there is generally vehicle access available to the evacuation centre at Abermain Bowling Club in all design events. Accordingly, these areas are classified as Rising Road Access areas.

A similar classification is given to areas in Weston and Loxford that are to the east and south of the creek (*refer* **Figure 10.2**). This part of Weston has the most population at risk of flooding up to the PMF. Evacuation away from the creek needs to take place in a timely manner, or people may become stranded. If required, residents would be able to take refuge at the Weston Workers Club, or otherwise at Kurri Kurri High School.

The most "at risk" communities located along Swamp Creek are considered to be the '*High Trapped Perimeter'* areas. However, despite the lack of continued access, for these communities there is sufficient space for residents to move to higher ground as floodwaters advance, so the direct threat to life is limited.

There is a localised area of Weston to the west of the creek that would fall into this category, due to a lack of road connection with higher ground further north (*refer red hatched area in* **Figure 10.2**).

The same would apply to areas of Abermain to the south of the creek, in addition to areas south of Cessnock Road (*'under the subway'*). Cessnock Road at Chinamans Hollow would firstly be cut during flooding greater than the 5% AEP event. Then Cessnock Road at Abermain would be cut in events greater than the 1% AEP flood.

Figure 10.2 also shows the number of people potentially at risk from flooding, which has been estimated by counting the number of properties located within the PMF extent and multiplying by a nominal occupancy rate of 3 persons per household.

The total number of at risk residents is expected to be about 1,350 (~ 450 houses); although this would be much less in flooding up to the 1% AEP event (*approximately 120 persons*).

Assuming sufficient warning time can be provided, in a 1% AEP flood it is anticipated that a door-knocking effort similar to that for Hunter River flooding would be required to warn and evacuate creek-side residents. This would

10.8.3 Vulnerable Groups

An assessment has been made to identify vulnerable groups who, due to their age or health, may be more vulnerable to flooding and may need special consideration during a flood event. This has been undertaken using available Census data as well as the results of an internet business registry search.

A search was undertaken for hospitals, care homes and schools located within the extent of the Probable Maximum Flood (*PMF*). Kurri-Kurri District Hospital is located above the level of the PMF. No care homes were identified as being located within the PMF extent. Three infant schools are located in the study area, but these are outside of the PMF extent.

The 2011 Census data showed that about 14% of the population in the study area are aged over 65. According to the total estimated population at risk during the PMF, this equates to about 190 elderly residents at risk, who may require help in moving furniture / valuables to higher floors. They may also be less mobile and require help to evacuate.

Approximately 7% of residents in the Kurri-Kurri, Weston, and Abermain areas reported that they did not have a car registered at their address. This might equate to about 100 persons within the area affected in the PMF who may require transport to be made available in the event of evacuation.

10.9 RECOMMENDATIONS

In light of the findings outlined above, it is recommended that the following measures be implemented in an attempt to improve flood emergency response management in the study area:

R1. Installation of an automated weather station (*continuous rainfall gauge*) in the upper catchment of Swamp Creek. This would ideally be operated by and linked to the Bureau of Meteorology's flood warning system. Possible locations may be Elrington, Abernethy or Kearsley (*refer* **Figure 10.4**).

R2. Installation of a telemetered river level gauge at an appropriate upstream location. In order to provide a the longest possible warning time to residents, while also picking-up a significant portion of the upstream catchment area, it is recommended that a site at the Lake Road crossing of the creek between Kearsley and Elrington be investigated further. A second automatic gauge could be installed further downstream (*say half way between Lake Road and Abermain*) to verify the gauge readings in the upper catchment and thereby confirm if the potential for imminent flooding is real (*refer* **Figure 10.4**).

R3. Establishment of appropriate venues as short-term flood refuges for the identified High Trapped Perimeter areas, including in the area of Weston to the west of the creek, which is expected to become isolated during events greater than the 10% AEP event. Consideration should also be given to temporary refuges in the areas of Abermain to the south of the creek, and those areas south of the railway (*refer* **Figure 10.2**).

R4. Update the Cessnock City Local Flood Plan with relevant information from this study, as appropriate. It is recommended that the existing door-knocking arrangements for the Hunter River flooding scenario could be adapted to also cater for a local catchment flooding scenario. Using similar resources, those residents affected by the 1% AEP flood should be able to be notified within 5 hours of receiving a flood warning. It should, however, be recognised that 5 hours warning time may not always be available in the case of local flash flooding.

It is also recommended that the following measure be implemented to increase community awareness and preparedness for flooding:

R5. Develop and implement a community flood awareness and preparedness program, working with SES to use FloodSafe education program materials.

11. THE ROLE OF PLANNING IN FLOODPLAIN MANAGEMENT

Flooding is a significant naturally occurring hazard to the utilisation of land. Since the early days of European settlement of New South Wales, development has occurred within the floodplain which has not fully appreciated the implications of the nature and extent of the flood hazard. Development of these areas has occurred due to the proximity of transport corridors such as the rivers flowing through the floodplain, the flatness of floodplain lands which rendered them easier to build on, and more recently, the relatively lower cost per hectare.

Further development of areas along the fringes of the Swamp Creek floodplain between Abermain and Loxford has occurred in recent times, including residential estates and industrial lots.

In this context, appropriate floodplain management needs to recognise the full flood risk. That is, it must relate to the whole of the floodplain and not just to one isolated component of the floodplain defined by a particular flood occurrence, such as the area inundated in the 1% AEP flood.

This, however, does not mean that there should be restrictions on development within the entire floodplain. Instead, there should be a holistic approach to the management of the floodplain commencing from its broadest extent and progressively focusing inwards to more critical aspects of the use of the floodplain, such as development on land frequently affected by floods. This holistic approach may in some cases, reveal the capacity for more intense development for certain types of land-uses, as opposed to the rigid application of a global flood standard.

Generally, the management of a floodplain is approached by the imposition of either structural or non-structural measures. Traditionally, structural measures have played a major role. However, contemporary thinking in floodplain management is more focussed toward the implementation of non-structural measures. Non-structural measures include increased public awareness, property acquisition and the establishment of flood evacuation procedures. More recently, there has been an increased emphasis on developing floodplain management plans that recommend changes to planning controls contained within Council planning instruments such as Local Environmental Plans (*LEPs*) and Development Control Plans (*DCPs*).

11.1 FLOOD PLANNING LEVEL

The Flood Planning Level for the Swamp Creek study area has been determined according to the 1% AEP flood level plus a 0.5m allowance for freeboard. WorleyParsons' *waterRIDE* software has been used to apply the 0.5m freeboard to the detailed flood modelling results for the 1% AEP flood to prepare a map of the Flood Planning Area (*refer* **Figures 11.1** *and* **11.2**).

In order to account for potential backwater flooding from the Hunter River, the adopted 1% AEP modelling incorporates a tailwater level equivalent to the 1% AEP Hunter River flood level. Despite the fact that the focus of this study is the management of local catchment flooding, the tailwater effects from the Hunter River will influence peak flood levels at the very downstream limit of the study area. Accordingly, the consideration of Hunter River flooding is appropriate for the purposes of setting the Flood Planning Level.

11.2 REVIEW OF CURRENT PLANNING INSTRUMENTS

A review of Council's existing planning instruments was undertaken. This primarily involved the review of the Cessnock Local Environmental Plan 2011 (*LEP*) and the Cessnock Development Control Plan 2010 (*DCP*).

11.2.1 Cessnock Local Environmental Plan 2011

Flood-related clauses are contained in Section 7.3 of the LEP as follows:

7.3 Flood planning

(1) The objectives of this clause are as follows:

(a) to minimise the flood risk to life and property associated with the use of land,

(b) to allow development on land that is compatible with the land's flood hazard, taking into account projected changes as a result of climate change,

(c) to avoid significant adverse impacts on flood behaviour and the environment.

(2) This clause applies to land at or below the flood planning level.

(3) Development consent must not be granted to development on land to which this clause applies unless the consent authority is satisfied that the development:

(a) is compatible with the flood hazard of the land, and

(b) is not likely to significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties, and

(c) incorporates appropriate measures to manage risk to life from flood, and

(d) is not likely to significantly adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses, and

(e) is not likely to result in unsustainable social and economic costs to the community as a consequence of flooding.

(4) A word or expression used in this clause has the same meaning as it has in the Floodplain Development Manual (ISBN 0 7347 5476 0), published in 2005 by the NSW Government, unless it is otherwise defined in this clause.

(5) In this clause, ***flood planning level*** means the level of a 1:100 ARI (average recurrent interval) flood event plus 0.5 metre freeboard.

These clauses are considered to be typical of flood-related controls contained in most LEPs prepared by Local Government. Clause 3 refers to the need to satisfy Council that any proposed development will not increase the risk to life, or impact on other properties.

These controls, although adequately spanning the fundamentals of best floodplain management practice, like most LEPs they do not contain any specific quantification of items; e.g., the tolerable limit of flood level increases resulting from a development.

The Flood Planning Level is specified as the 100 year ARI (*1% AEP*) level plus 0.5 metres freeboard, and it is clear that this section of the LEP applies to land at or below this level.

11.2.2 Cessnock Development Control Plan 2010

The Cessnock DCP 2010 contains General Guidelines in Part C and guidelines for Specific Development in Part D. Controls for Specific Areas are provided in Part E of the DCP.

Part C contains several sections, including Contaminated Lands, Waste Management and Minimisation, and Trees and Vegetation Management. It is noted that there is no section specifically related to flooding and drainage.

Part D – Specific Development

Part D of the DCP includes sections for Subdivision (*D1*), Urban Housing (*D2*) and Industrial Development (*D3*). Sections D2 and D3 contain no controls related to flooding.

Section D1 – Subdivision includes the following relevant clauses:

> 1.3.1 General Development principles with respect to subdivision:
>
> (iii) adequate all weather flood-free access shall be available to each allotment to be created by the subdivision and located so as to minimise the risk of soil erosion
>
> (v) each allotment to be created by the subdivision shall include flood-free land for building sites and in rural areas for the movement of stock during floods

Under specific requirements for RU2 Rural Subdivision and for R5 Large Lot Residential Subdivision, the DCP contains the requirement that:

> Subdivision of flood prone land shall not result in increased risk to life or property, on the subject land or adjoining lands.

It is noted that the Flood Planning Level is not referred to in the DCP. It is also noted that the Dictionary within the DCP does not contain any definition of *flood prone land* or *flood-free land* or any attempt to draw these back to the Flood Planning Level.

Schedule 3 of Section D1 – Subdivision includes some specific information on land at *Abermain North* that is zoned R5 Large Lot Residential under the LEP. The location and extent of the area in question is shown in **Figure 11.1**. Schedule 3 refers to a very limited area along Deep Creek being classified as floodplain or drainage according to criteria used in slope stability and soils reporting. Erosion and sediment control measures are required according to the included controls, but there is no reference to flood related controls in Schedule 3.

Part E – Specific Areas

The specific areas of the DCP that are relevant to the Swamp Creek study area include E.5 – Gingers Lane Weston, and E.6 – HEZ (Hunter Economic Zone).

The Gingers Lane area at Weston is shown in **Figure 11.1**. As discussed in Section 4, the HEZ is located in the subcatchment upstream from Hebburn Reservoir (*refer* **Figure 4.3**).

The controls relating to HEZ (*Section E.6*) do not include any specific flood-related controls, but they do refer to the Water Cycle Management Strategy that has been developed for the site, which is understood to include provisions for drainage and appropriate stormwater management.

Gingers Lane Weston is a subdivision in the R5 Large Lot Residential zone and hence contains lots that are typically 1 hectare in size or larger.

Section E.5 of the DCP contains the following information regarding Swamp Creek:

Importance of Swamp Creek

Swamp Creek traverses the southern portion of the site and adjoining lands. It provides important habitat for resident wombats, aboreal and terrestrial mammals and provides access linkages between the site and surrounding lands.

The southern portion of the land contains important riparian habitat, potential archaeological reserves and is unsuitable for building due to flooding constraints. It is also an integral corridor link in the movement of fauna throughout the site and through to the adjacent Peace Park / Chinaman's Hollow.

In light of primarily riparian and other conservation issues, the development precinct was separated into *Conservation Precinct 'A'* and *Development Precinct 'B'* (*refer* **Figure 11.1**). The construction of dwellings and other development is essentially limited to Development Precinct 'B' (*excluding special controls for fencing*).

As shown in **Figure 11.1**, the Development Precinct 'B' is located outside of the Flood Planning Area for Swamp Creek

The only other reference to flooding in Section E.5 is contained in the Road Design section, which indicates that the existing subdivision plan incorporated a road layout that permitted flood-free access to each lot. Investigations completed for emergency response planning (*refer* **Section 10**) confirm that flood-free access is provided to each lot.

11.2.3 Abermain North Development Area

The appropriateness of the proposed development at Abermain North has been reviewed in the context of the flood modelling results and mapping prepared as part of this study.

The footprint of the Development Principles Plan (*as contained in Schedule 3 of Part D1 of the DCP*) is overlaid on **Figure 11.1** for comparison to the Flood Planning Area.

As shown, the precinct is located to the north of the Flood Planning Area map for Swamp Creek. However, it is estimated that the Flood Planning Area along Deep Creek and South Deep Creek will encroach into approximately 50 to 60 of the new lots in the Abermain North development area. Up to 10 lots would be completely within the Flood Planning Area.

Hence, it is recommended that the proposed Development Plan and associated lot layout be assessed in more detail against the hydraulic category and flood hazard mapping presented in previous sections, in addition to emergency response management considerations.

11.2.4 Industrial Developments along Mitchell Avenue, Weston

Although not covered by the DCP, it is understood that there has been increased industrial development in the vicinity of Mitchell Avenue in Weston, which is located on the southern floodplain of Swamp Creek.

The approximate extent of the industrial development area (*including pre-existing and recent development*) is shown in **Figure 11.2** relative to the Flood Planning Area for Swamp Creek. It is understood that development of the area is on-going.

Council has indicated that there is no formal Development Plan or Policy for the area. As shown in **Figure 11.2**, the FPA encroaches into a significant portion of several sites along Mitchell Avenue and therefore, it is important that appropriate flood-related planning controls are applied.

11.2.5 Recommendations

The existing flood-related controls contained in the Cessnock DCP 2010 are considered to be lacking in detail compared to standard Flood Policies or Flood DCPs used by other NSW Councils.

The relevant controls in the Cessnock DCP include the requirement for flood-free access and flood-free land for building sites. They also require that any subdivision of flood prone land shall not result in increased risk to life or property, on the subject land or adjoining lands.

While these are sound principles that form the basis for good floodplain management, there is a lack of definition surrounding the terminology used in the DCP, including any correlation between flood prone land, flood-free land and the Flood Planning Level. Furthermore, there appear to be no flood-related controls that apply to Urban Housing or Industrial Development at existing sites.

Accordingly, it is recommended that a new Flood DCP or Flood Policy be developed, or otherwise a new chapter of the DCP be added to address flood-related planning controls. This is in accordance with Cessnock City Council's *Delivery Program & Operational Plan*, which includes the following action:

> 3.1.1.3 – Review the heritage, flooding and urban housing chapters of the Development Control Plan

It is noted that Patterson Britton & Partners (*now a part of WorleyParsons*) were previously working with Council to develop a *Cessnock City-Wide Flood Liable Lands Development Control Plan*. The DCP was last issued in draft format in 2006 (*Issue No.1*).

It is recommended that this draft DCP be finalised through consideration of the results of any flood modelling investigations completed since 2006. The Flood DCP / Flood Policy would not only apply to the Swamp Creek study area, but would instead cover the entire Cessnock LGA.

In conjunction with the development of a Flood DCP / Flood Policy, it is recommended that Council consider flood-related constraints as part of strategic planning, and also an update of the development assessment process.

11.3 PREPARATION OF A FLOOD DCP / FLOOD POLICY – OPTION P1

11.3.1 General

Ideally, a Flood DCP or Flood Policy should not just relate to development control but should also inform strategic planning decisions that determine and shape future development precincts.

In this regard, it should also be able to be linked to Council's Local Environmental Plan (*LEP*) and in particular to any available mapping of the Flood Planning Area and where possible, hydraulic category classification of the floodplain.

As an example, WorleyParsons and Council have defined hydraulic categories for the Swamp Creek floodplain as part of this Study. In particular, analysis has been undertaken to determine floodway areas which will need to be preserved into the future to ensure the orderly conveyance of floodwaters in major flood events.

Also, substantial investigation has been undertaken to understand potential emergency response management issues and to prioritise areas of the floodplain where evacuation may need to be undertaken in major flood events.

This hydraulic data-set is essential for sustainable planning and needs to be built into the psyche of those involved in strategic and emergency response planning in the study area. It is therefore important for the new Flood DCP/Policy to be linked to Council's Local Environmental Plan 2011 and to ensure that flood constraints are understood both at the strategic planning and development control level.

It is important to recognise that any Flood Policy or DCP needs to be "owned" by those parties that need to implement it. Therefore it needs to:

- be able to be interpreted and applied by planners and engineers involved in development assessment;
- be able to be interpreted and applied by developers, planners and engineers working in the private sector;
- be able to guide strategic planning at a regional and local level; and,
- be able to inform emergency response managers such as the State Emergency Service.

11.3.2 Flood Related Issues for Development Controls

The following issues should be considered:

- The need for appropriate development controls across a range of specific land uses.
- The presentation and format of the Flood Policy / Flood DCP.
- The associated Development Application assessment process.

Suggestions for inclusion in a Flood DCP / Policy are outlined below. These recommendations are provided primarily as a prompt for further discussion and work-shopping with Council, including staff from planning and engineering groups.

11.3.3 General Recommendations

A number of general recommendations for inclusion in the Flood DCP/Policy are listed below:

- Development controls recommended in the Flood DCP / Policy are to apply to flood prone land as defined by the *NSW Floodplain Development Manual* (*2005*). This refers to land affected by flooding for events up to and including the PMF.
- In this regard, the Flood DCP / Policy will supplement and provide additional information on the flood related clauses in the Cessnock LEP 2011, which applies to land affected by the "standard" Flood Planning Level.
- A summary of flood and floodplain management studies completed to date are to be provided (*e.g., this report for Swamp Creek*), including a summary of the data available which is relevant to the development applications (*e.g. hydraulic categorisation mapping*).
- A number of precincts may be identified, to which specific development controls may apply.

11.3.4 Permissible Development for Land Use Types

Hydraulic categorisation mapping, which defines floodway extents and flood storage areas has been completed for Swamp Creek. The hydraulic categorisation is summarised in **Section 7**. Flood hazard mapping has been prepared and is documented in **Section 6**.

Flood related controls which may apply to development are typically defined by a combination of the hydraulic and hazard classification and the proposed land use. As outlined in **Section 7**, the Floodplain Development Manual identifies three hydraulic categories, "floodway", "flood storage" and "flood fringe". The Manual identifies two hazard categories, namely "high hazard" and "low hazard". It is possible for any combination of hydraulic and hazard category to occur, although some are more likely (*e.g. "high hazard floodway"*) while others are less likely (*e.g. "high hazard flood fringe"*).

Three specific land use categories, namely "existing development", "infill development" and "rural" are discussed in the following as examples of the protocols recommended for consideration in the Flood DCP/Policy.

It is recognised that a range of land use types are not specifically addressed below (*e.g., subdivision*); however, these would need to be addressed in the draft Flood DCP.

11.3.5 Existing Development

Modifications to existing development may be subject to flood related controls that apply to any other development. That is, the presence of an existing development doesn't provide a "blank cheque" to carry out modifications as desired.

However, there is scope to modify existing development in certain circumstances, where new development would not normally be permitted. This is due to the fact that these modifications may be carried out while not fundamentally altering flood effects on adjacent properties or increase the demand on flood evacuation resources.

The following controls are recommended for existing development:

- Extensions to existing development are permissible in all areas except those defined as a “high hazard” floodway. Appropriate management of existing development in a high hazard floodway is discussed in detail below.

- Where extensions are carried out in a “low hazard” floodway, they are not to extend across the lateral path of floodwaters, unless it can be demonstrated that the flow is already blocked by a substantial structure upstream (*e.g., a building, but not merely a fence*).

- The permissible floor area for extensions to existing development will be defined in the Flood DCP/Policy. A variable scale would be proposed, favouring floor areas above the Flood Planning Level. Any extensions below this will be subject to strict limits, with no extensions allowed below the 5 AEP flood level.

- No flood related restriction will apply to an increase in the floor level sited above the residential Flood Planning Level, provided the applicant can satisfy that there is no increase to the population at risk associated with the proposal.

- Modifications to existing development may be exempt from any Flood Impact Assessment or Flood Risk Assessment, provided they conform to the recommendations outlined above.

- If a dwelling exists in a high hazard floodway and is destroyed by fire or other natural event, the replacement of the dwelling may be considered if the following can be demonstrated:

  - The dwelling has been permanently occupied immediately prior to the loss of the dwelling,

  - The replacement dwelling must meet current flood planning requirements. This may require the dwelling to be relocated within the property to a less hazardous area. Alternatively, the property may be considered for voluntary purchase.

11.3.6 Infill Development

Infill development refers to new developments (*dwellings or industrial lots*) on existing properties in areas currently zoned for that type of development.

The recommendations listed above for modifications to existing development will in general also apply to infill development. However, infill development is also subject to a number of additional controls, including:

Infill development will be considered in high hazard areas, provided it meets the following conditions:

- Not in a high hazard floodway area.
- A building entitlement already exists.
- The development is limited to single occupancy dwellings.
- There is a limited number of similar sites in the same area. This number will be a function of the evacuation requirements and population at risk.

Each proposal will be considered on case by case basis. A Flood Impact Assessment and/or a Flood Risk Assessment may be required.

11.3.7 Rural

A number of recommendations are made in regard to assessing development proposals for rural land use. Given the nature of the development, these are principally associated with appropriate evacuation requirements. The following is recommended for inclusion in the Flood DCP/Policy:

The development may be acceptable, subject to consideration of potential evacuation issues and provided the land use conforms to the following:

- the fill footprint area is below a limit, expressed as the lower of either an absolute area (*say 200 m^2*) or as a percentage of the total site area (*say 20%*); and,
- a minimum distance between the fill platform and the upstream and lateral property boundaries is maintained (*say 20 metres*);
- a minimum culvert cross sectional area of (*say*) 5 m^2 is provided along every 100 metres of any new access road or driveway constructed across the path of flooding.

The following is proposed for any rural development classed as 'Flood Island', 'Trapped Perimeter', 'Rising Road Access' and 'Overland Escape Routes' as defined by the Floodplain Risk Management Guideline titled, *'Flood Emergency Response Planning Classification of Communities*' (*SES*, *DECC, 2007*).

- The applicant must demonstrate that there is sufficient available warning time to facilitate evacuation along the proposed route.

- Safe evacuation will need to be provided from the development to land above the PMF, preferrably to an approved flood evacuation centre.

Where the above is not possible, a proposed evacuation route from a rural property must conform with the following requirements as an absolute minimum:

- The absolute minimum flood immunity for an evacuation route, including any proposed access road is the 5% AEP flood level.
- The evacuation route should grade upwards towards land above the PMF.
- Where it is not feasible for the access road to facilitate safe evacuation to an area flood-free during the PMF, an alternate all weather access track must be available which leads to land above the PMF (*i.e., high ground on or adjacent to the site*).
- If a site above the PMF is not possible the Flood Planning Level (*FPL*) shall be raised to the PMF to provide on-site refuge.

Notwithstanding the above development controls, the proposed Flood DCP / Policy will need to include provision for activities and ancillary development on the floodplain, which are considered consistent with the rural zoning.

11.3.8 Other General Flood Related Controls for All Land Use Types

The following protocols, which typically apply across all land use types, are recommended for consideration in the Flood DCP / Policy:

- No development should be permitted in areas classed as a high hazard floodways.
- Similarly, no new development should be permitted in low hazard floodways, since this will still impede the flow of floodwater.

11.3.9 Presentation and Format of the Flood DCP

In regard to land use, it is recommended that the DCP / Flood Policy be structured to address each land use type in an individual sub-section of a chapter which addresses applicable flood related development controls. It is anticipated this would also include a section listing what controls (*if any*) are common to all land uses.

While this approach may generate a certain repetition of controls within the document, this structure is considered to better delineate different controls for the majority of users of the Flood DCP / Policy. Similarly, this process can be streamlined, when used in conjunction with a standard assessment matrix approach.

11.3.10 Exempt and Complying Developments

It is recommended that any development that falls within a floodway or flood storage area should not, by definition, be a complying development.

11.3.11 Management of Climate Change

Councils are required to consider the impacts of projected sea level rise and the impact of climate change in establishing suitable planning controls. These requirements are outlined in the Department of Environment & Climate Change Guideline titled, *'Practical Consideration of Climate Change'* (*2007*).

Sea level rise is not expected to affect the Swamp Creek study area. Flood modelling has been carried out to assess the potential increase in 1% AEP flood levels along Swamp Creek due to increases in rainfall intensities associated with climate change (*refer* **Section 5**).

11.3.12 Internal Council Development Application Referral and Approval Process

It is suggested that the following approach be adopted for Council's internal referral and approval process:

- The planning group/section is to define the flood immunity, hydraulic and hazard category of the property from the available information.
- All development applications for land above the FPL be managed by development planners, except for applications relating to critical infrastructure (*e.g. electrical sub-stations, water supply infrastructure, emergency management facilities*) and vulnerable development (*e.g., nursing homes*).
- Flood fringe development proposals will need to be assessed on a case by case basis, with reference to the proposed land use. As a first pass, it is recommended that proposals for critical infrastructure, vulnerable development and sub-division are referred internally for specialist assessment.
- Development in areas proposed as flood storage and floodway should be referred internally for specialist assessment.
- Additionally, all sub-division and rezoning applications should be referred internally for specialist comment.

11.4 FLOOD-RELATED CONSTRAINTS FOR STRATEGIC PLANNING – OPTION P2

Ideally, a Flood DCP or Flood Policy should not just relate to development control but should also inform strategic planning decisions that determine and shape future development precincts.

Flood related constraints need to be considered as part of the strategic planning for future development and land release areas.

The flood constraints of greatest importance to this process are:

- Has the Flood Planning Area been considered in terms of defining development precincts?
- Has the full range of floods been considered? If the land release precinct looks like it will be suitable for development in floods up to the planning flood (*i.e., the 1% AEP flood*), will there be the risk of a disaster if a flood that is a little larger occurs?
- Have emergency response management issues been considered? Can people who would live in future development precincts be safely evacuated should a flood rarer than the planning flood occur? What happens in a PMF?

In conjunction with this, it is important for Council's planners to consider the potential cumulative impact of future development on flooding and the potential for evacuation before actually promoting development as part of separate land release precincts.

There can be no doubt that as population grows, pressures will increase to push development down into the floodplain. This Study, and similar studies for other floodplains, will provide the flood data that will identify those areas of the floodplain that will need to be preserved into the future for the purposes of flood conveyance.

Hence, the pressures for future development are likely to extend into flood storage areas. The loss of some of these flood storage areas can be justified both hydraulically and from the perspective of not sterilising all of the floodplain. However, it will be necessary to establish the cumulative impact of potential future development scenarios on flooding. Therefore, the following should be considered:

- Identification of the future development precincts that are earmarked for the next 20 years and a hydraulic analysis of the cumulative impact of all of those areas being developed (*i.e., filled*).
- Identification of those areas currently zoned RU2 Rural Landscape (*and RU4 Primary Production Small Lots*) that are likely to be the subject of rezoning applications at some stage over the next 10 years. These should be assessed as soon as possible to determine a Council position on whether development of these areas would be consistent with Council's overall strategy for development or whether their development would be at odds with flooding constraints under a cumulative impact scenario.
- Assessment of individual development precincts in total rather than ad hoc site specific Flood Impact and Flood Risk Assessments.

11.5 UPDATE OF DEVELOPMENT ASSESSMENT PROCESS – OPTION P3

It is also considered worthwhile to update Council's development assessment process so that it takes advantage of the new flood data that has been generated from recent work undertaken for the Swamp Creek Floodplain Risk Management Study (*and similar studies*).

This new data includes flood fringe, flood storage and floodway extent mapping, emergency management data including critical road level information, and provisions for the impact of climate change. This data should be considered for all development proposals within the Flood Planning Area.

It is suggested that the following steps form the basis for development assessment:

Step 1 Establish whether the site of the proposed development falls within the Flood Planning Area (*FPA*) as defined in mapping similar to that in **Figures 11.1** and **11.2**.

If critical infrastructure / services are proposed on the land, assess whether the land falls within the area between the FPA and the PMF extent.

Step 2 If the development site falls within the FPA, establish whether the proposed land use is appropriate relative to the flood conditions. This should consider peak flood level, depth, hazard and the location of the site relative to floodway, flood storage and flood fringe areas that have been mapped in this study and similar studies.

Step 3 If the development site falls within a designated floodway, development should be refused.

Step 4 If the development site falls within a designated flood fringe or flood storage area, then consideration of the development proposal can proceed in accordance with the requirements of Council's Flood DCP / Flood Policy.

Step 5 The development site should be assessed relative to the requirements of the Flood Policy to establish whether:

(i) a Flood Impact Assessment is required, involving an assessment of the potential for adverse impacts on adjoining property measured in terms of increases in peak flood level and/or flow velocity;

(ii) whether a Flood Risk Assessment is required, measured in terms of the risk to future occupants of the site, including consideration of evacuation potential; or,

(iii) whether both a Flood Impact Assessment and a Flood Risk Assessment are required.

Step 6 Ensure the proponent undertakes investigations required to address the conclusions drawn from completing Step 5, viz.:

- Undertake flood modelling as required to complete a Flood Impact Assessment for the development proposal

- Undertake emergency response management assessment to minimise any risk that the development could result in loss of life.

Step 7 Assess the development proposal and the outcomes from Steps 2 to 6 inclusive relative to the Flood Policy.

The application of the above process would be intrinsically linked to the proposed Flood Policy / Flood DCP. As discussed, it is to be prepared as an LGA-wide Flood DCP or Policy that is linked to the LEP 2011 and hydraulic category mapping that has been generated as part of this study and similar studies.

12. COMMUNITY CONSULTATION

As discussed in **Section 2.1.3**, community consultation activities were initially undertaken during the exhibition of the 2011 report titled, *'Abermain / Weston Floodplain Risk Management Study; Preliminary Options Assessment'*, prepared by WorleyParsons.

The outcomes of this consultation led to the further detailed investigation of potential flood mitigation options, such as excavation of the channel bed, the clearing of vegetation from the channel and flood detention options for Hebburn Dam, as outlined in the above report.

12.1 PUBLIC EXHIBITION OF DRAFT REPORTS

A draft of this Floodplain Risk Management Study (*and Plan*), incorporating the majority of recommendations in **Section 13**, was placed on public exhibition for a period of approximately six weeks during August and September 2013.

A community information session was held at the Kurri Kurri Community Centre on 5th September 2013. Approximately 10 local residents attended the session and were interested to discuss the project and recommendations.

12.2 PUBLIC SUBMISSIONS

Two submissions were received during the exhibition period. Copies of the submissions are included in **Appendix J**. A summary of the key floodplain management issues is provided in **Table 12.1** overleaf, along with a discussion of these issues in the context of the study recommendations. The implications on the final recommendations of the Floodplain Risk Management Study and Plan are also outlined, where relevant.

Note that the submissions also contain some comment on wider catchment management issues, such as the source of sediments draining to the creek and the potential contamination of these sediments. Addressing any related issues in detail has not been within the scope of this Floodplain Risk Management Study, which is focused on the magnitude and volume of flows along the creek rather than the water quality within the creek.

Notwithstanding this, it should be recognised that some allowance for dealing with potentially contaminated sediments has been incorporated into the cost estimates of mitigation options, typically within 'environmental management' contingencies (*refer to cost estimates in* **Appendix F**).

Table 12.1 PUBLIC EXHIBITION COMMENTS

ISSUE RAISED/ RECOMMENDATION	DISCUSSION	REPORT REFERENCE
Excessive cost of works to excavate the channel (*Options 1 and 2*).	The cost estimates of $15.7m and $25.3m for Options 1 and 2 incorporate an allowance for works across the entire study area between Abermain and Weston (*9.5km length*). If works are to be confined to comparatively short sections, it is estimated the costs would still be in the order of $10m to $15m. Conservatively assuming the same level of flood reduction, the Benefit-Cost Ratio would still be less than 0.5. The selected option of targeted vegetation clearing is more worthwhile from a benefit-cost perspective.	Section 9.2.1
Time of Concentration: Detention options at the Hunter Economic Zone (HEZ) and Hebburn Dam	The critical duration storm for flooding along Swamp Creek has been assessed as part of the 2011 *Wallis and Swamp/Fishery Creeks Flood Study*. As in all flood modelling, the critical duration relates to a theoretical catchment-wide storm, which can be different to each historic storm event but is regarded as the most appropriate approach for design flood modelling. The critical duration of flows from HEZ catchments (*as calculated in HEZ stormwater reports*) and from Hebburn Dam is much shorter than that of the upstream Swamp Creek catchment, meaning that the temporary detention of flows from these areas can lead to a coincidence of peak flows from the two sources, thereby potentially increasing downstream flows to Weston. This has been confirmed through detailed hydrologic modelling of the entire catchment.	Section 9.2.6
Use of detention basins in the HEZ site	The effect of the existing HEZ detention basins (*culverts beneath the HEZ road*) is to reduce the previous 1% AEP flow from Hebburn Reservoir to about the magnitude of the 5% AEP event. While this represents a 30% decrease in flow from Hebburn Reservoir, the effect on downstream peak flows in Swamp Creek is a reduction of less than 4%. Further incorporation of slotted gabion walls upstream from the HEZ culverts is not expected to provide any additional flood storage to that already provided in the HEZ basins. For other suggested detention options at the western end of the HEZ site, the percentage of flow reduction claimed in shorter duration events will not be as great during longer duration storms that are critical to the wider catchment.	Section 9.2.6

Use of Hebburn Dam to provide flood detention	Three related options have been assessed as part of this report, which showed that significant reconfiguration of the dam is required to provide any notable reduction in downstream Swamp Creek flows. The modification to the existing reservoir, either via raising the embankment or installing a low flow outlet, will trigger dam safety considerations, which will require that the dam can safely pass the Probable Maximum Flood or similar extreme event. This requires additional works and costs, as outlined for Options 7B and 7C.	Section 9.2.6
Clearance of obstructions at Cessnock Road crossing of Swamp Creek at Abermain	The modification of the existing road bridge and railway bridge, in addition to services, to raise them above the 1% AEP flood level has been investigated as Option 5. It was shown that this would only provide limited benefit for properties as far upstream as William Street. The reduction in flood damages is not expected to outweigh the cost of works at Cessnock Road, which would involve significant traffic management, and create inconvenience to motorists. The removal of any unused pipes beneath the road bridge may be possible with minimal traffic disruption, but the potential benefit on flood hydraulics would be limited due to the remaining impact of piers and other critical service lines. Notwithstanding this, an additional Option S3 has been incorporated into Floodplain Risk Management Study and Plan to investigate the removal of existing service pipes that are no longer in use, particularly if the pipes are at mid-height between the creek bed and the level of Cessnock Road bridge.	Section 9.2.4
Clean out the vegetation choked narrow gorge at Fifth Street, Weston	The clearing of vegetation in this location is included within the scope of works for Option S1, which has been selected for implementation.	Section 9.5.1
Increase in flood flow passage at Loxford to minimise flooding in Kurri Kurri	The Kurri Kurri drain, and associated flooding through Kurri Kurri, is not included within the study area for the Swamp Creek Floodplain Risk Management Study and Plan. It is understood that areas of Kurri Kurri are above the floodplain of Swamp Creek and are therefore, affected by local overland drainage issues rather than mainstream flooding. Accordingly, options to improve drainage through Kurri Kurri have not been investigated.	

Channel excavation options: Potential for excavated material to be sold, thereby improving benefit-cost	At this stage, no cost allowance has been made for the sale, treatment, or disposal of excavated materials as part of Options 1 and 2, which is considered to be appropriate in light of the following. The incorporation of standard material disposal costs would likely double or triple the overall cost of Options 1 and 2. And so the cost estimates have assumed that the material can be used elsewhere. A deposit site has not been chosen, but it is acknowledged that environmental assessments would be required for any such disposal. If the excavated material is to be sold, then it is expected that significant treatment costs would offset any benefit from the sale of the material.	Section 9.2.1
Climate Change assessment	The flood modelling of potential climate change impacts has been completed and is documented in Section 5.4. This has included the assessment of the 1% AEP storm with increased rainfall intensities of 10, 20 and 30%. Council will consider the results of this assessment in the development of appropriate flood planning controls as part of the recommended Flood DCP/ Policy.	Section 5.4

13. RECOMMENDATIONS

It is recommended that the Floodplain Risk Management Plan for Swamp Creek contain the following inclusions. The recommendations have been developed in light of the structural options assessment conducted as part of this study and through review of emergency response measures and planning controls. Community feedback during public exhibition of the Draft Study has also been considered.

It should be noted that the implementation of these measures (*particularly on-ground structural works*) will be subject to funding and further investigations.

13.1 FLOOD MODIFICATION WORKS

The following flood modification works have been identified as an outcome of this study:

S1. **Targeted Vegetation Clearing along Swamp Creek**

It is recommended that targeted vegetation clearing along the creek be undertaken at the areas identified in **Figure 9.19**. This option is expected to reduce 1% AEP flood levels by up to 0.4 metres in Abermain and 0.8 metres in Weston, thereby reducing the Average Annual Damages by $188,000.

The calculated Benefit-Cost Ratio of 1.39 shows that the reduction in flood damages is expected to outweigh the lifecycle cost of the works (*refer* **Table 13.1**). This option also scored highest in terms of Triple-Bottom-Line compared to all other options.

Table 13.1 BENEFIT-COST ANALYSIS FOR OPTION S1

OPTION	DESCRIPTION	CAPITAL COST	PRESENT VALUE OF COSTS	PRESENT VALUE OF DAMAGES REDUCTION	BENEFIT-COST RATIO
S1	Targeted Vegetation Clearing	$1.27m	$1.38m	$1.92m	1.39

It is envisaged that the exact scale and extent of works could be further refined (*and possibly reduced*) at the concept and detail design stages of the works, in order to provide an economically achievable outcome for Council and OEH. Alternatively, a staged implementation could be pursued in order to align with restrictions on Council's budgeting, which would target the most worthwhile areas first.

It is recognised that further environmental assessment is required as part of initial design work to confirm the extent and potential impact on Endangered Ecological Communities

(*EECs*) at the proposed sites for vegetation removal. This will require flora and fauna surveys, and may result in the investigation of suitable vegetation offset arrangements.

S3. **Investigate and Remove any Unused Services Pipes at Cessnock Road, Abermain**

The investigation of Option 5 (*bridge improvements at Abermain*) indicated that modification of the Rail Bridge, Cessnock Road and service crossings to raise them above the 1% AEP flood level would offer only limited reduction in flooding in areas upstream to William Street. The costs of such works are expected to significantly outweigh the benefit, particularly considering the measures required to manage traffic along Cessnock Road.

Notwithstanding this outcome, it is recommended that the existing services across the creek in this area be investigated to determine if any pipes are no longer in use and can therefore be removed. This will require further consultation with service providers and utilities. The investigation is to focus on a pipe that is set at mid-height between the creek bed and the level of the Cessnock Road Bridge, which is likely to cause the most obstruction to flow and collection of debris.

A nominal allowance of $50,000 has been made for removal of the unused pipe. A benefit-cost analysis has not been completed, but costs in the order of this magnitude are considered acceptable in light of anticipated hydraulic benefit. The potential disruption to traffic on Cessnock Road, and its appropriate management, will need to be considered further and may incur additional cost.

If the mid-height pipe is found to be in use, relocation of the pipe to a level in line with the road bridge deck may also be an option, but would need to be further justified in light of the additional cost.

13.2 PROPERTY MODIFICATION MEASURES

The following planning recommendations have been identified as an outcome of this study (*refer* **Section 11** *for further information*):

P1. It is recommended that a new Flood DCP or Flood Policy be developed, or otherwise a new chapter of the existing DCP be added to address flood-related planning controls. The DCP would apply across the entire Cessnock LGA.

The Flood DCP should be linked to Council's Local Environmental Plan (*LEP*) and also to any available mapping of the Flood Planning Area and where possible, hydraulic category classification of the floodplain (*i.e., including the mapping in* **Section 7** *above*).

P2. In conjunction with the development of a Flood DCP / Flood Policy, it is recommended that Council incorporate flood-related constraints into strategic planning.

P3. It is recommended that Council consider an update of the development assessment process with respect to flood planning controls.

It is not recommended that voluntary house raising or purchase be pursued (*refer Section 9.5.2 for further details*).

13.3 RESPONSE MODIFICATION MEASURES

It is recommended that the following emergency response management measures be implemented:

R1. Installation of an automated weather station (*continuous rainfall gauge*) in the upper catchment of Swamp Creek. This would ideally be operated by and linked to the Bureau of Meteorology's flood warning system. Possible locations may be Elrington, Abernethy or Kearsley.

R2. Installation of a telemetered river level gauge at an appropriate upstream location. In order to provide a the longest possible warning time to residents, while also picking-up a significant portion of the upstream catchment area, it is recommended that a site at the Lake Road crossing of the creek between Kearsley and Elrington be investigated further. A second automatic gauge could be installed further downstream (*say half way between Lake Road and Abermain*) to verify the gauge readings in the upper catchment and thereby confirm if the potential for imminent flooding is real.

R3. Establishment of appropriate venues as short-term flood refuges for the identified High Trapped Perimeter areas, including in the area of Weston to the west of the creek and areas of Abermain to the east of the creek, both north of the railway and south of the railway.

R4. Update the Cessnock City Local Flood Plan with relevant information from this study, as appropriate. It is recommended that the existing door-knocking arrangements for the Hunter River flooding scenario could be adapted to also cater for a local catchment flooding scenario. Using similar resources, those residents affected by the 1% AEP flood should be able to be notified within 5 hours of receiving a flood warning. It should, however, be recognised that 5 hours warning time may not always be available in the case of local flash flooding.

It is also recommended that the following measure be implemented to increase community awareness and preparedness for flooding:

R5. Develop and implement a community flood awareness and preparedness program, working with SES to use FloodSafe Program materials.

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FIGURE 1.1

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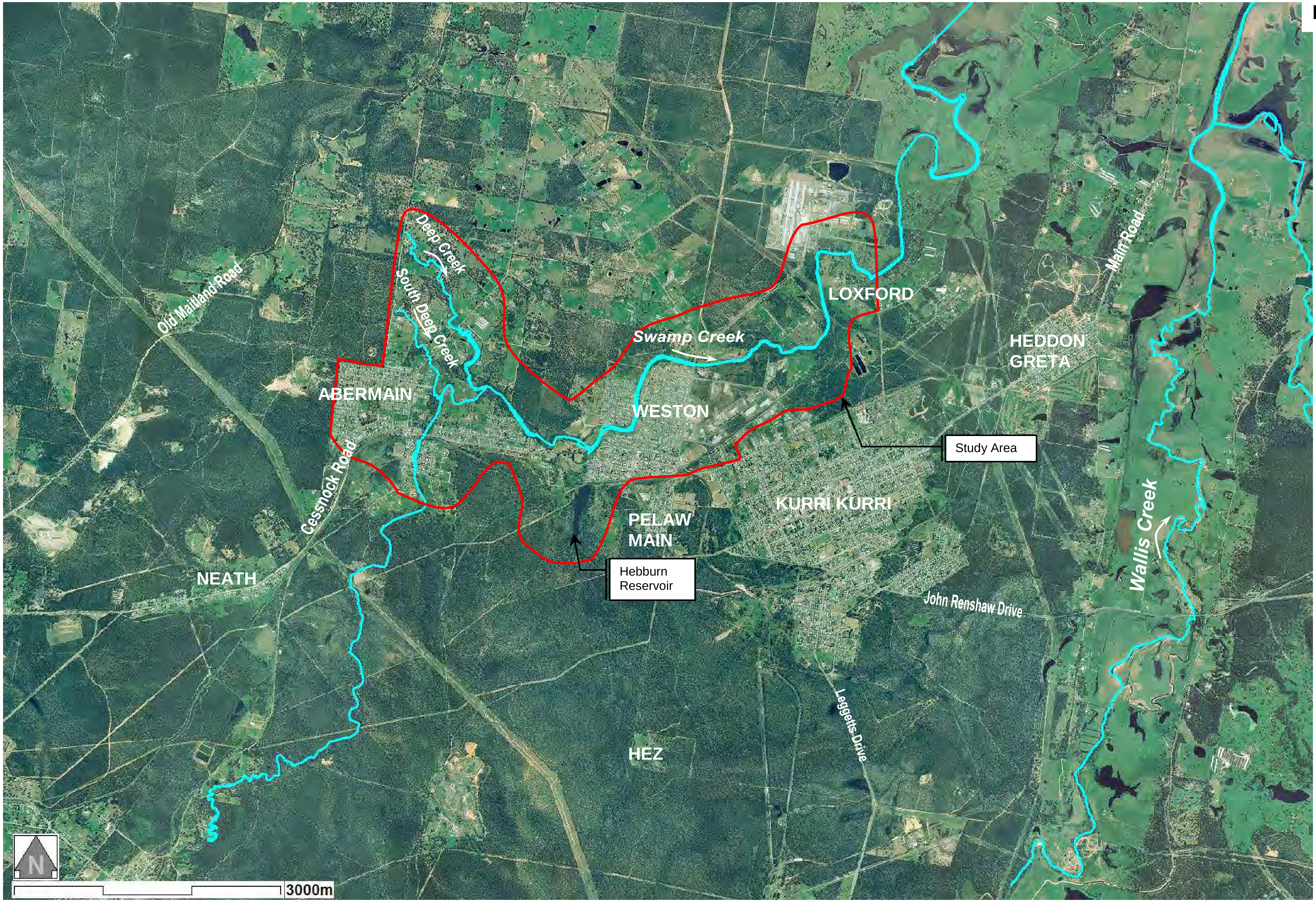
301015-02996 - Swamp Creek FRMS and Plan
02996ja130319fig1.1-Locality Map Data.doc

SWAMP CREEK STUDY AREA RELATIVE TO NEWCASTLE AND CESSNOCK

FIGURE 1.2



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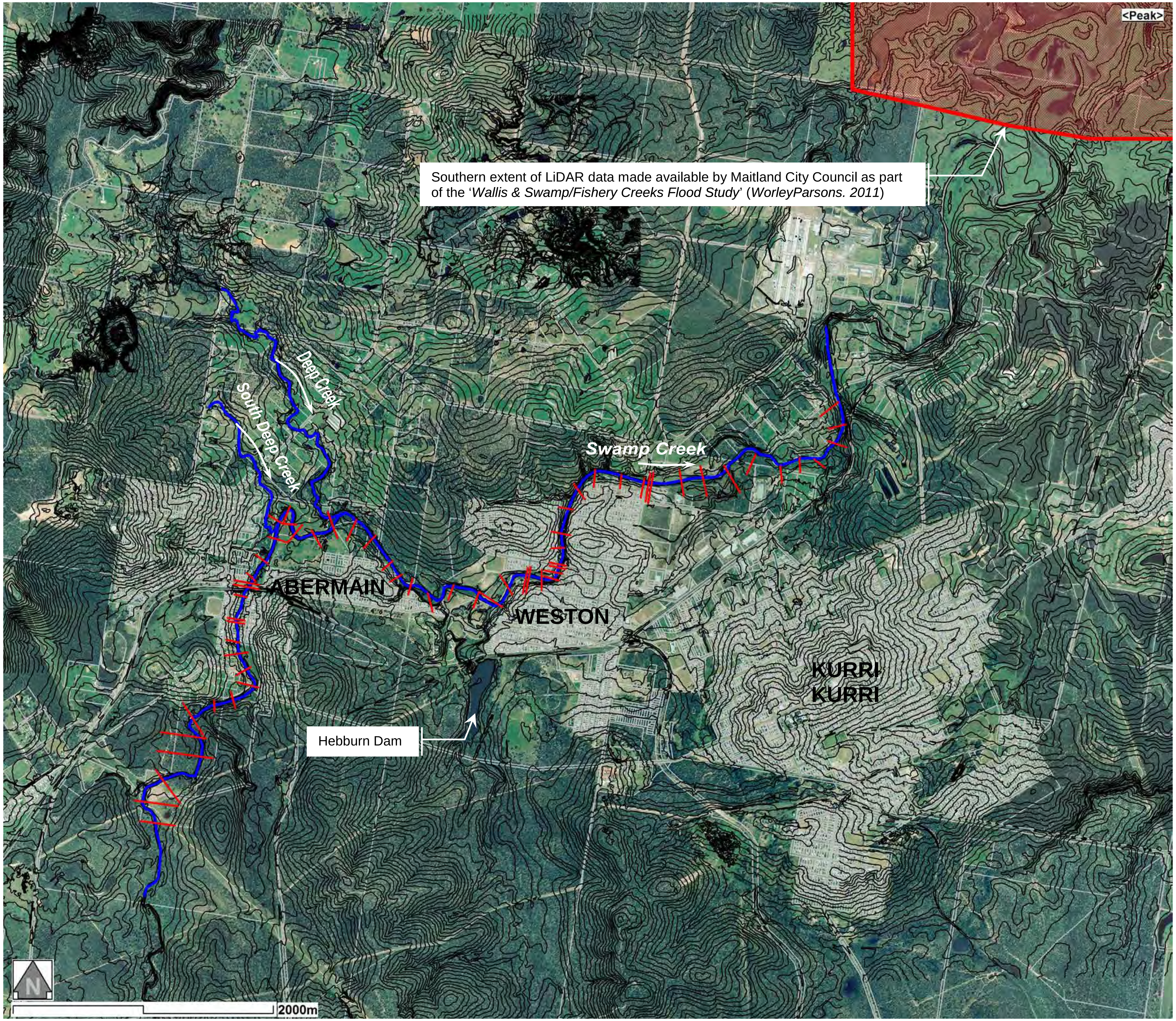
SWAMP CREEK STUDY AREA

301015-02996 - Swamp Creek FRMS and Plan
02996ja130319fig1.2-Detailed Locality Map Data.doc

FIGURE 4.1



LEGEND

Contour data previously available (*2m Intervals*)

HEC-RAS Cross-sections (Flood Study Model)

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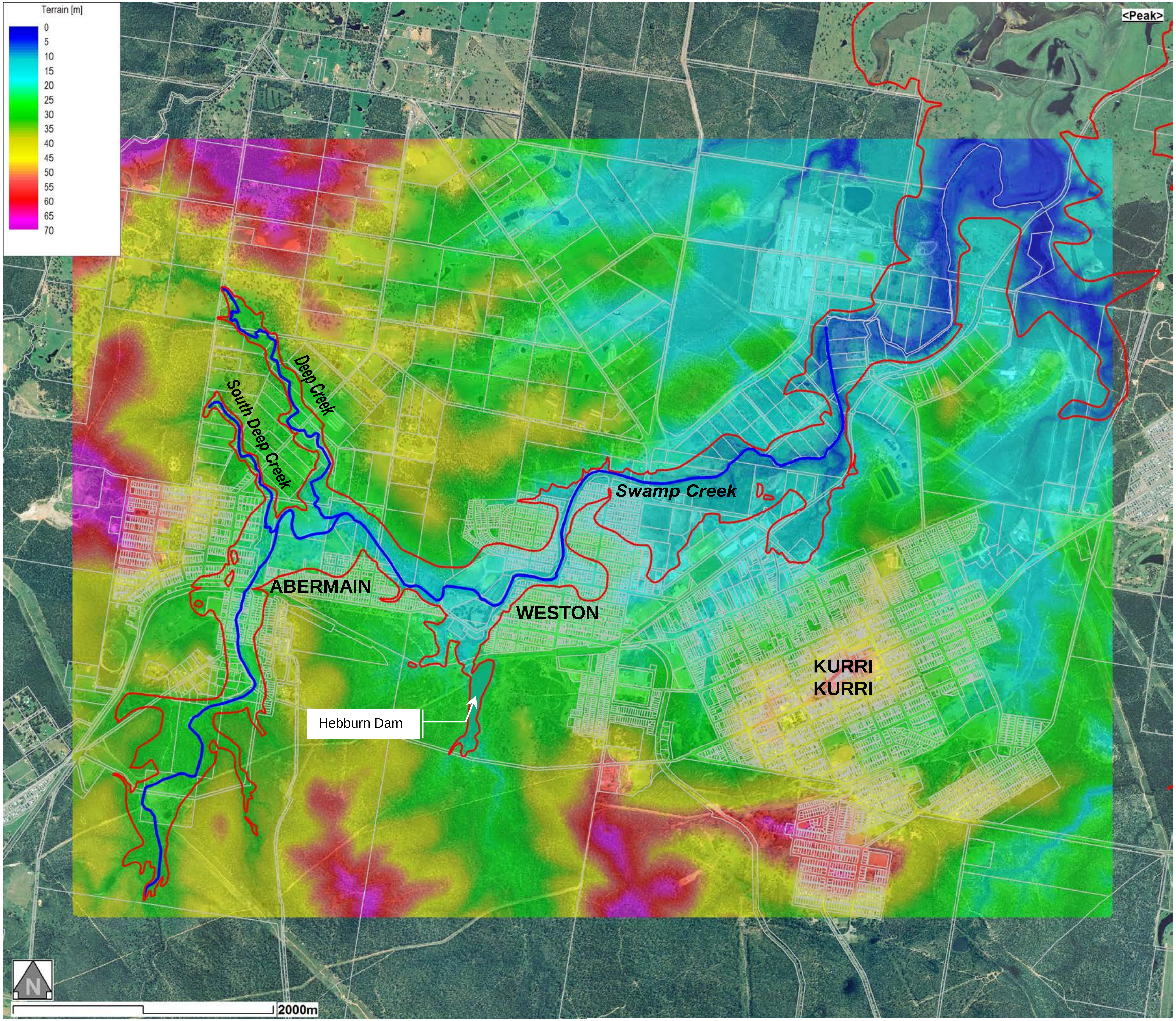
301015-02996 - Swamp Creek FRMS and Plan
02996rg121025fig1-Available Flood Study Data.doc

TOPOGRAPHIC DATA AVAILABLE FOR 2011 FLOOD STUDY

FIGURE 4.2



LEGEND

Extent of LiDAR gathered for use in the FRMS

Approximate extent of the Probable Maximum Flood (*PMF*)

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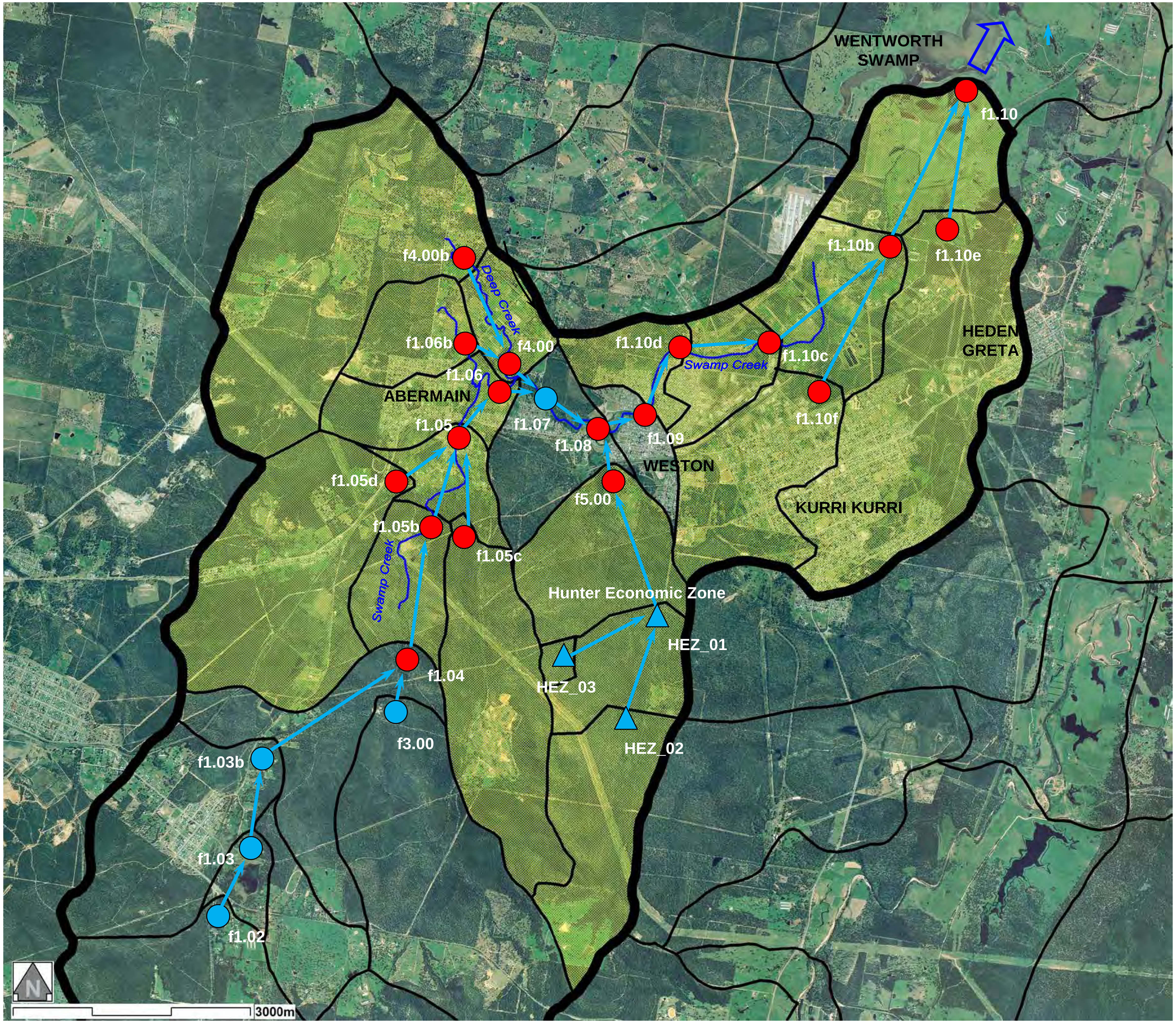
301015-02996 - Swamp Creek FRMS and Plan
02996rg121025fig2-Additional Data Collected for FRMS.doc

ADDITIONAL TOPOGRAPHIC DATA COLLECTED FOR THE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE 4.3



LEGEND

- Boundary of Swamp/Fishery Creek Catchment
- XP-RAFTS Sub-catchments boundaries
- XP-RAFTS Sub-catchments updated as part of the FRMS
- XP-RAFTS model node used as an input to the updated RMA-2 model
- XP-RAFTS model node
- XP-RAFTS detention basin
- XP-RAFTS model link

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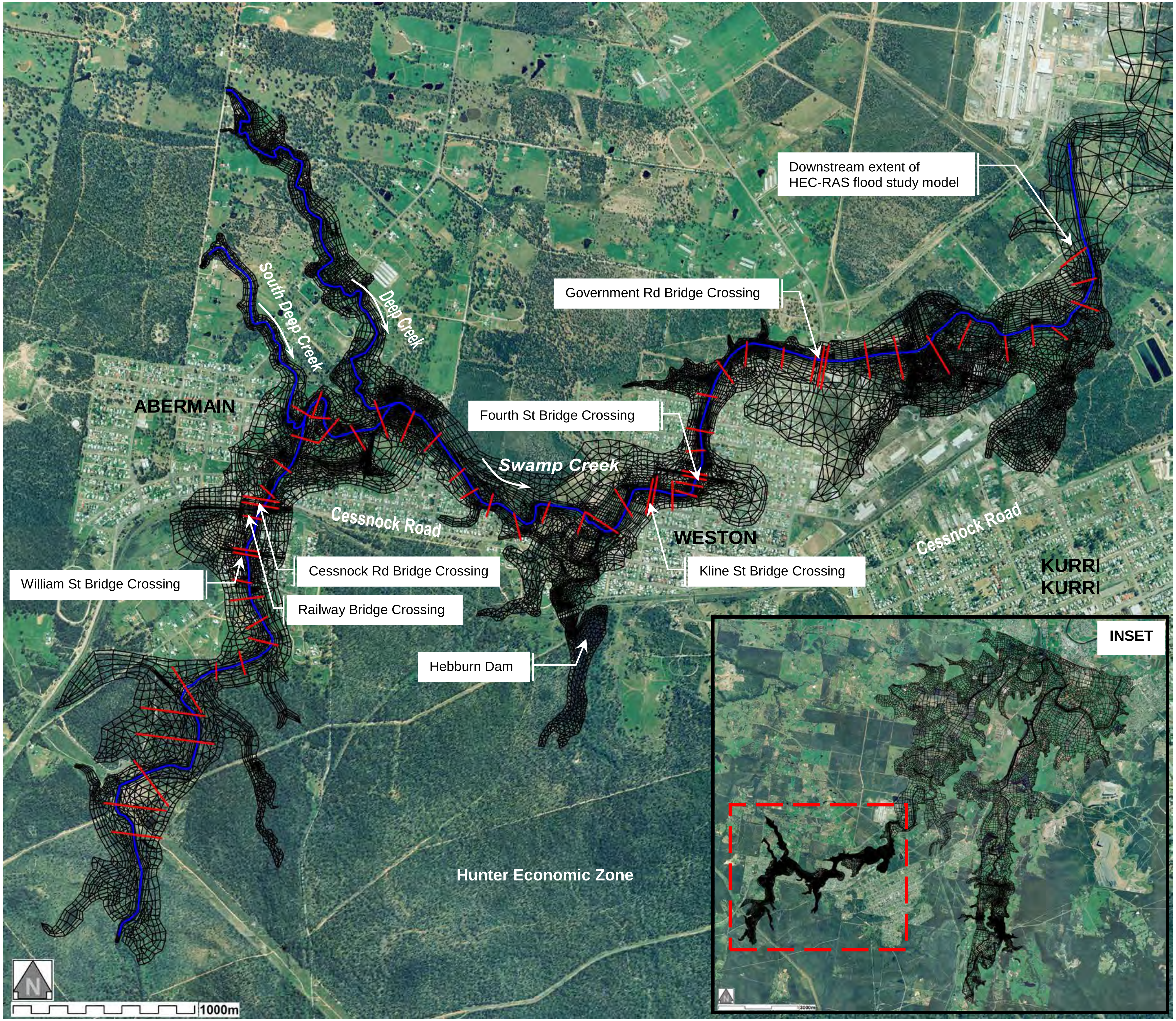
301015-02996 - Swamp Creek FRMS and Plan
02996ja120921fig2-XP-RAFTS Layout Modifications.doc

UPDATED XP-RAFTS HYDROLOGIC MODEL NODE AND LINK ARRANGEMENT



LEGEND

Updated RMA-2 Model Network

HEC-RAS Cross-sections (Flood Study Model)

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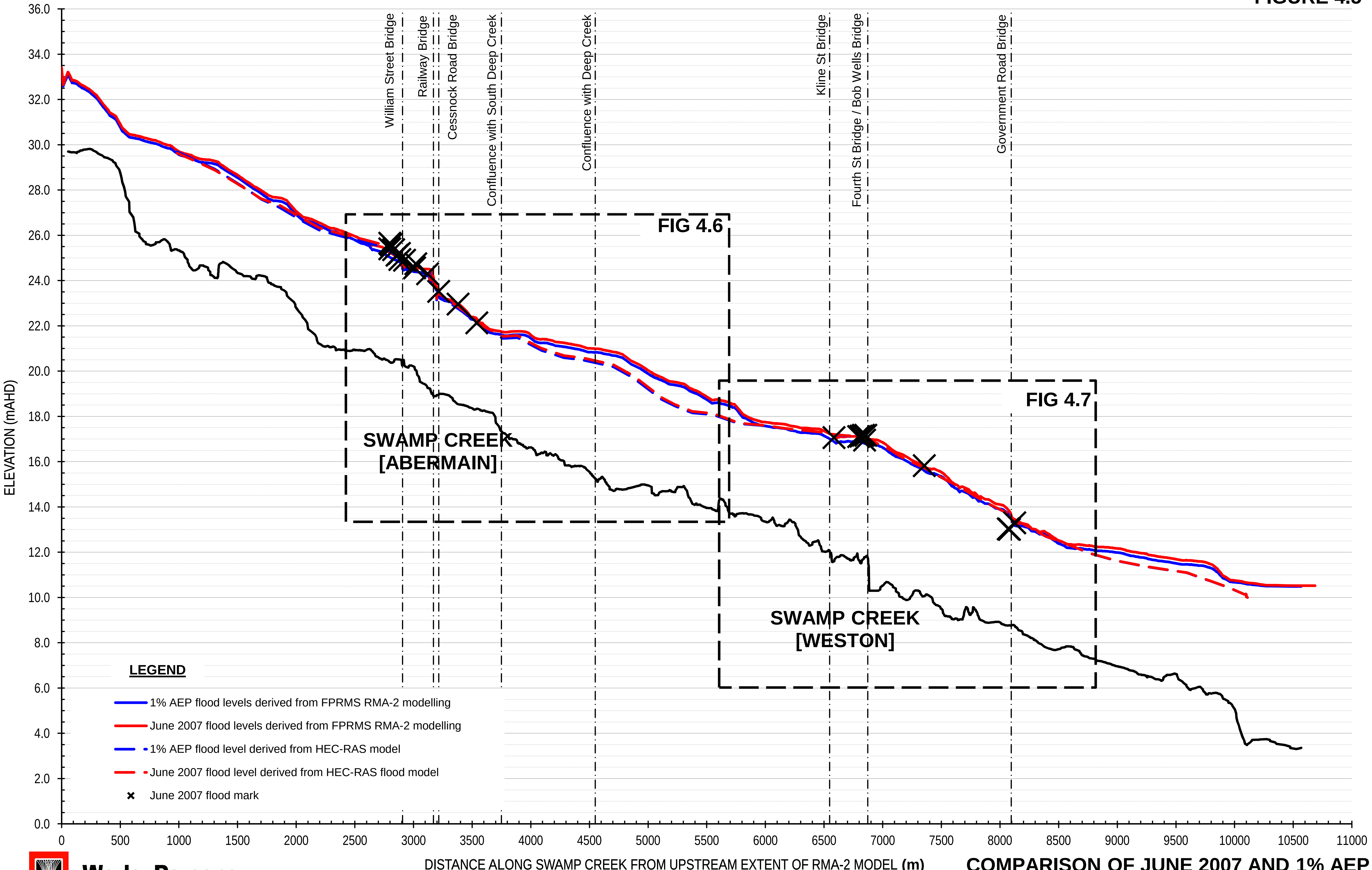
301015-02996 - Swamp Creek FRMS and Plan
02996rg121025fig4-Updated RMA-2 Network.doc

UPDATED RMA-2 MODEL NETWORK FOR THE SWAMP CREEK STUDY AREA

FIGURE 4.5



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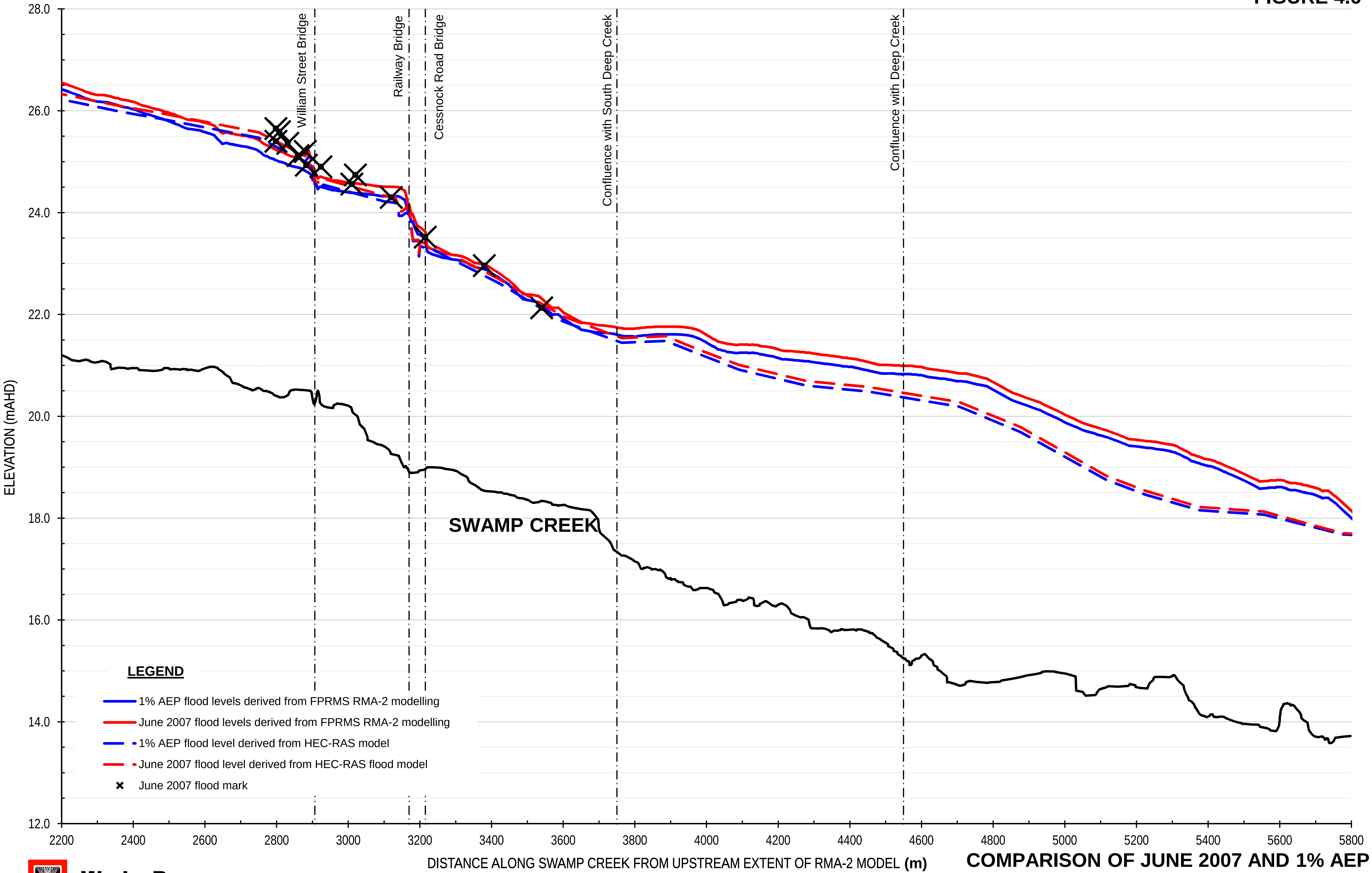
301015-02996 - Swamp Creek FRMS and Plan
fg2996_01ja120921-Calibration WSP.xls

COMPARISON OF JUNE 2007 AND 1% AEP WATER SURFACE PROFILES BASED ON HEC-RAS AND RMA-2 MODELLING [OVERVIEW OF RESULTS]

FIGURE 4.6



COMPARISON OF JUNE 2007 AND 1% AEP WATER SURFACE PROFILES BASED ON HEC-RAS AND RMA-2 MODELLING [IN THE VICINITY OF ABERMAIN]

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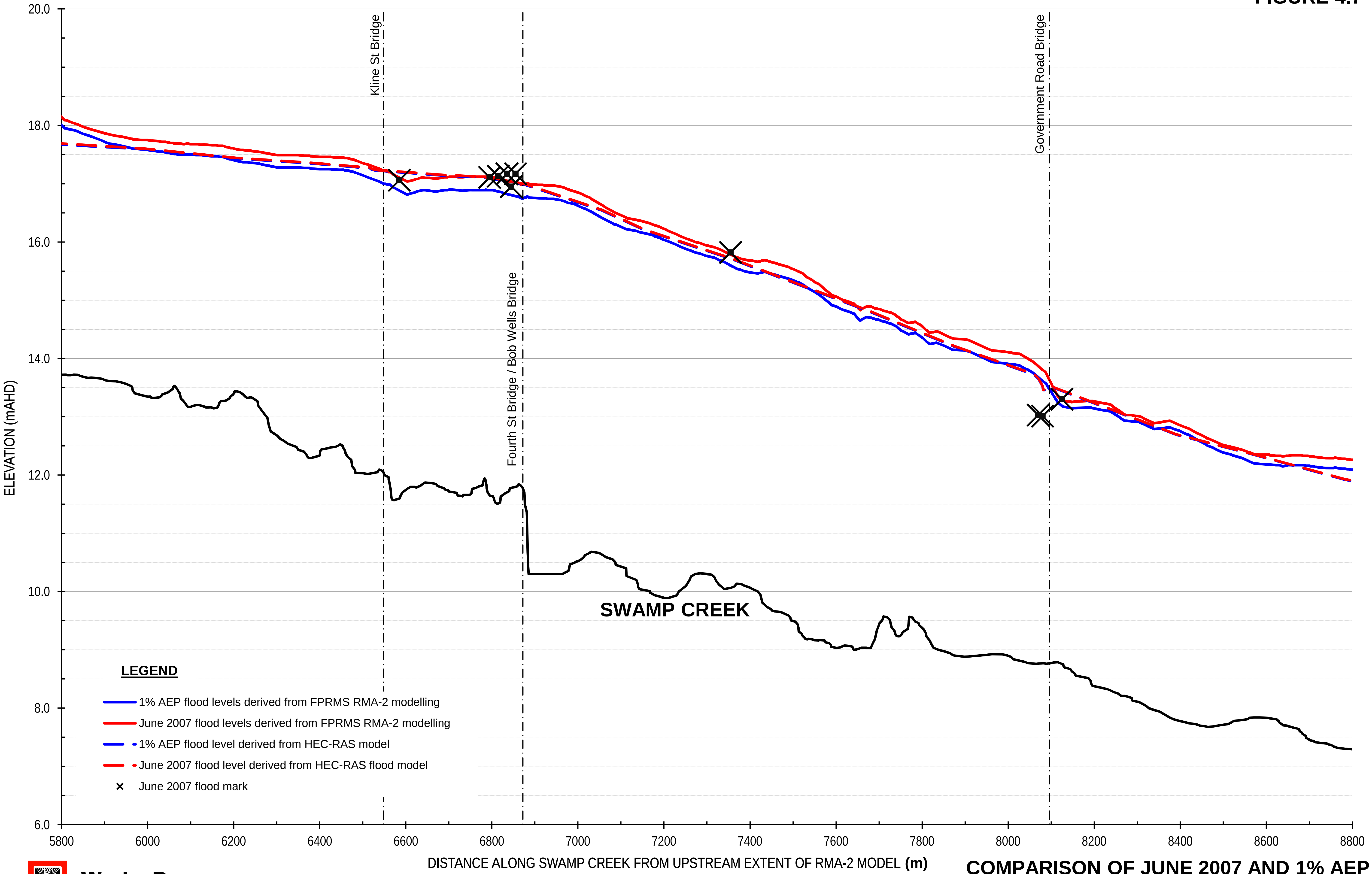
301015-02996 - Swamp Creek FRMS and Plan
fg2996_01ja120921-Calibration WSP.xls

FIGURE 4.7



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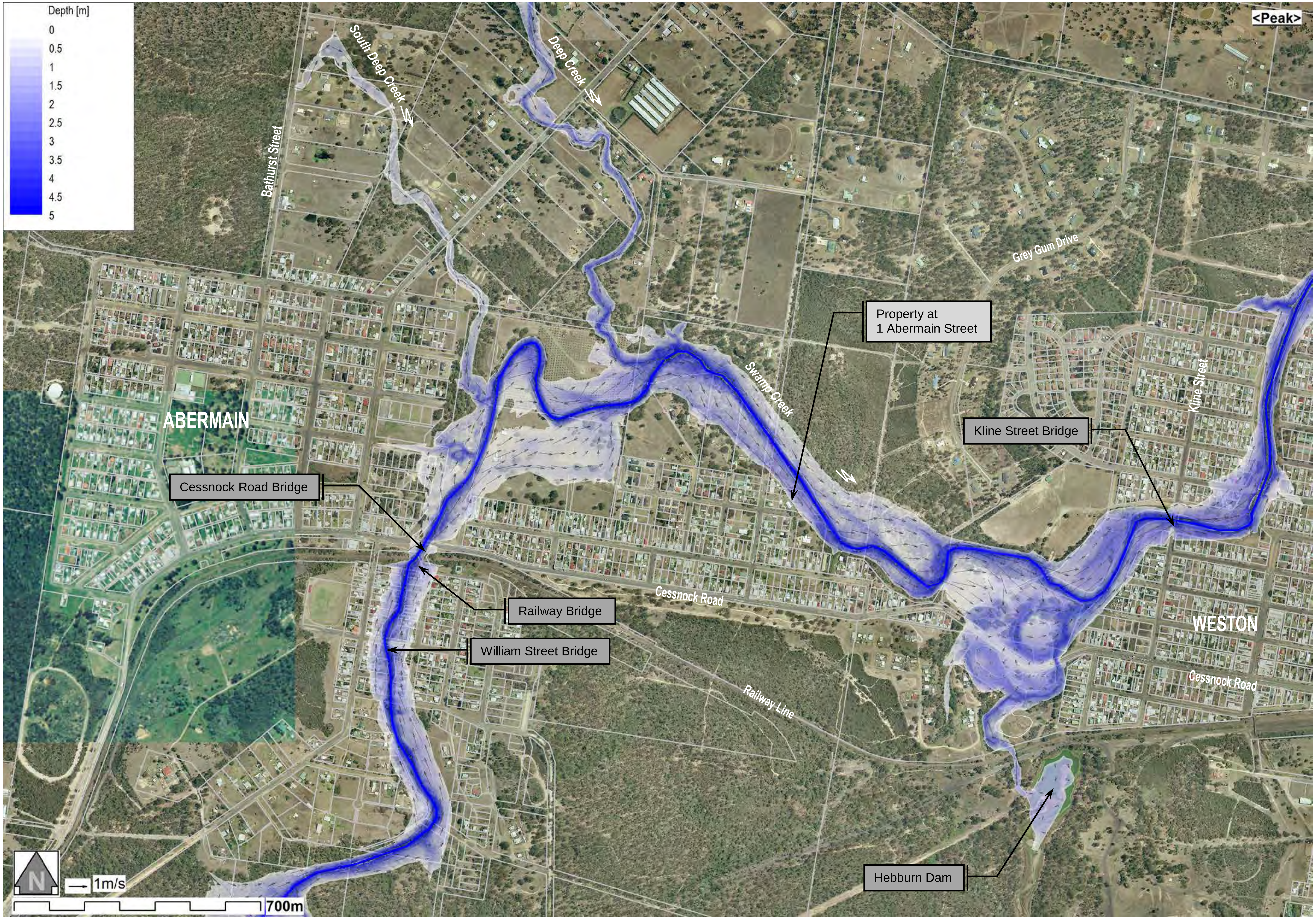
301015-02996 - Swamp Creek FRMS and Plan
fg2996_01ja120921-Calibration WSP.xls

COMPARISON OF JUNE 2007 AND 1% AEP WATER SURFACE PROFILES BASED ON HEC-RAS AND RMA-2 MODELLING [IN THE VICINITY OF WESTON]



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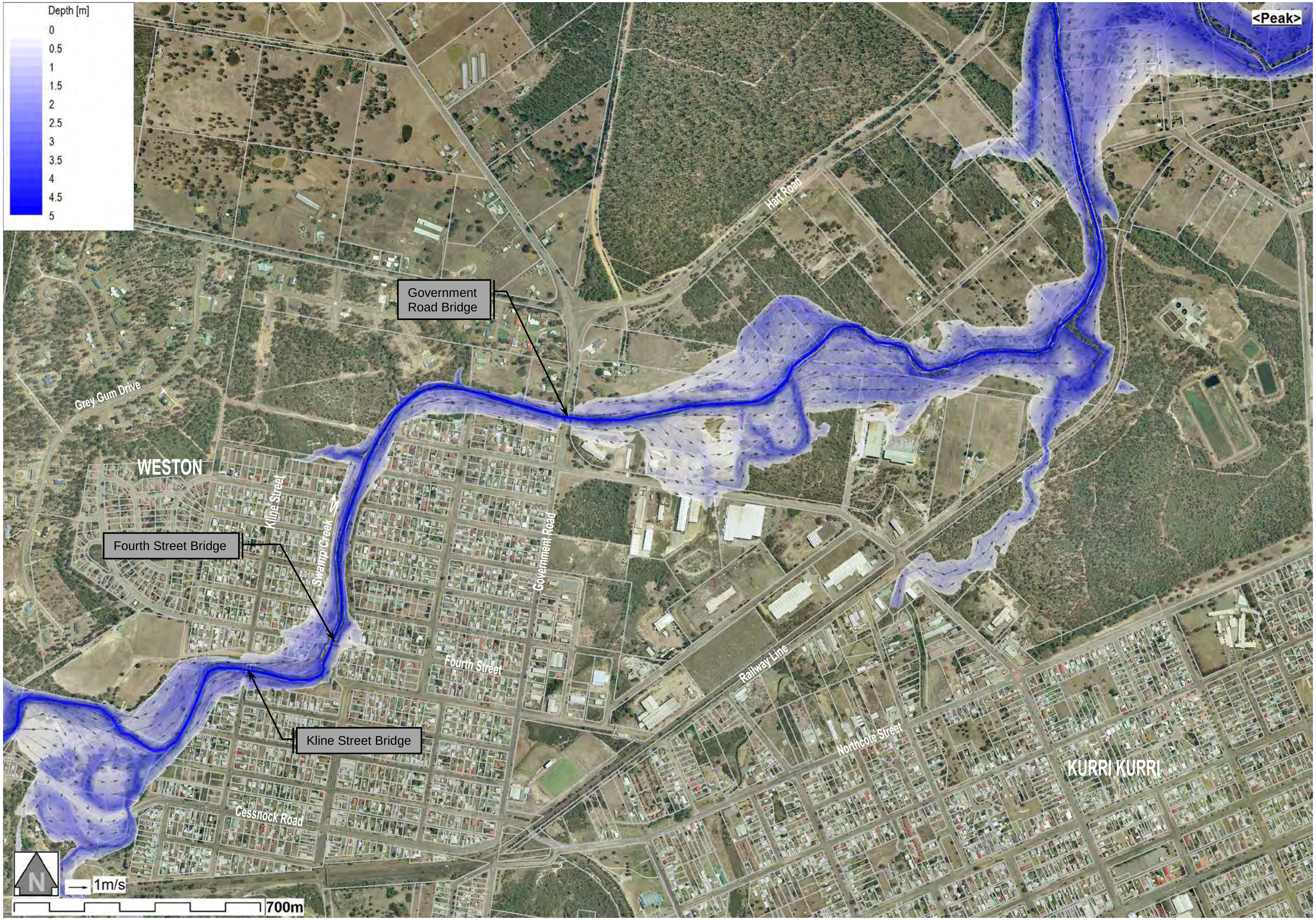
DEPTH & VELOCITY MAPPING FOR THE JUNE 2007 EVENT [SHEET 1]

FIGURE 4.9



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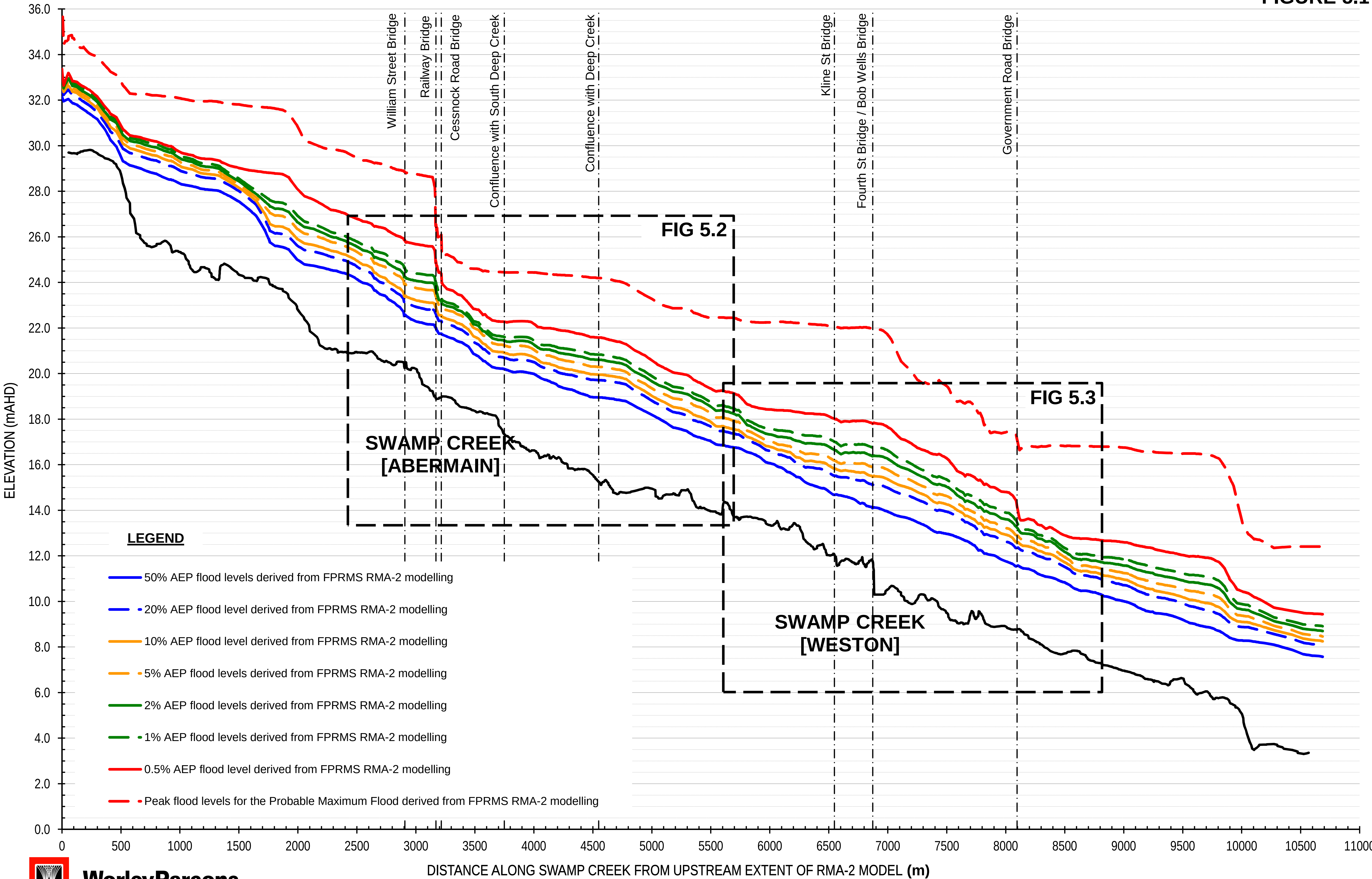
301015-02996 - Swamp Creek FRMS and Plan
02996nm121112fig09-DepthVel 2007 Weston.doc

DEPTH & VELOCITY MAPPING FOR THE JUNE 2007 EVENT [SHEET 2]

FIGURE 5.1



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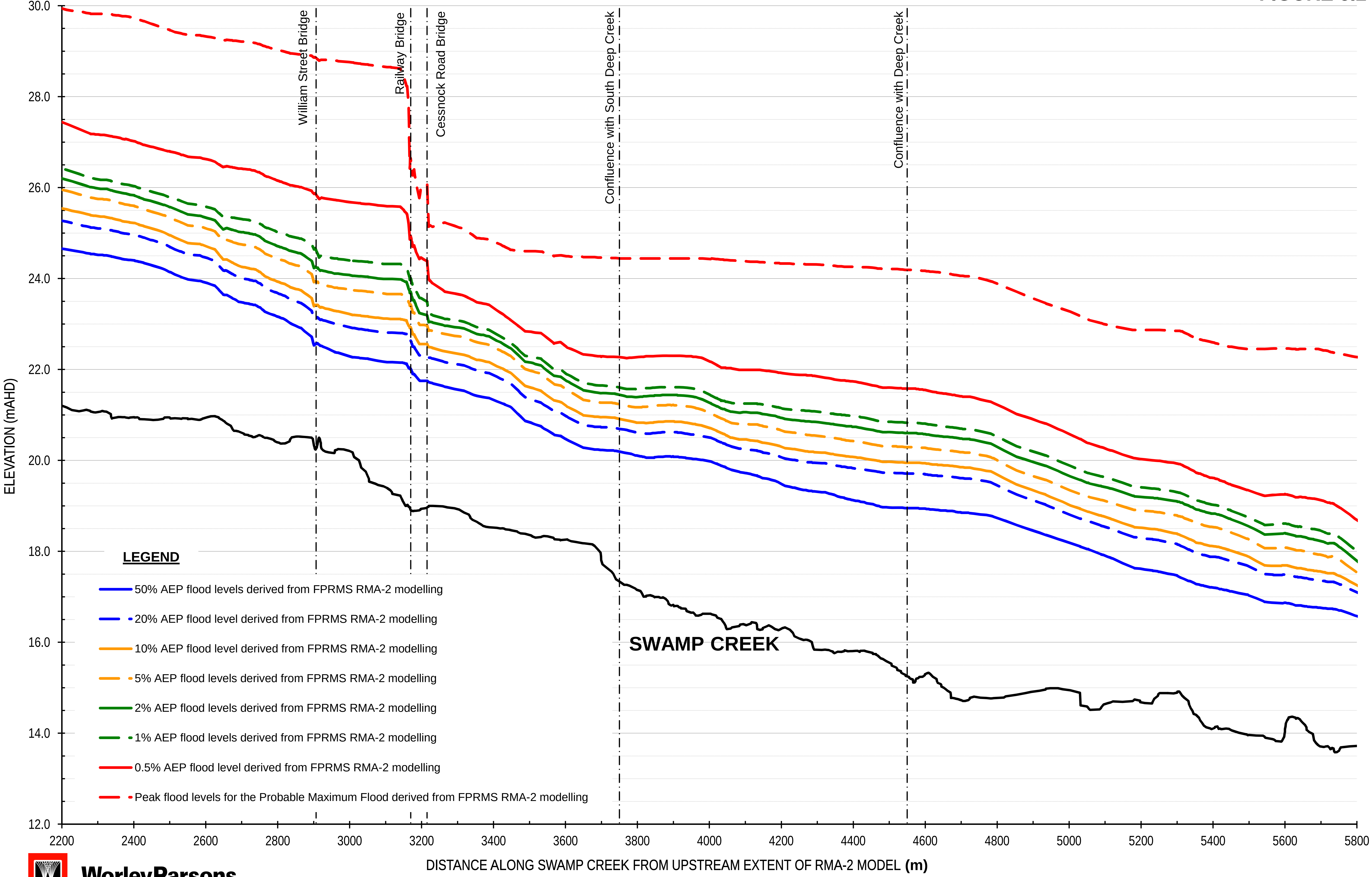
fg2996_01ja120921-Calibration WSP.xls

DESIGN WATER SURFACE PROFILES DERIVED FROM RMA-2 MODELLING [OVERVIEW OF RESULTS]



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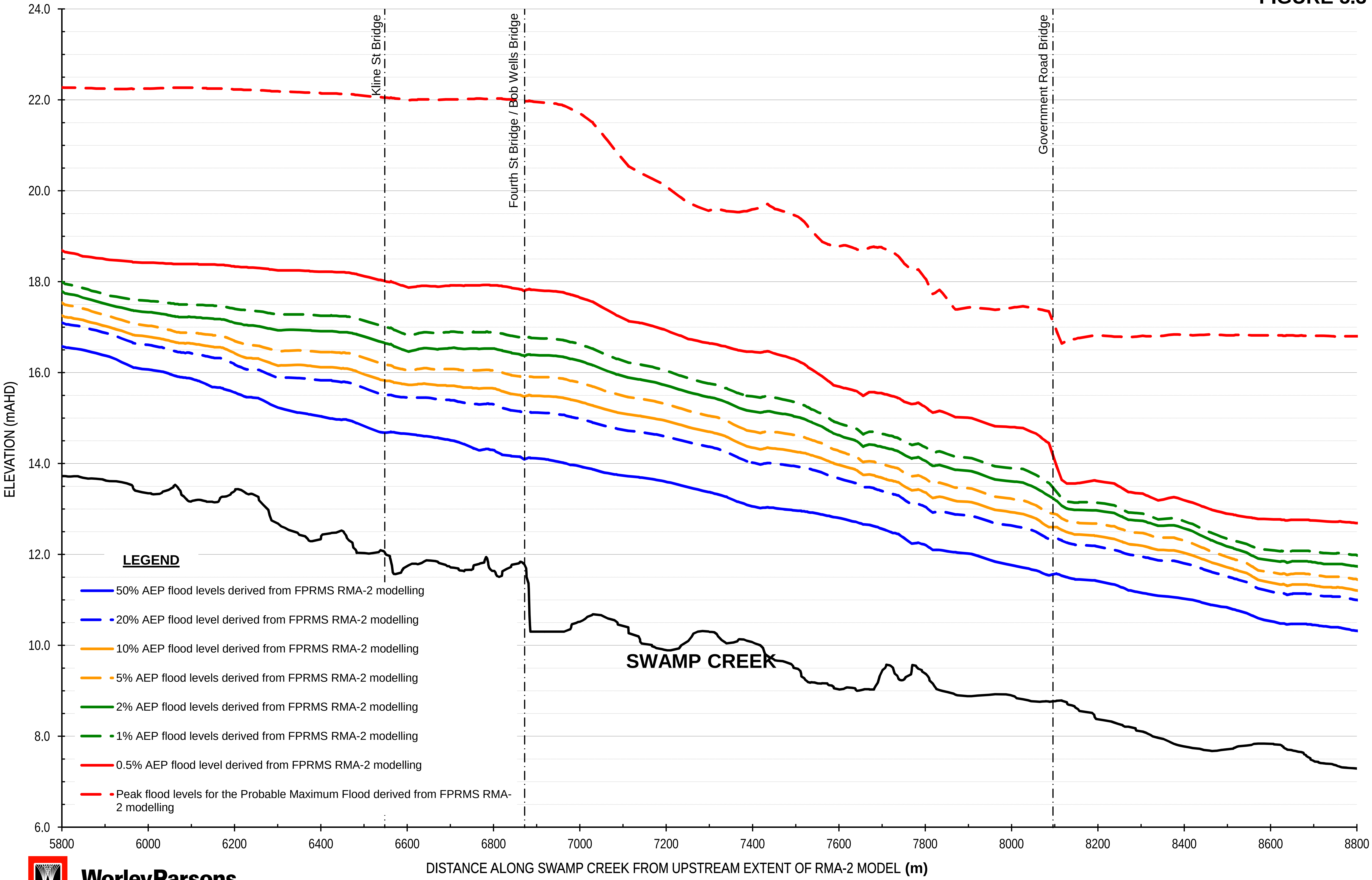
301015-02996 - Swamp Creek FRMS and Plan
fg2996_01ja120921-Calibration WSP.xls

DESIGN WATER SURFACE PROFILES DERIVED FROM RMA-2 MODELLING
[IN THE VICINITY OF ABERMAIN]

FIGURE 5.3



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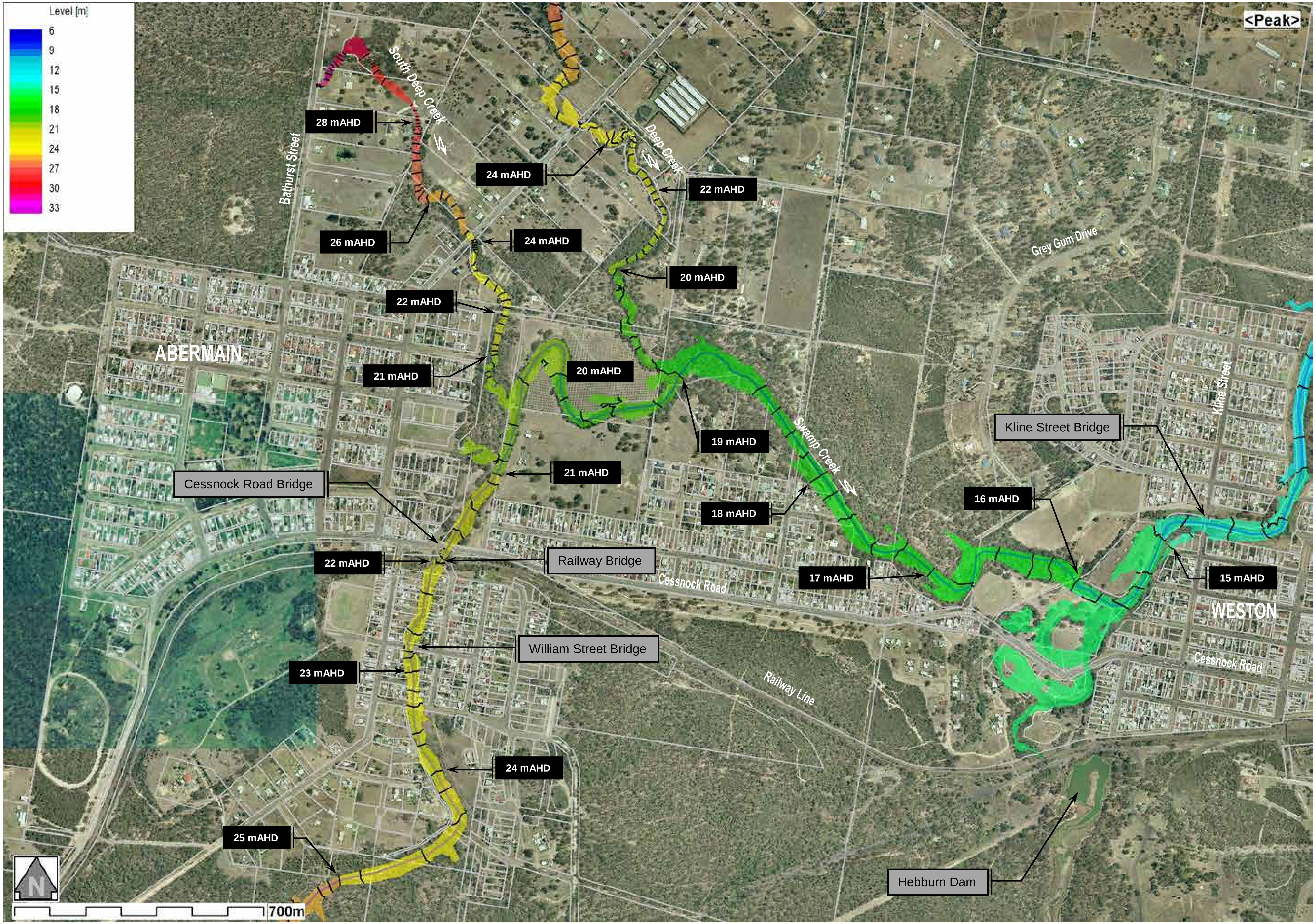
301015-02996 - Swamp Creek FRMS and Plan
fg2996_01ja120921-Calibration WSP.xls

DESIGN WATER SURFACE PROFILES DERIVED FROM RMA-2 MODELLING [IN THE VICINITY OF WESTON]

FIGURE 5.4



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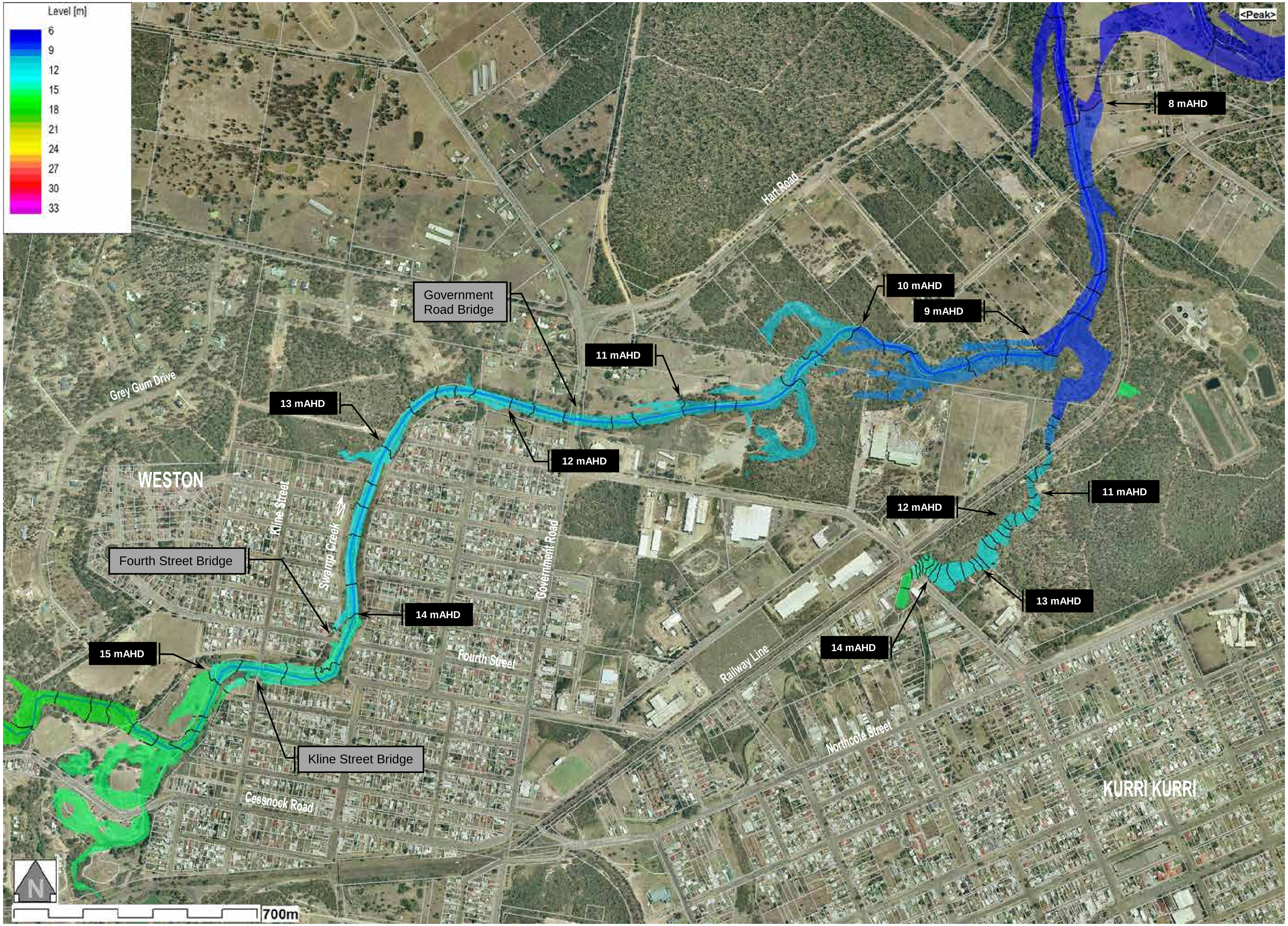
301015-02996 - Swamp Creek FRMS and Plan
02996ja121207fig13-002yr Level Abermain.doc

PEAK 50% AEP FLOOD LEVEL CONTOURS [SHEET 1]

FIGURE 5.5



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301015-02996 - Swamp Creek FRMS and Plan
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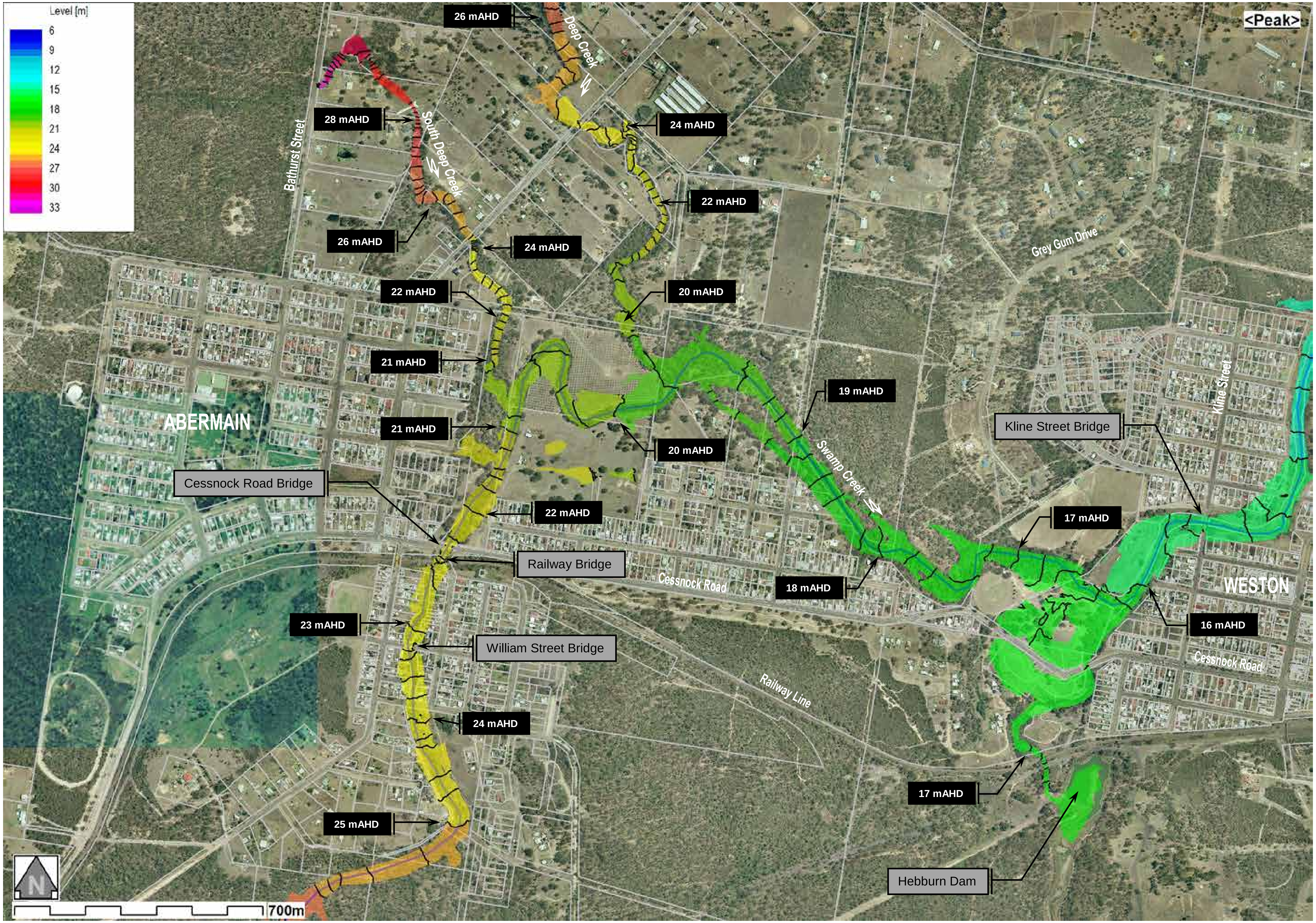
PEAK 50% AEP FLOOD LEVEL CONTOURS [SHEET 2]

FIGURE 5.6



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resources & energy

301015-02996 - Swamp Creek FRMS and Plan
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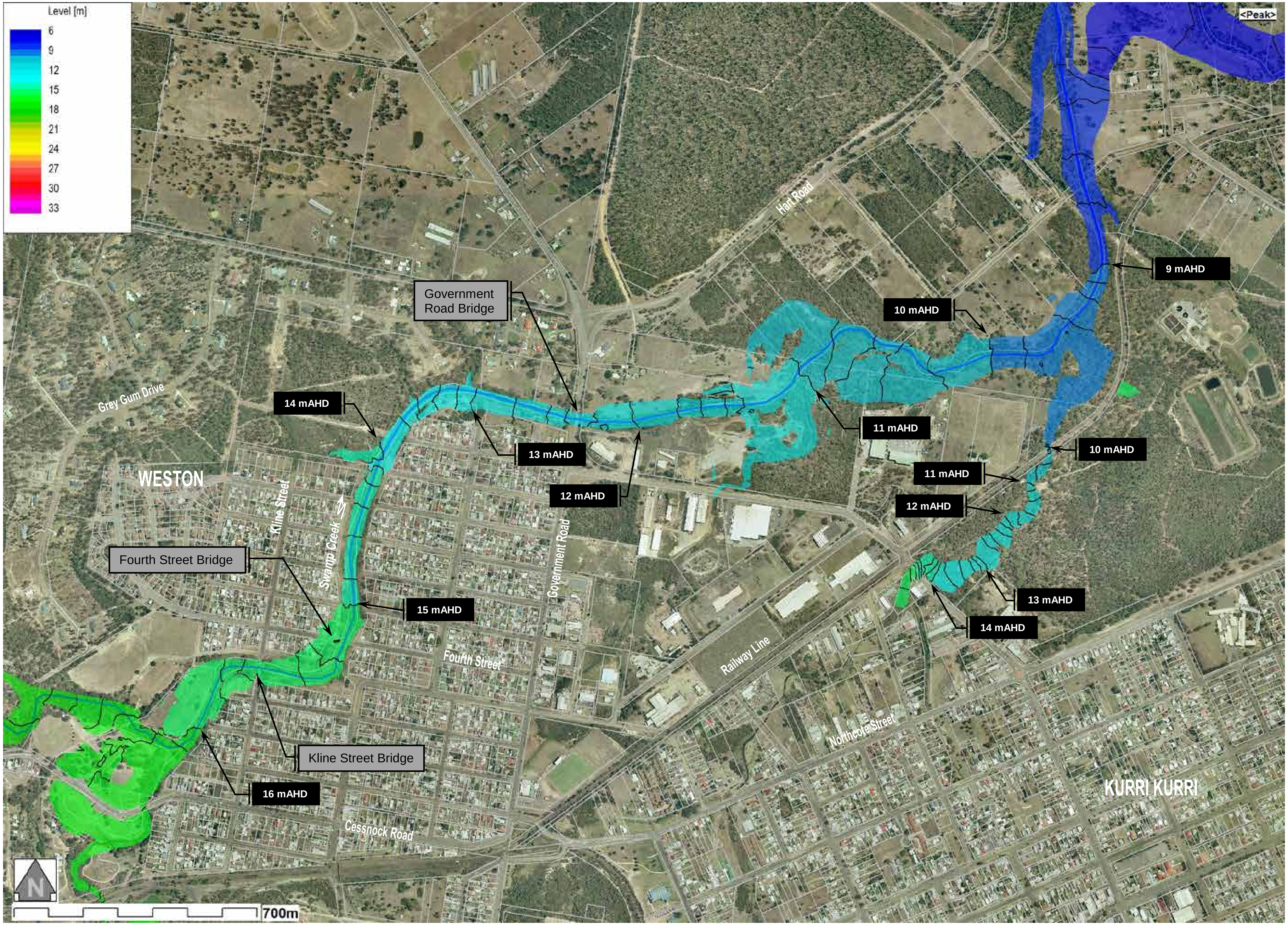
PEAK 20% AEP FLOOD LEVEL CONTOURS
[SHEET 1]

FIGURE 5.7



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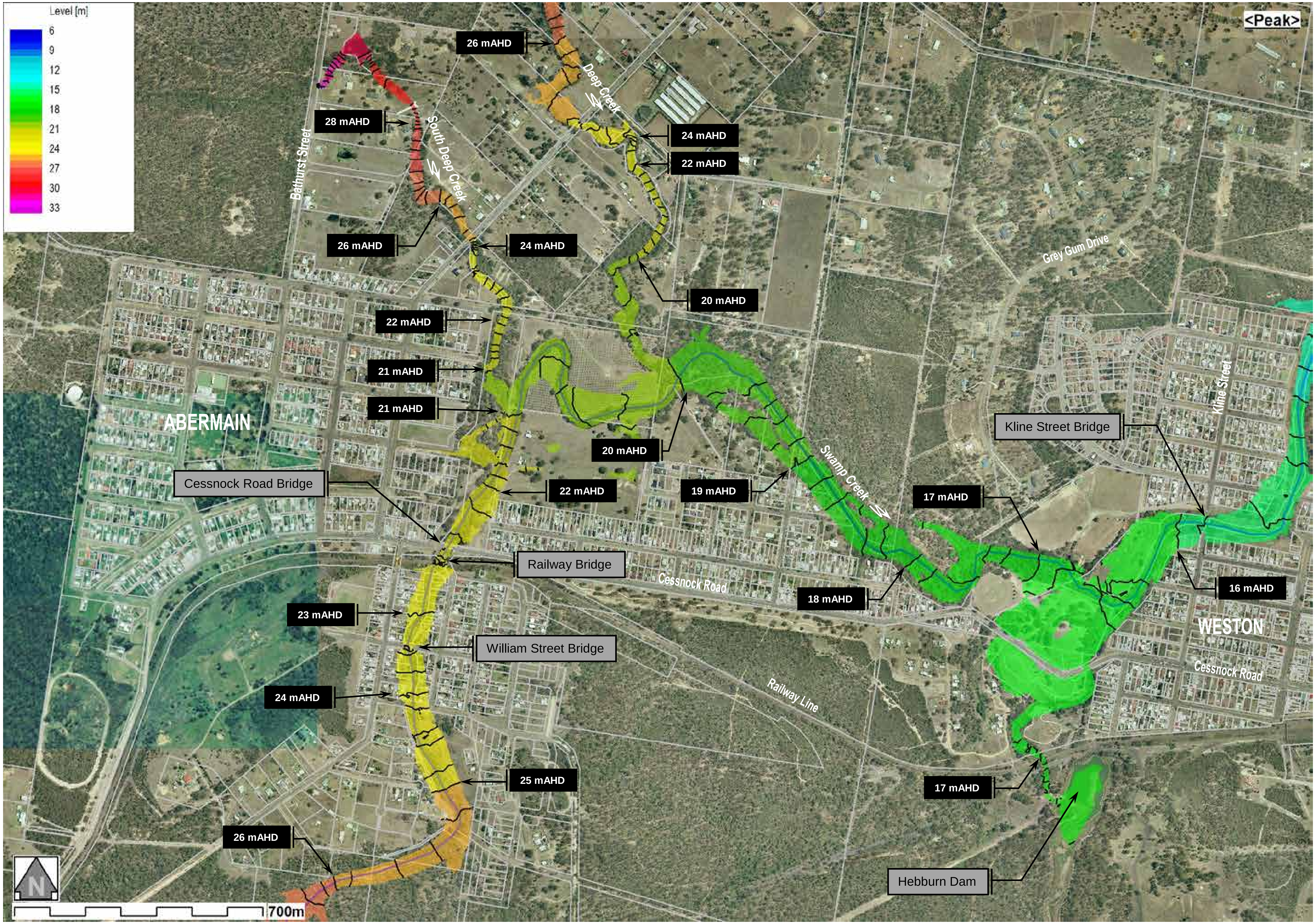
301015-02996 - Swamp Creek FRMS and Plan
02996ja121207fig16-005yr Level Weston.doc

PEAK 20%AEP FLOOD LEVEL CONTOURS [SHEET 2]

FIGURE 5.8



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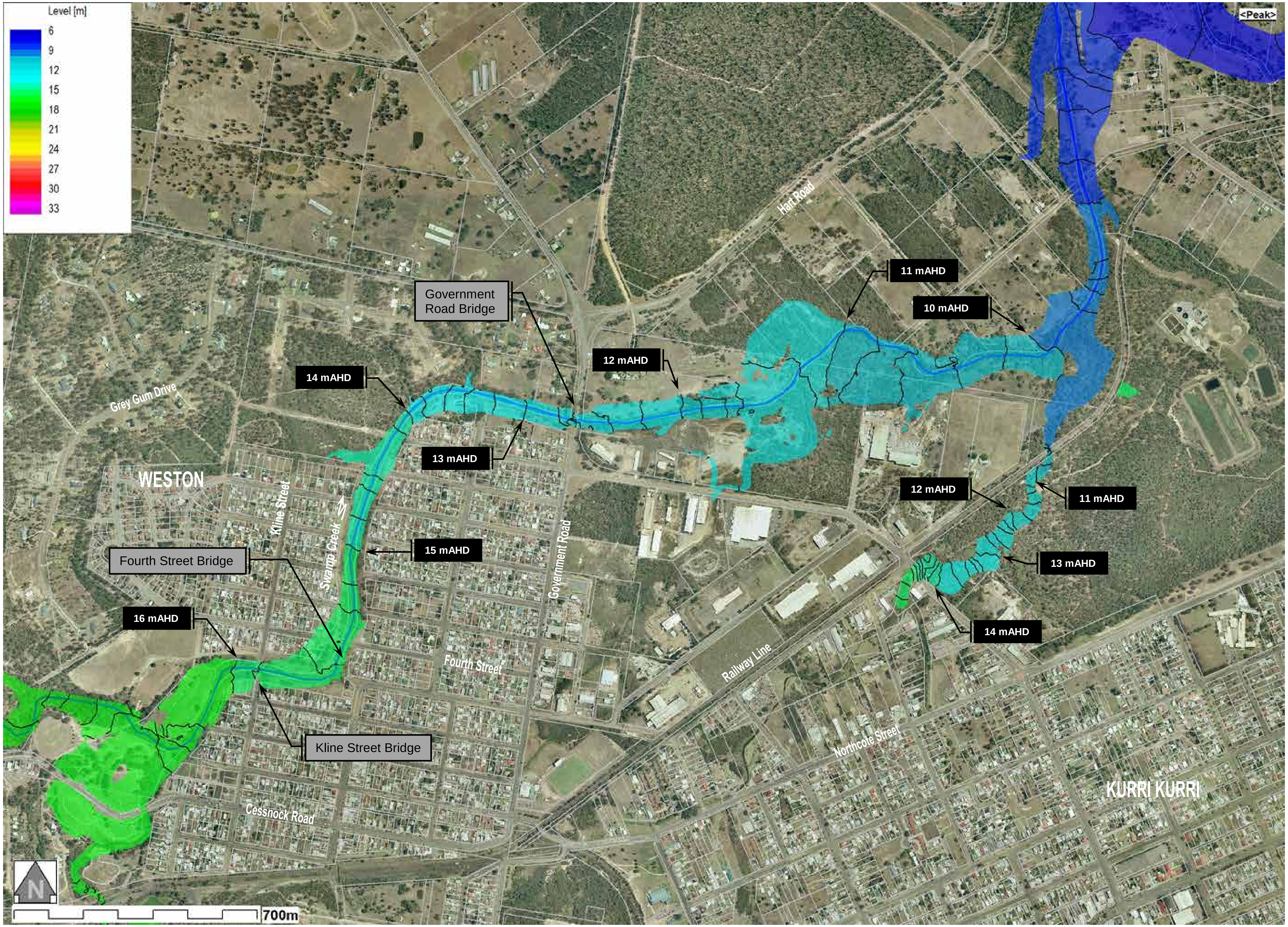
301015-02996 - Swamp Creek FRMS and Plan
02996ja121207fig17-010yr Level Abermain.doc

PEAK 10% AEP FLOOD LEVEL CONTOURS [SHEET 1]

FIGURE 5.9



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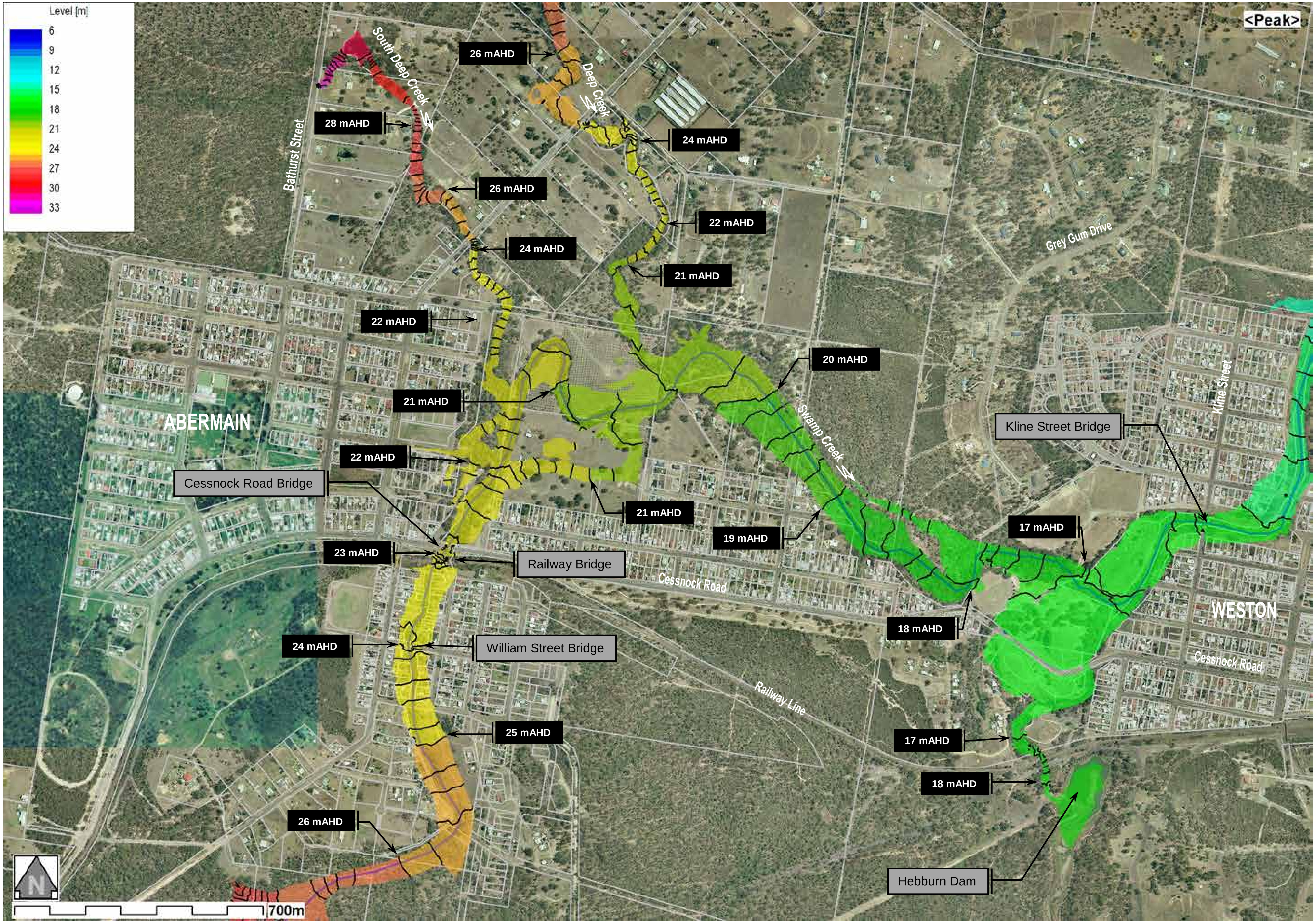
PEAK 10% AEP FLOOD LEVEL CONTOURS [SHEET 2]

FIGURE 5.10



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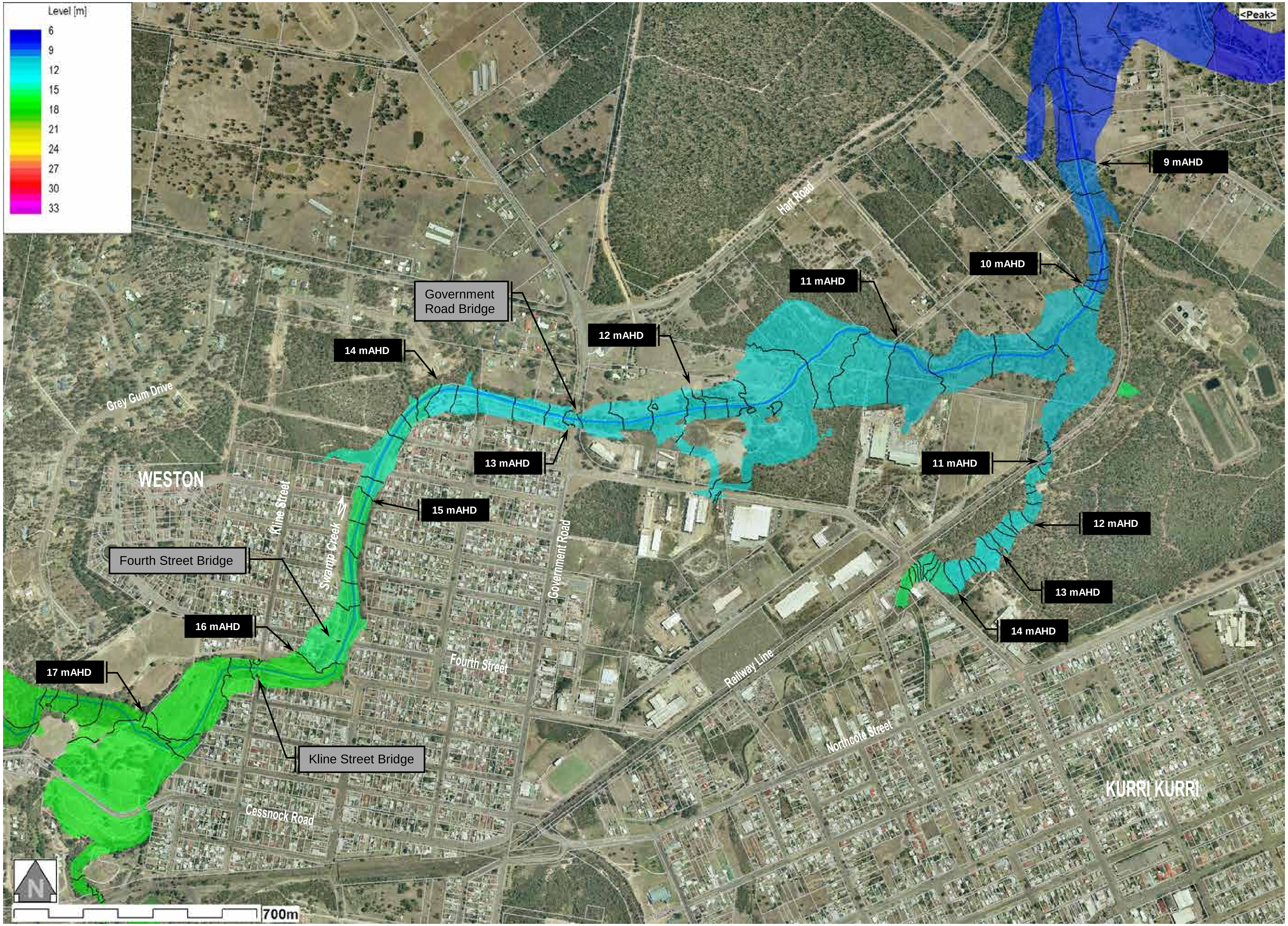
301015-02996 - Swamp Creek FRMS and Plan
02996ja121207fig19-020yr Level Abermain.doc

PEAK 5% AEP FLOOD LEVEL CONTOURS
[SHEET 1]

FIGURE 5.11



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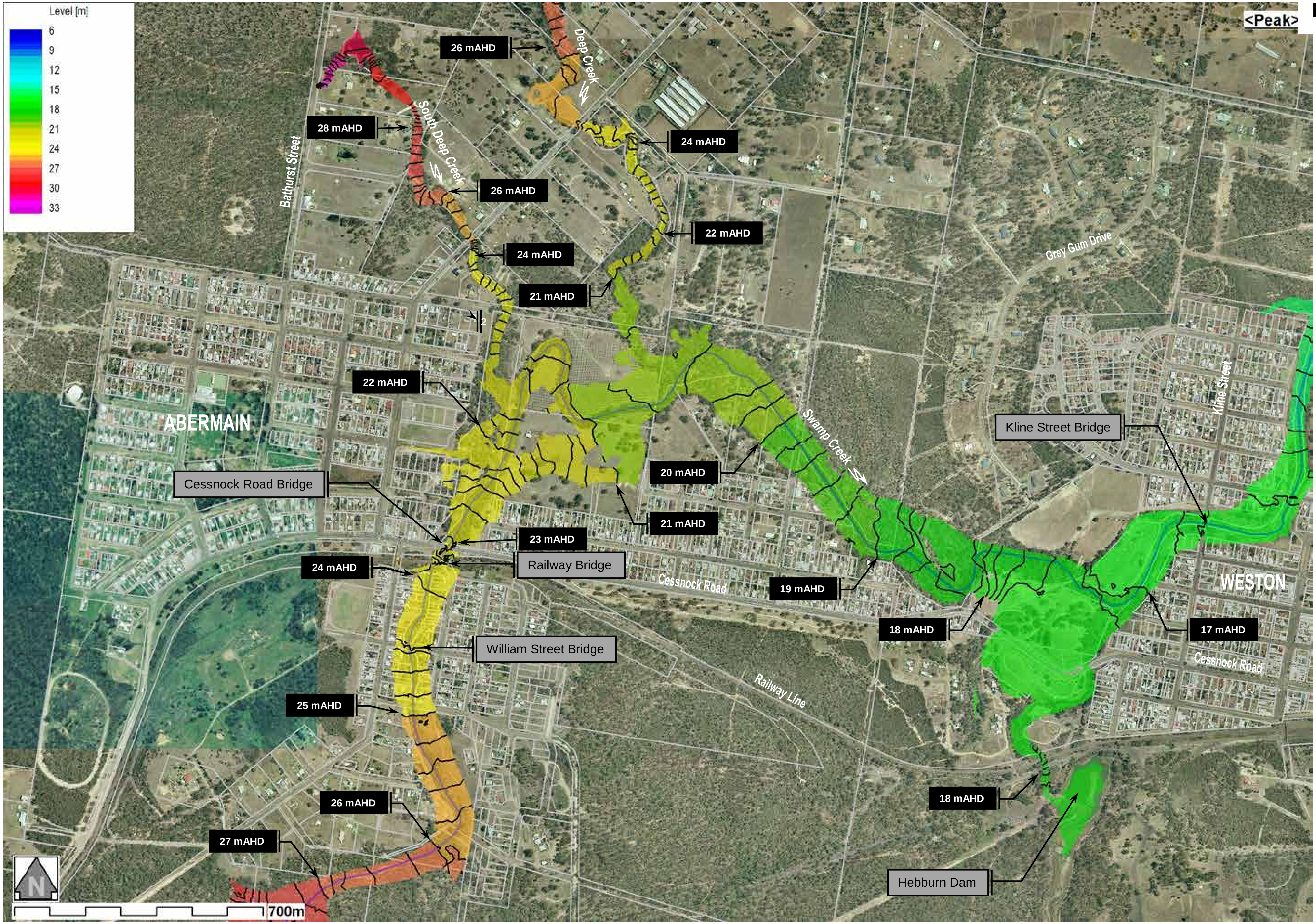
02996ja121207fig20-020yr Level Weston.doc

PEAK 5% AEP FLOOD LEVEL CONTOURS [SHEET 2]

FIGURE 5.12



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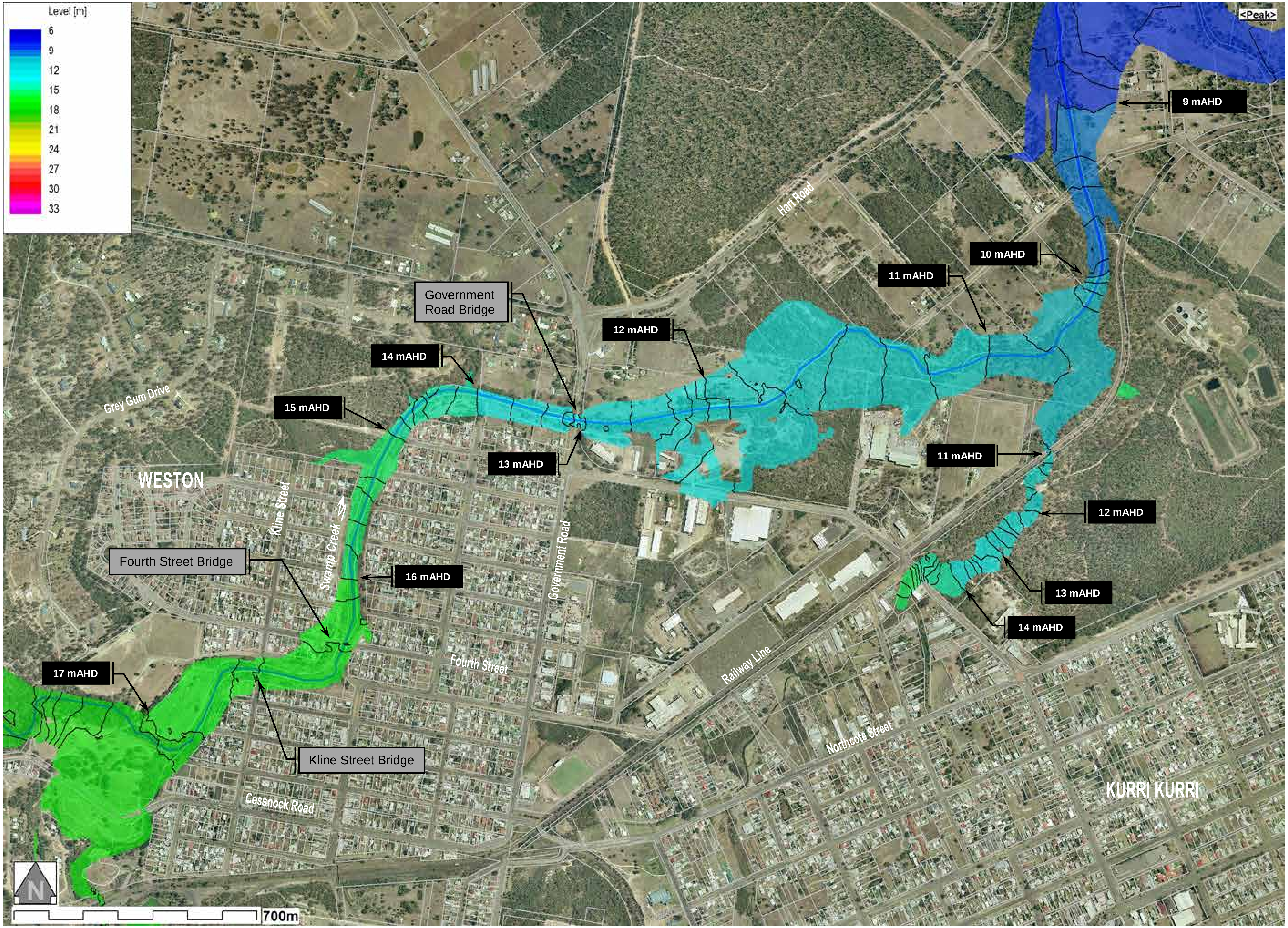
301015-02996 - Swamp Creek FRMS and Plan
02996ja121207fig21-050yr Level Abermain.doc

PEAK 2% AEP FLOOD LEVEL CONTOURS
[SHEET 1]

FIGURE 5.13



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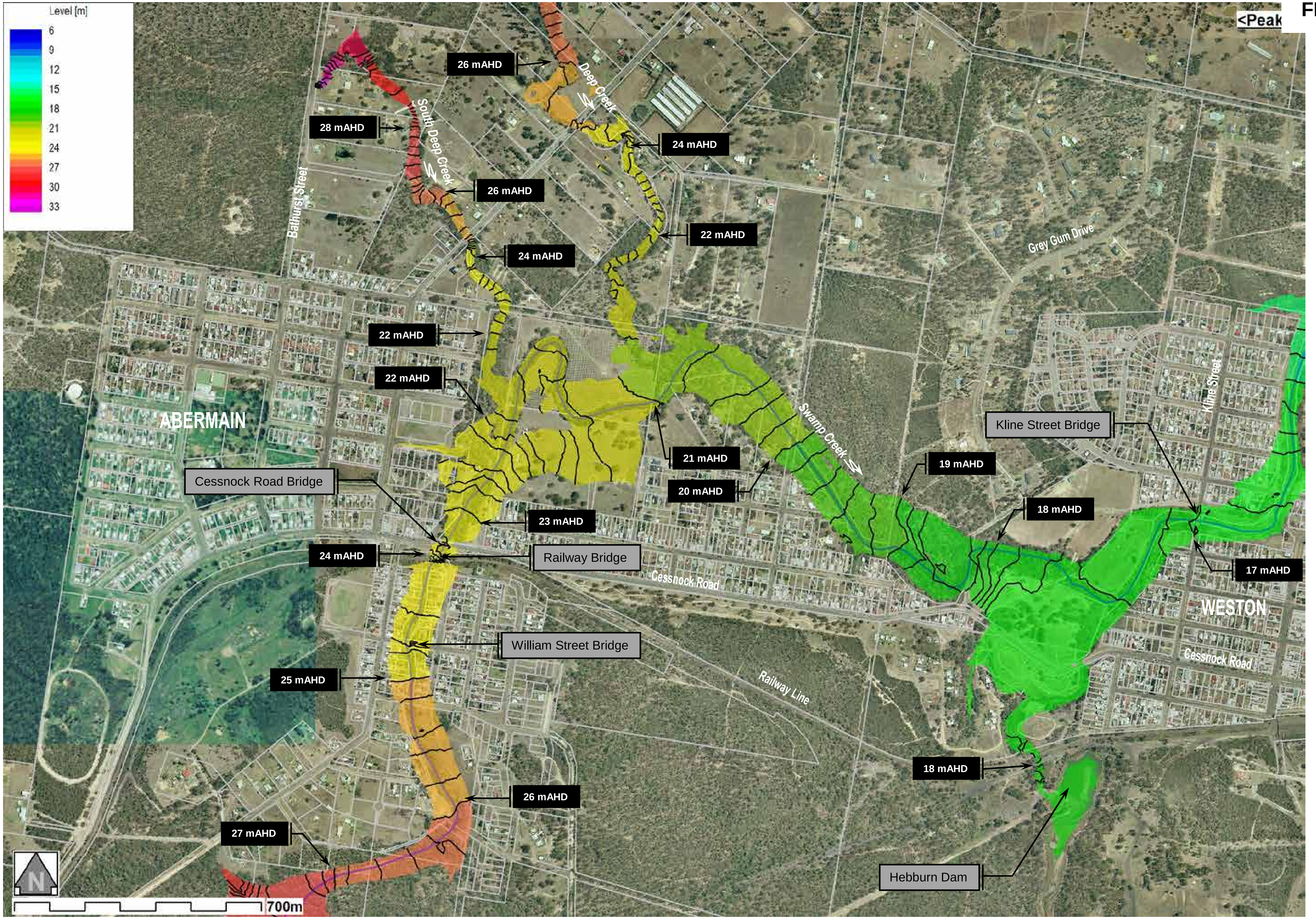
02996ja121207fig22-050yr Level Weston.doc

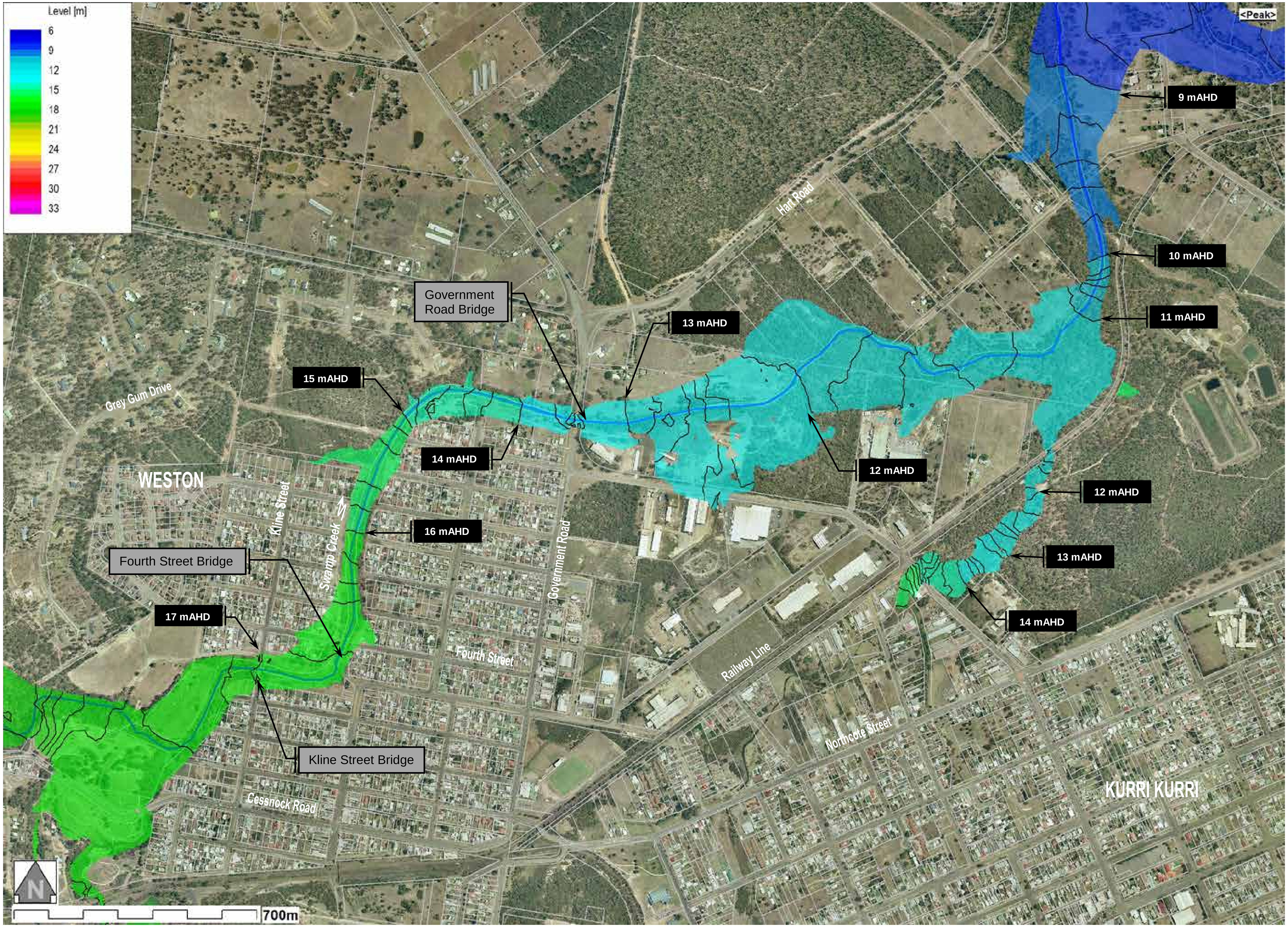
PEAK 2% AEP FLOOD LEVEL CONTOURS [SHEET 2]

FIGURE 5.14



PEAK 1% AEP FLOOD LEVEL CONTOURS
[SHEET 1]

FIGURE 5.15



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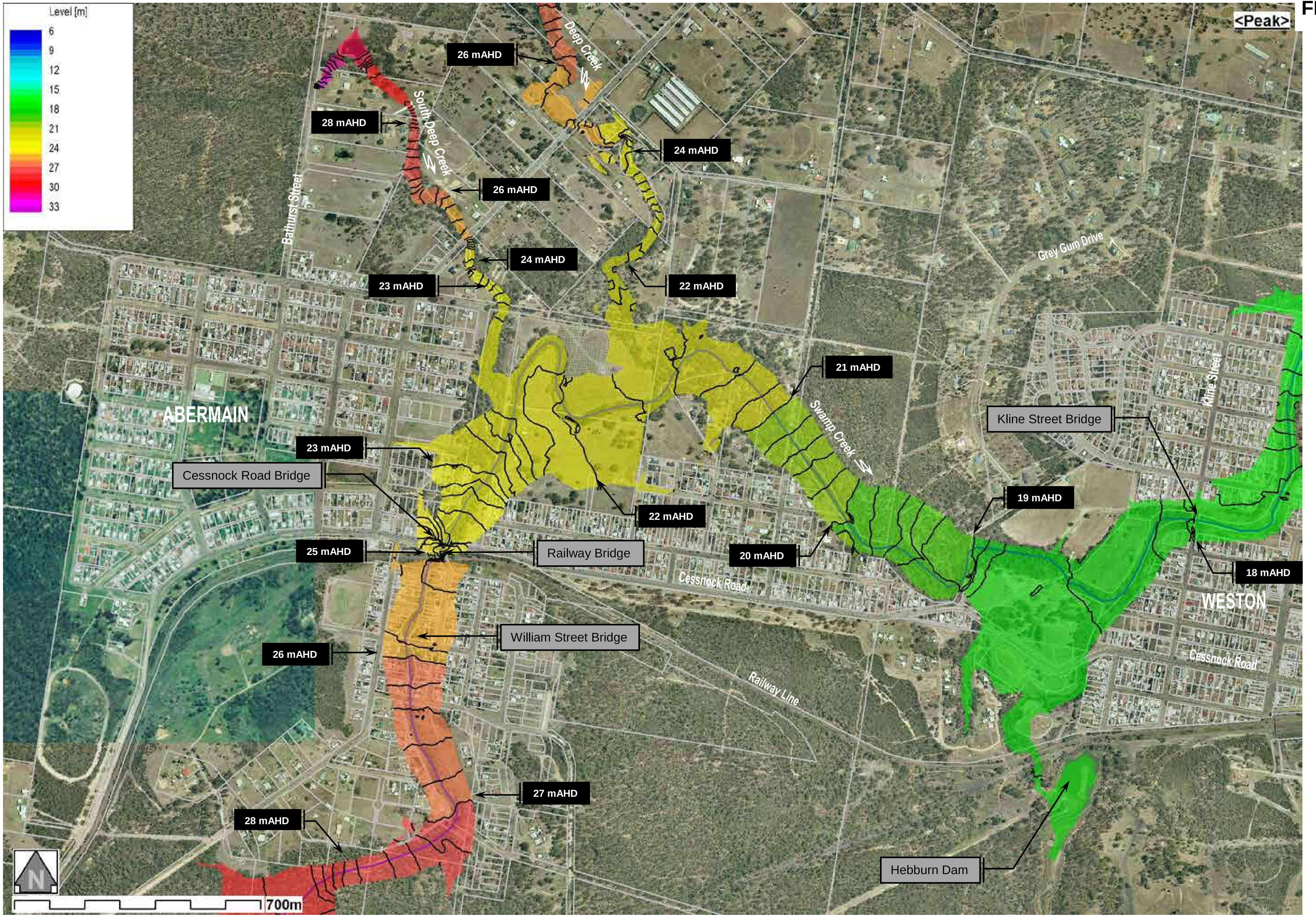
301015-02996 - Swamp Creek FRMS and Plan
02996ja121207fig24-100yr Level Weston.doc

PEAK 1% AEP FLOOD LEVEL CONTOURS
[SHEET 2]

FIGURE 5.16



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02996ja121207fig25-200yr Level Abermain.doc

PEAK 0.5% AEP FLOOD LEVEL CONTOURS
[SHEET 1]

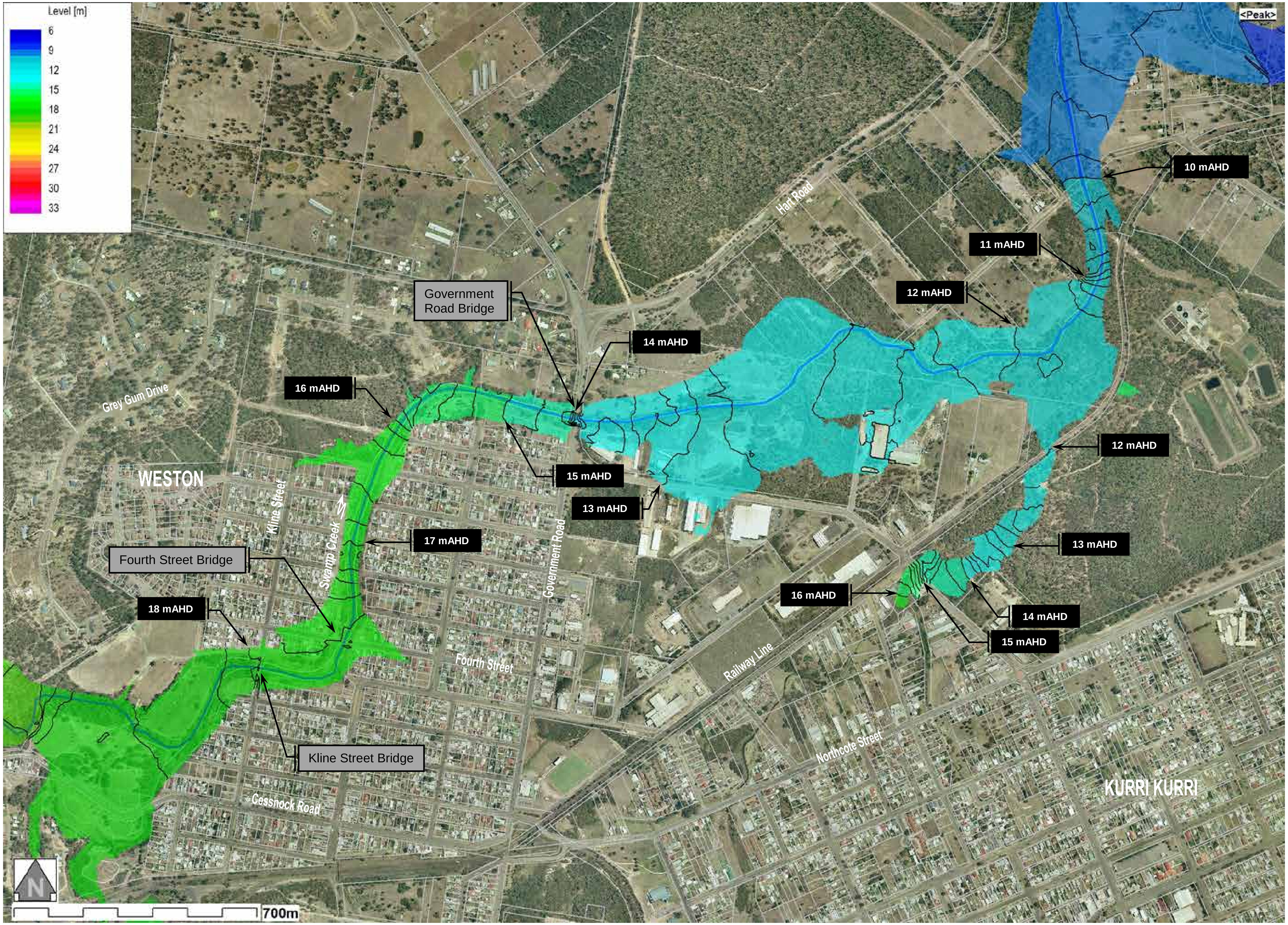

FIGURE 5.17

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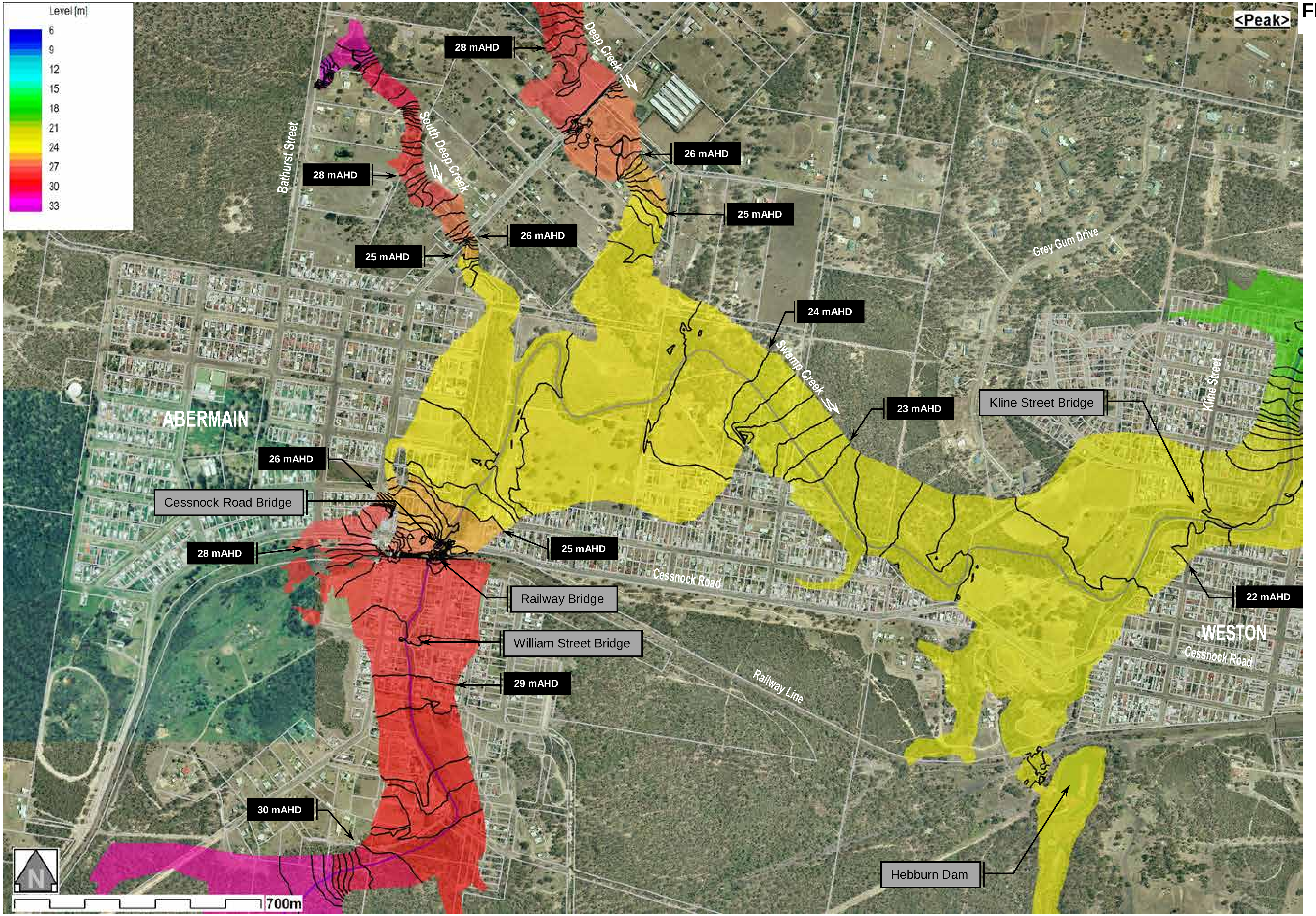
02996ja121207fig26-200yr Level Weston.doc

PEAK 0.5% AEP FLOOD LEVEL CONTOURS [SHEET 2]

FIGURE 5.18



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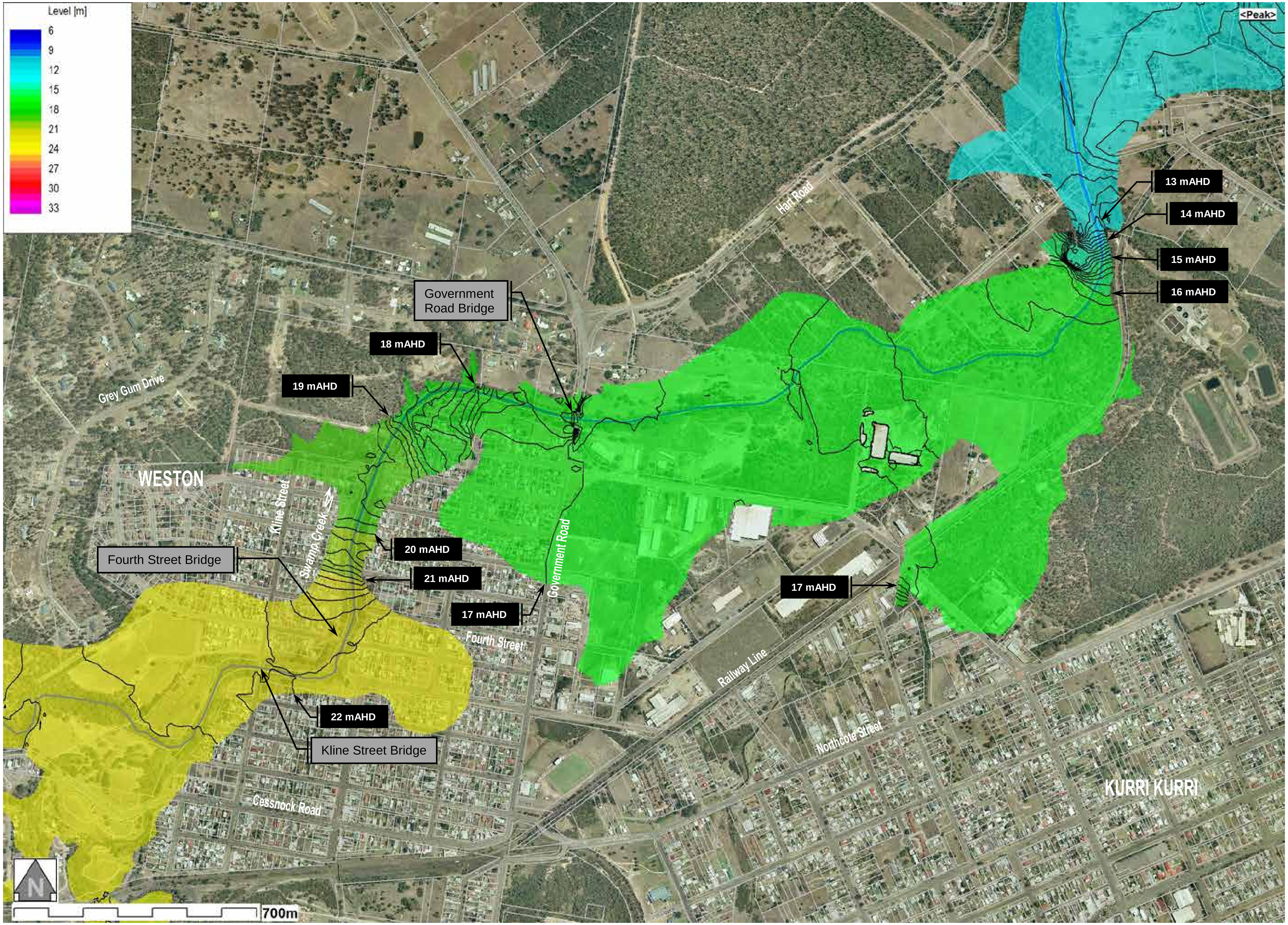
301015-02996 - Swamp Creek FRMS and Plan
02996ja121207fig27-PMF Level Abermain.doc

PEAK PROBABLE MAXIMUM FLOOD LEVEL CONTOURS
[SHEET 1]



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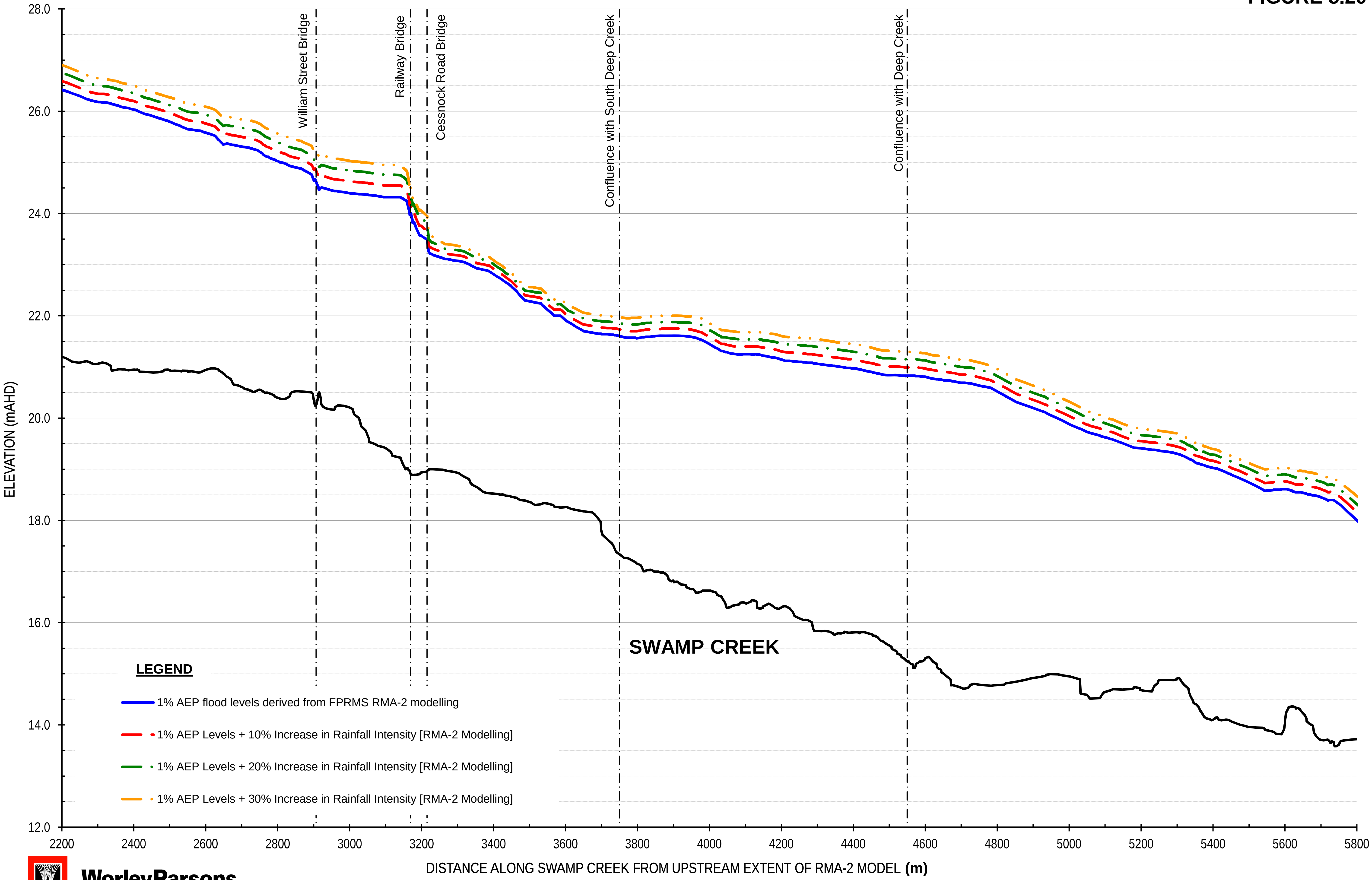
PEAK PROBABLE MAXIMUM FLOOD LEVEL CONTOURS [SHEET 2]

FIGURE 5.20



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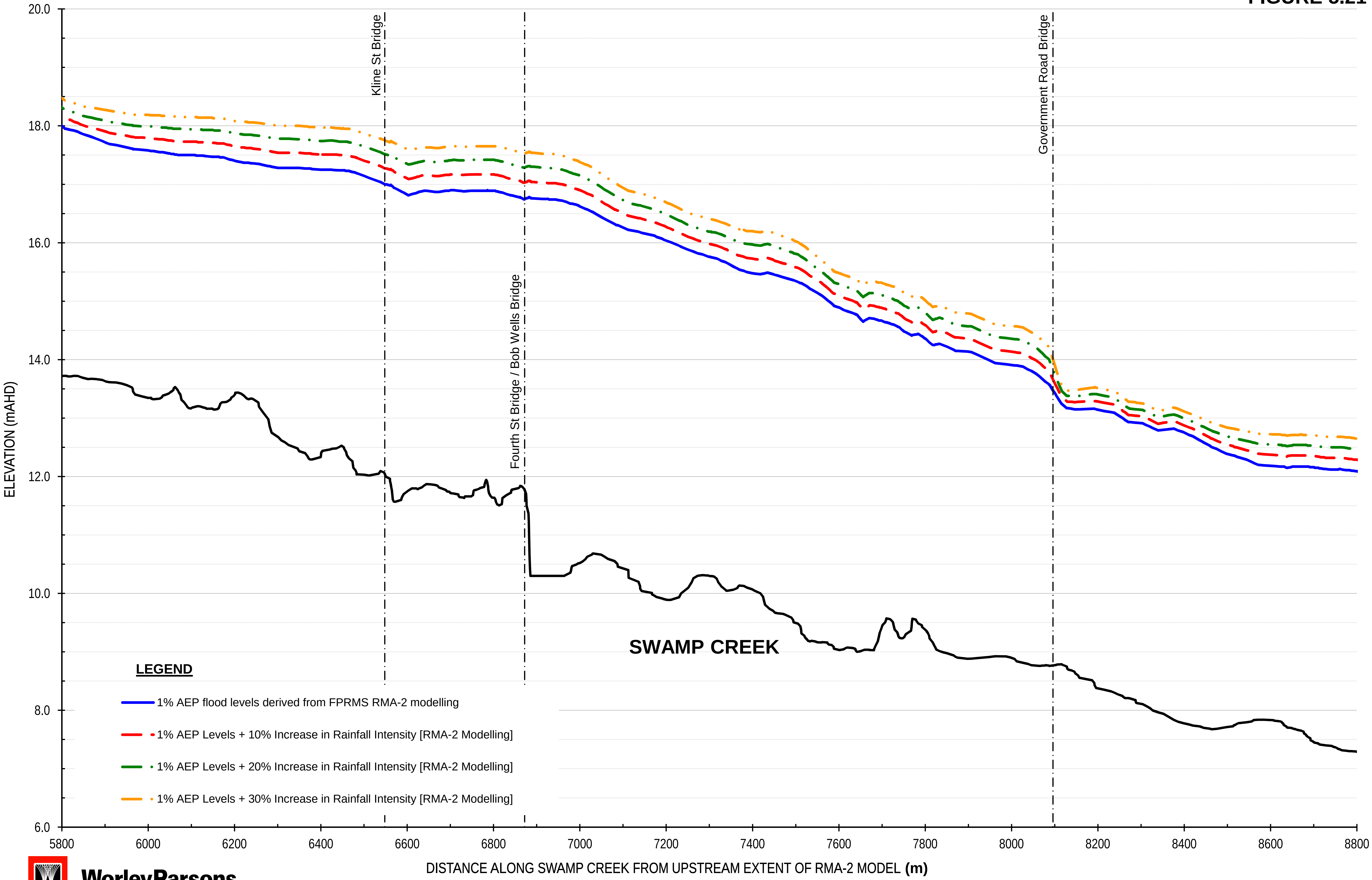
301015-02996 - Swamp Creek FRMS and Plan
fg2996_01ja120921-Calibration WSP.xls

CLIMATE CHANGE SURFACE PROFILES DERIVED FROM RMA-2 MODELLING
[IN THE VICINITY OF ABERMAIN]

FIGURE 5.21



WorleyParsons
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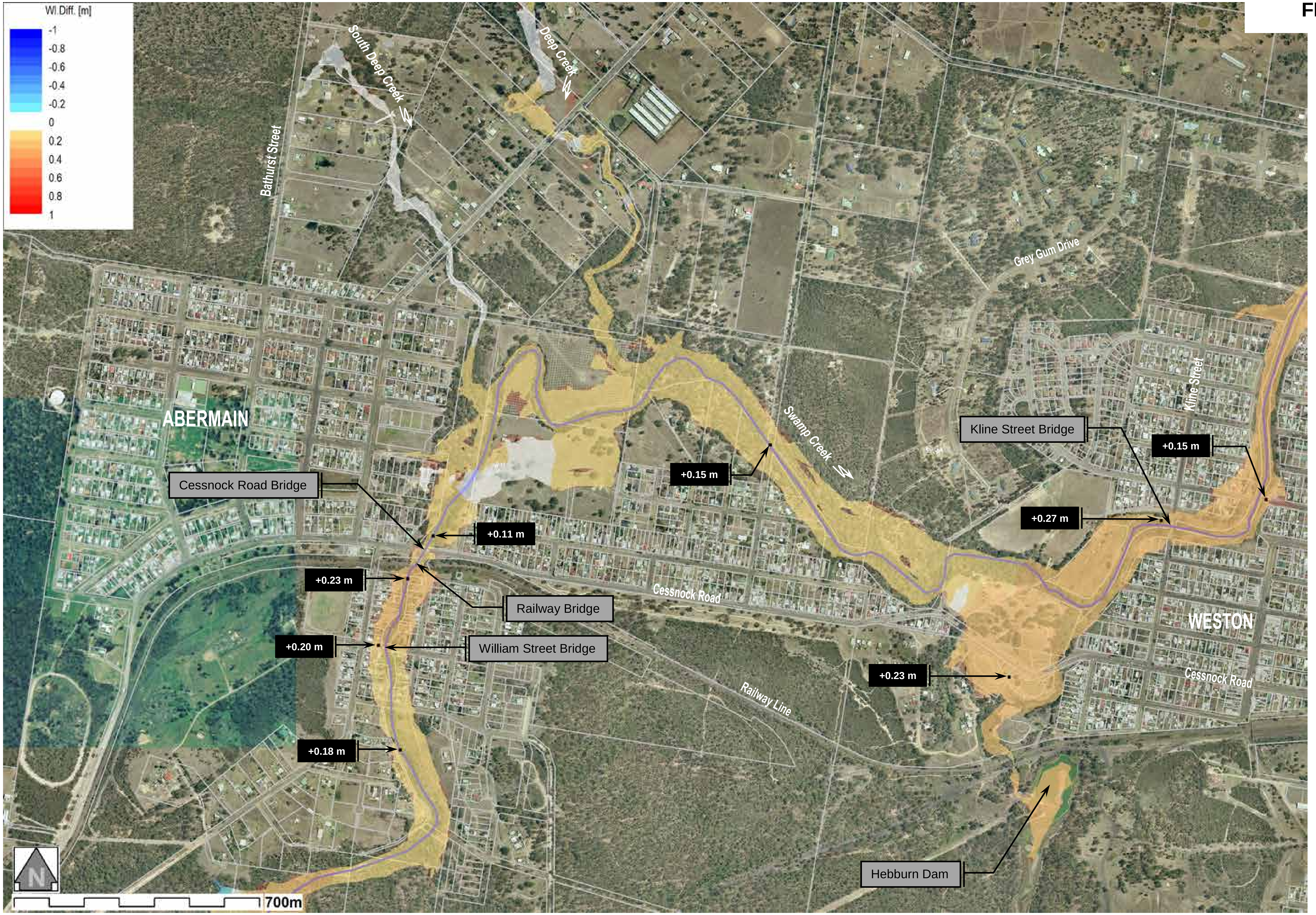
301015-02996 - Swamp Creek FRMS and Plan
fg2996_01ja120921-Calibration WSP.xls

CLIMATE CHANGE SURFACE PROFILES DERIVED FROM RMA-2 MODELLING [IN THE VICINITY OF WESTON]

FIGURE 5.22



WorleyParsons
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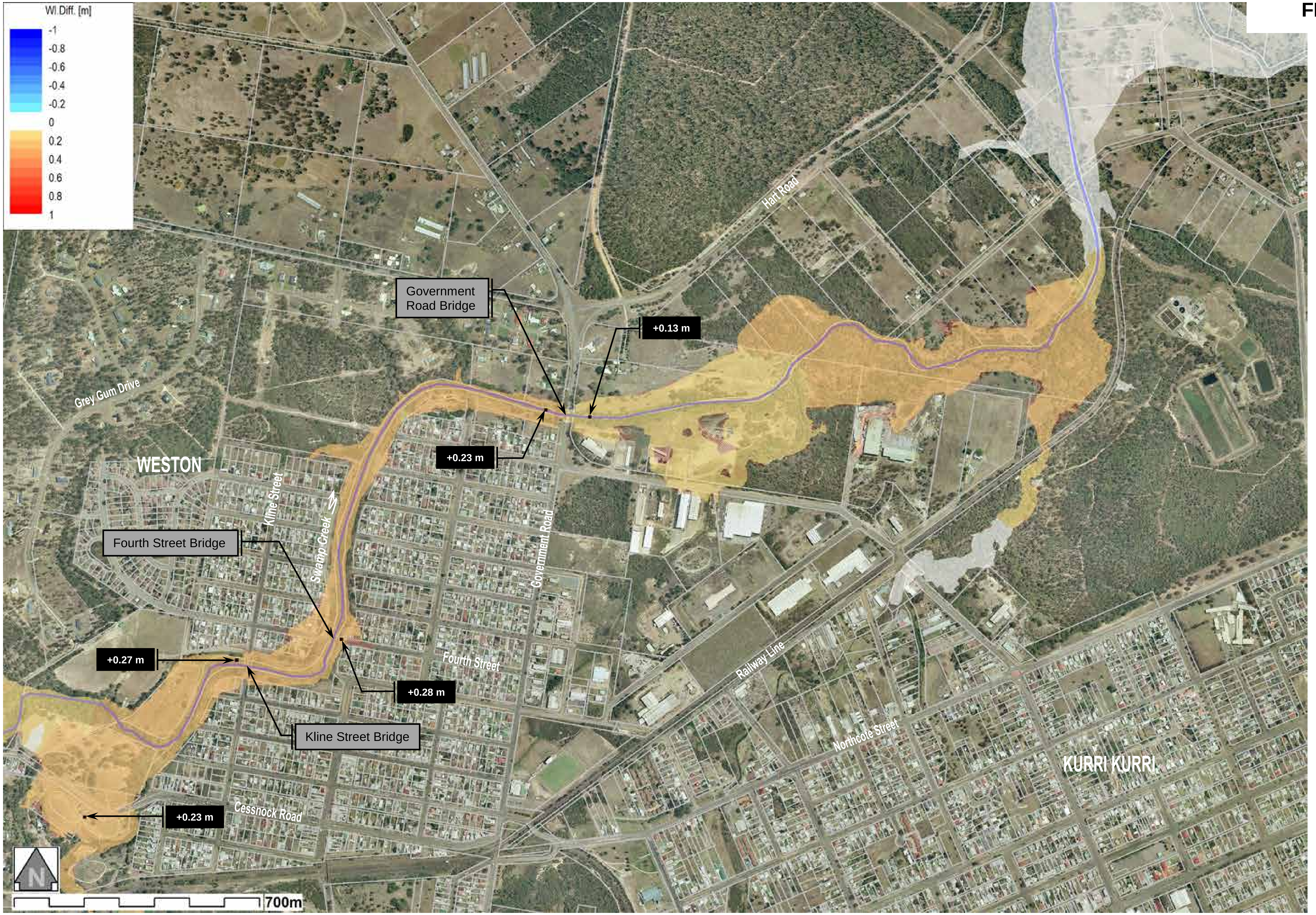
301015-02996 - Swamp Creek FRMS and Plan
02996nm121112fig31-Impact CC+10% Abermain.doc

IMPACT OF CLIMATE CHANGE ON PEAK 1% AEP FLOOD LEVELS DUE TO A 10% INCREASE IN RAINFALL INTENSITY [SHEET 1]

FIGURE 5.23



WorleyParsons
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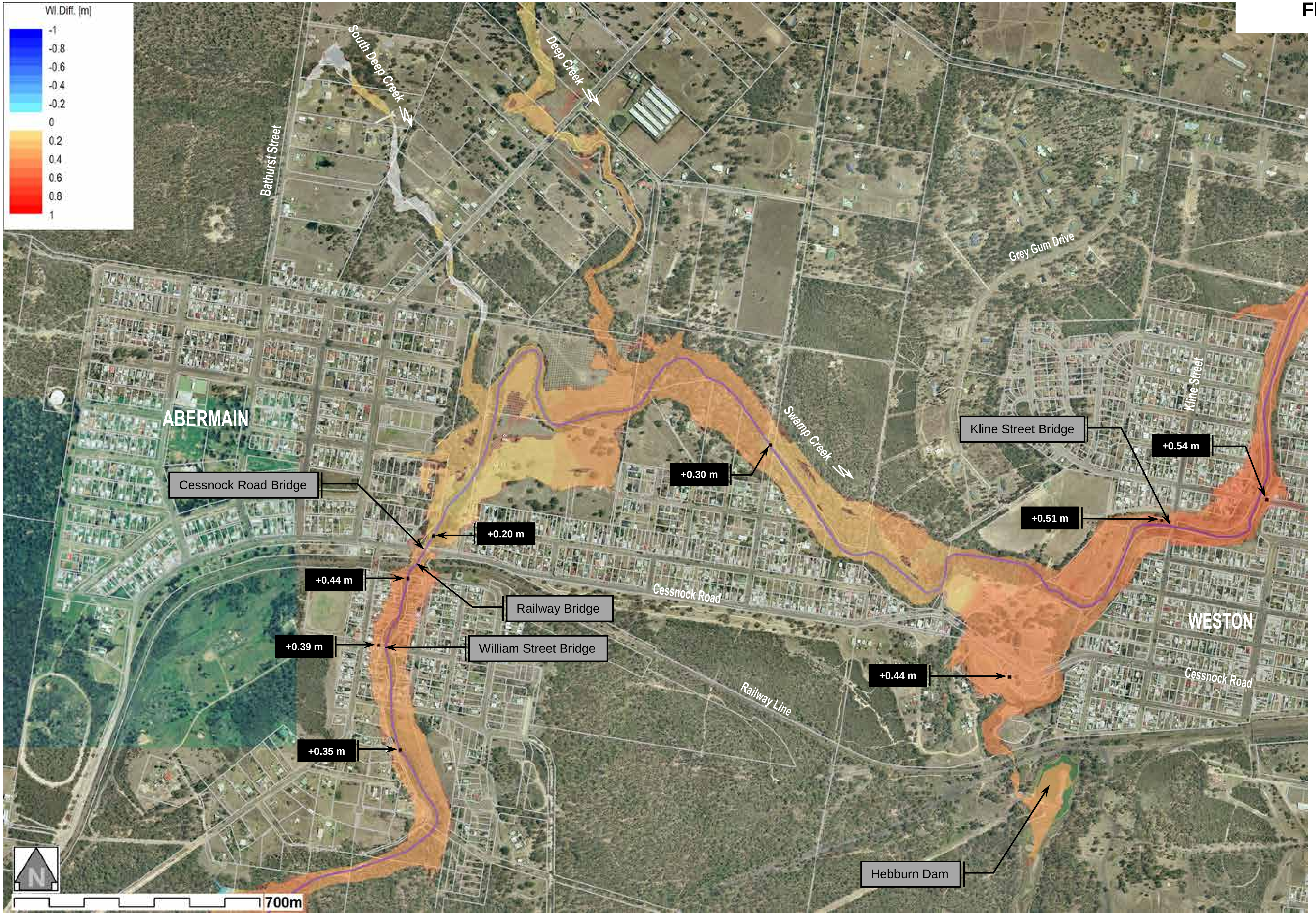
301015-02996 - Swamp Creek FRMS and Plan
02996nm121112fig32-Impact CC+10% Weston.doc

IMPACT OF CLIMATE CHANGE ON PEAK 1% AEP FLOOD LEVELS DUE TO A 10% INCREASE IN RAINFALL INTENSITY [SHEET 2]



WorleyParsons
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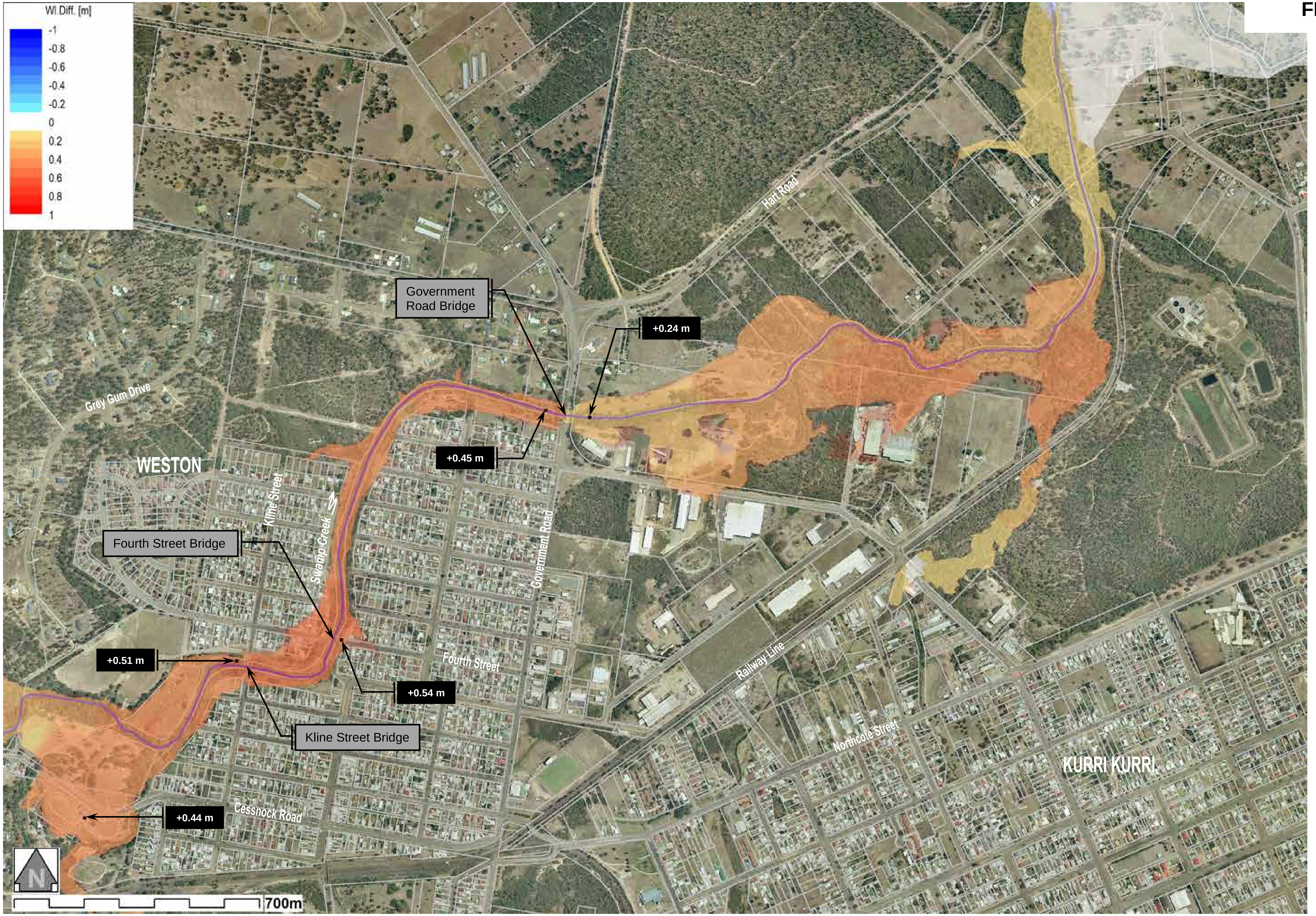
301015-02996 - Swamp Creek FRMS and Plan
02996nm121112fig33-Impact CC+20% Abermain.doc

IMPACT OF CLIMATE CHANGE ON PEAK 1% AEP FLOOD LEVELS DUE TO A 20% INCREASE IN RAINFALL INTENSITY [SHEET 1]



WorleyParsons
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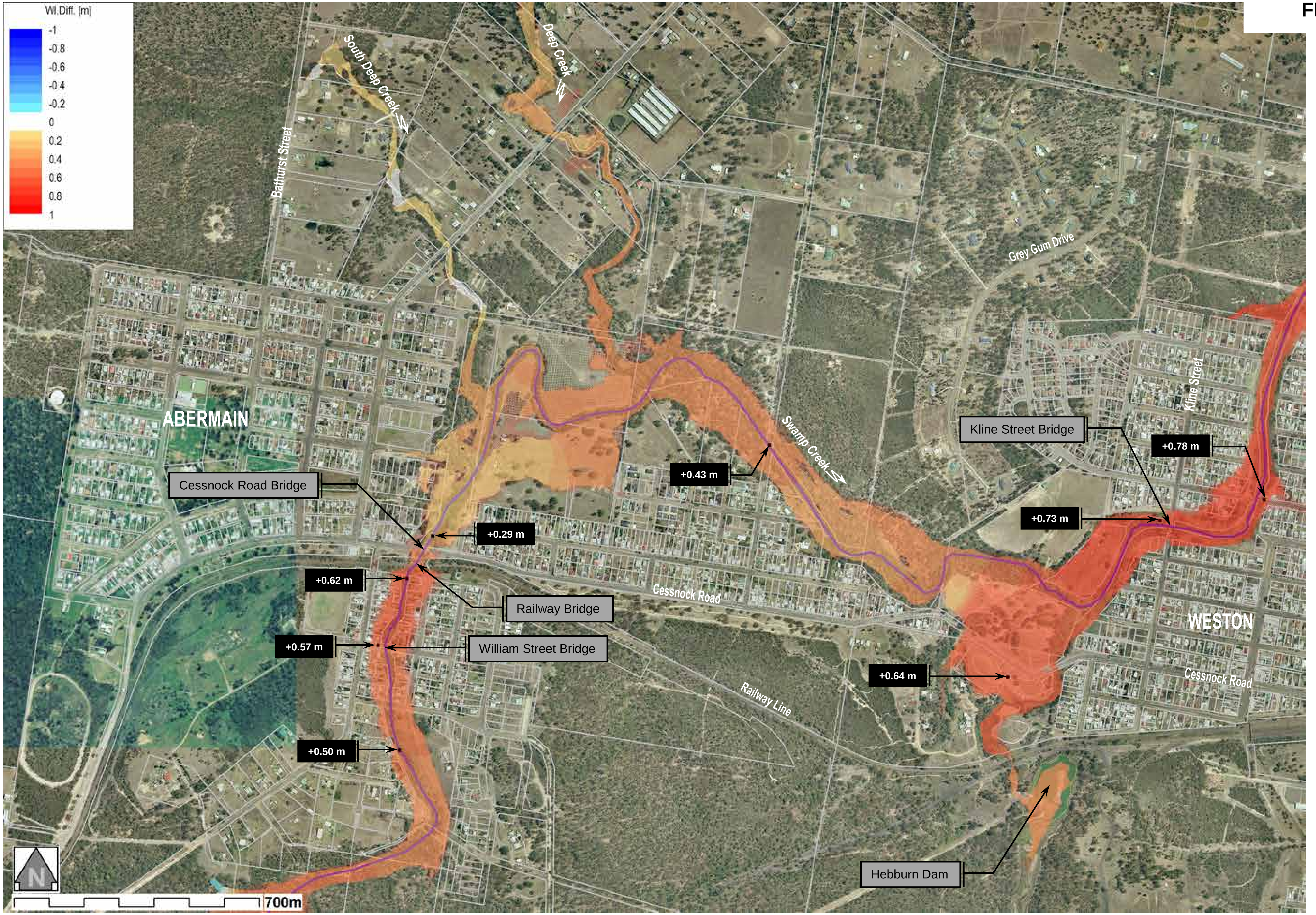
301015-02996 - Swamp Creek FRMS and Plan
02996nm121112fig34-Impact CC+20% Weston.doc

IMPACT OF CLIMATE CHANGE ON PEAK 1% AEP FLOOD LEVELS DUE TO A 20% INCREASE IN RAINFALL INTENSITY [SHEET 2]

FIGURE 5.26



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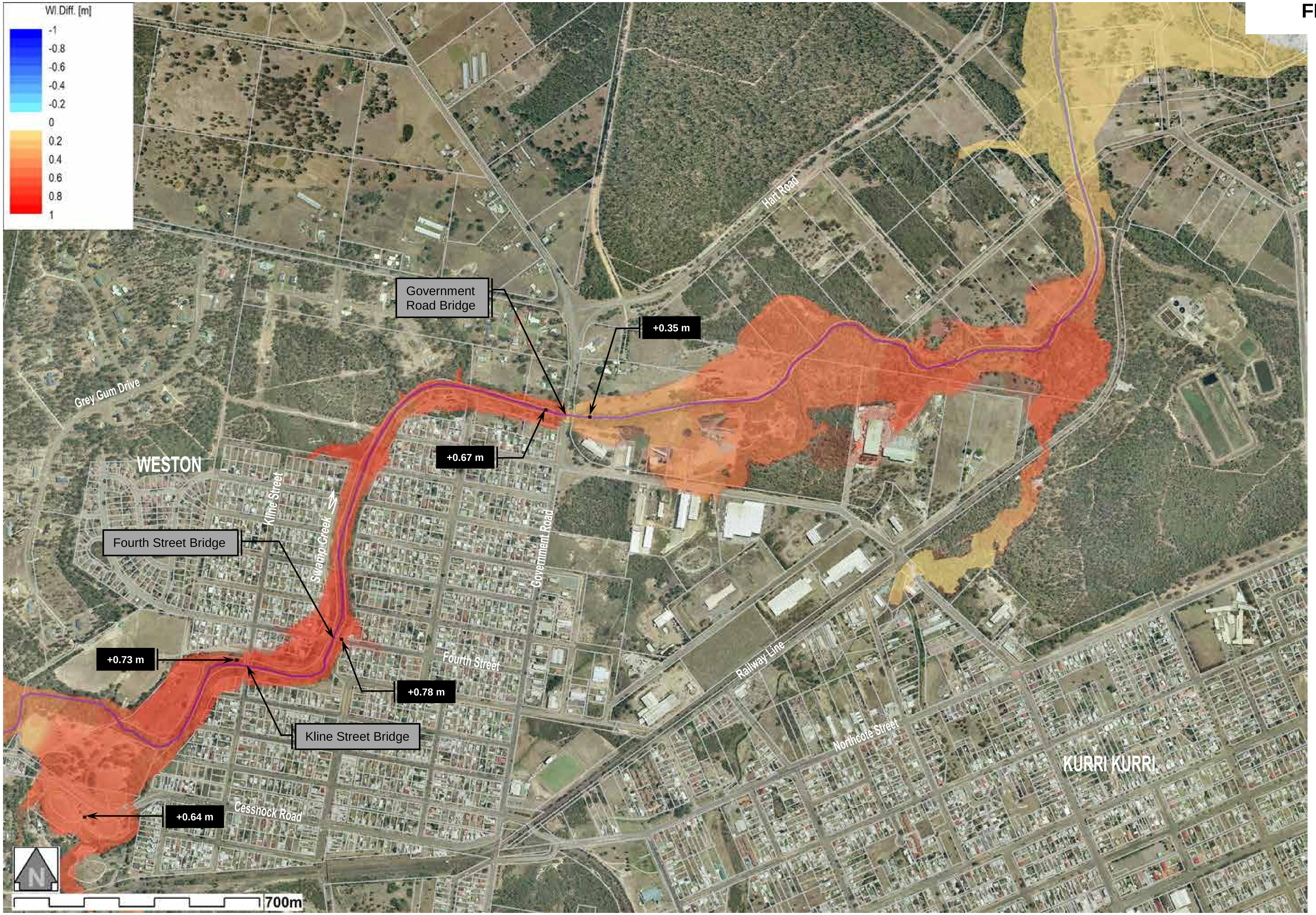
301015-02996 - Swamp Creek FRMS and Plan
02996nm121112fig35-Impact CC+30% Abermain.doc

IMPACT OF CLIMATE CHANGE ON PEAK 1% AEP FLOOD LEVELS DUE TO A 30% INCREASE IN RAINFALL INTENSITY [SHEET 1]

FIGURE 5.27



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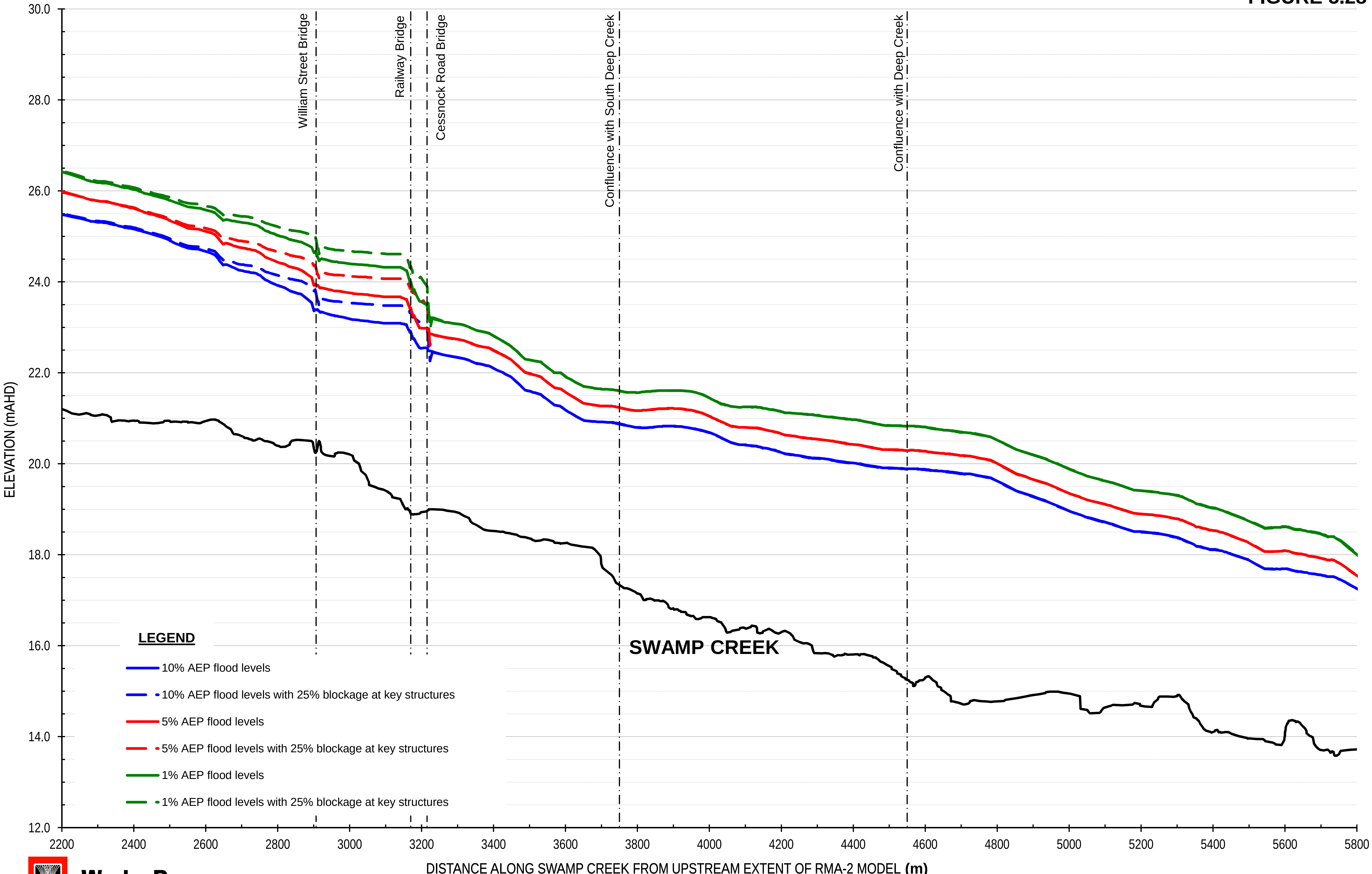
301015-02996 - Swamp Creek FRMS and Plan
02996nm121112fig36-Impact CC+30% Weston.doc

IMPACT OF CLIMATE CHANGE ON PEAK 1% AEP FLOOD LEVELS DUE TO A 30% INCREASE IN RAINFALL INTENSITY [SHEET 2]

FIGURE 5.28



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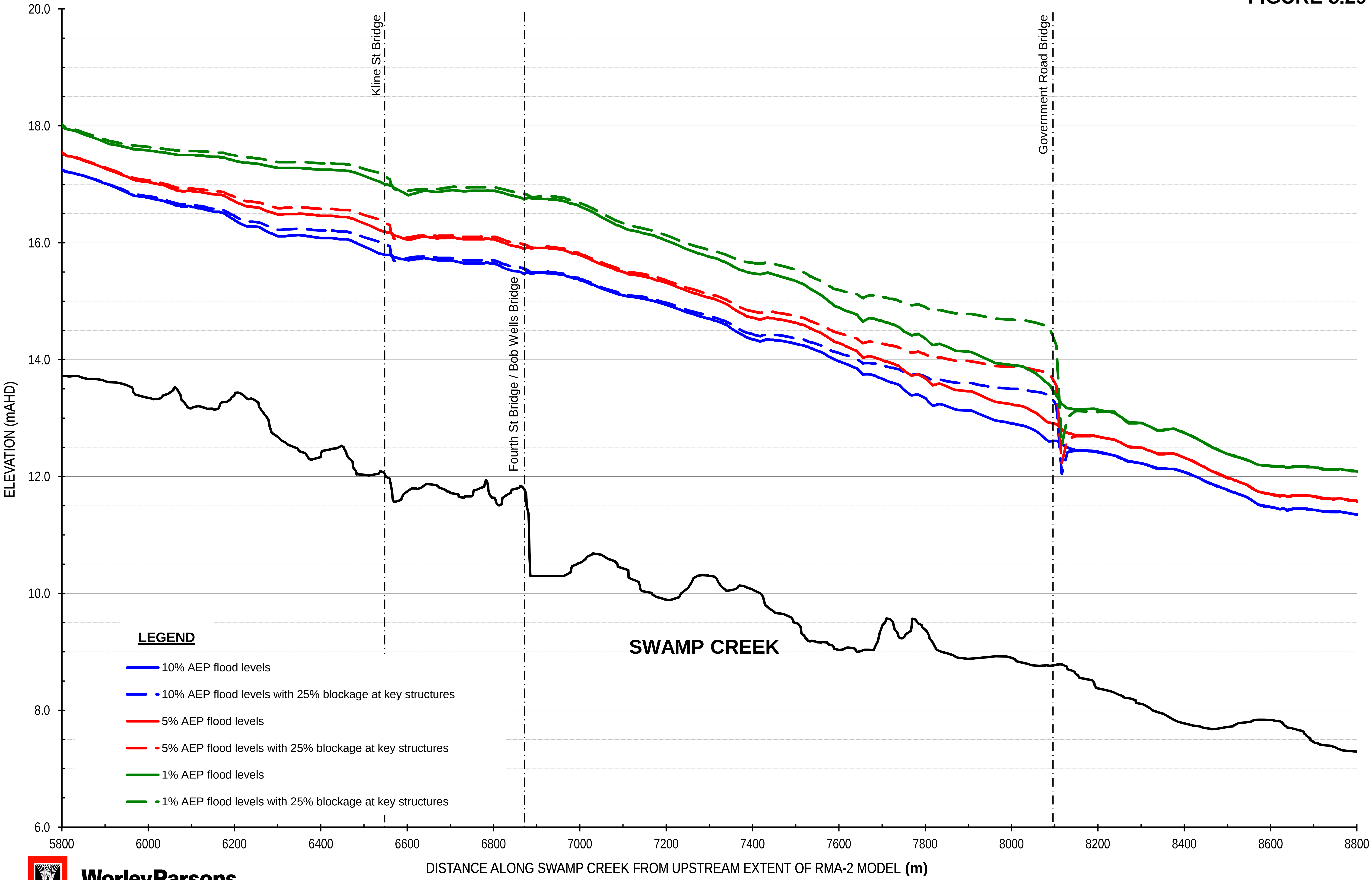
301015-02996 - Swamp Creek FRMS and Plan
fg2996_01ja120921-Calibration WSP.xls

IMPACT OF 25% BLOCKAGE SCENARIO ON PEAK DESIGN WATER SURFACE PROFILES [IN THE VICINITY OF ABERMAIN]

FIGURE 5.29



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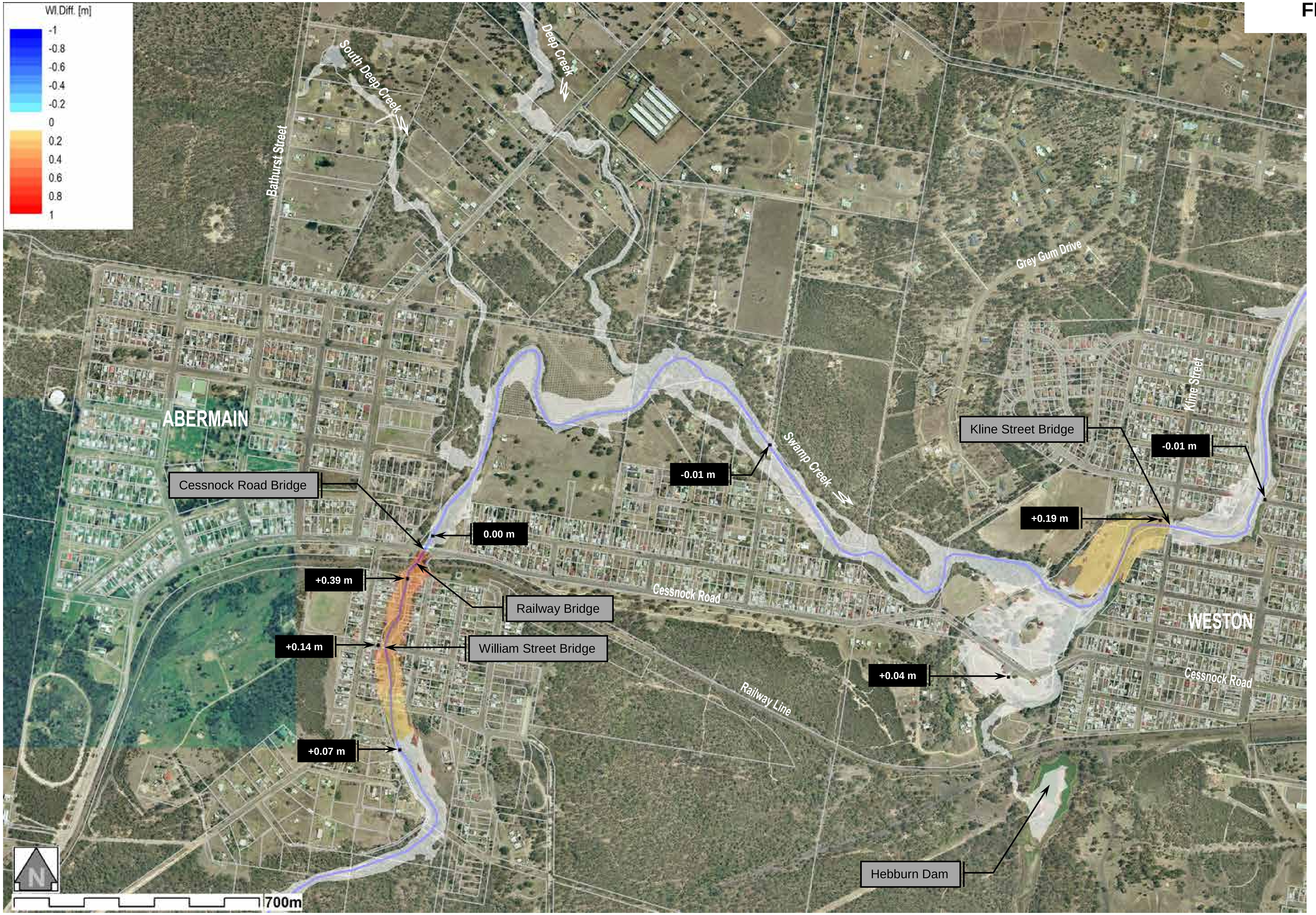
301015-02996 - Swamp Creek FRMS and Plan
fg2996_01ja120921-Calibration WSP.xls

IMPACT OF 25% BLOCKAGE SCENARIO ON PEAK DESIGN WATER SURFACE PROFILES [IN THE VICINITY OF WESTON]

FIGURE 5.30



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301015-02996 - Swamp Creek FRMS and Plan
02996nm121112fig39-Impact Block 010yr Abermain.doc

IMPACT OF BLOCKAGE AT STRUCTURES ON PEAK 10% AEP FLOOD LEVELS [SHEET 1]

FIGURE 5.31

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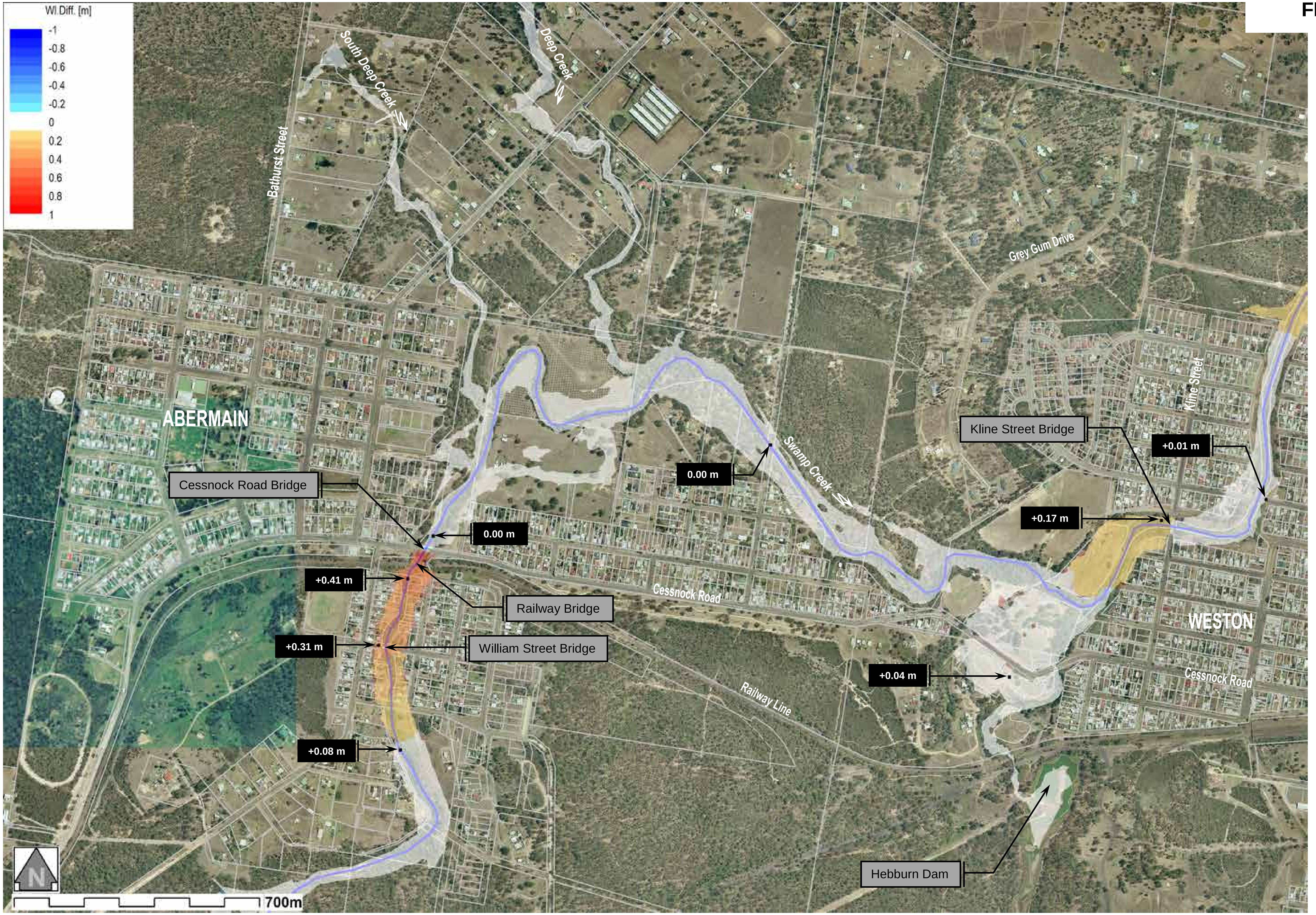
301015-02996 - Swamp Creek FRMS and Plan
02996nm121112fig40-Impact Block 010yr Weston.doc

IMPACT OF BLOCKAGE AT STRUCTURES ON PEAK 10% AEP FLOOD LEVELS [SHEET 2]

FIGURE 5.32



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301015-02996 - Swamp Creek FRMS and Plan
02996nm121112fig41-Impact Block 020yr Abermain.doc

IMPACT OF BLOCKAGE AT STRUCTURES ON PEAK 5% AEP FLOOD LEVELS [SHEET 1]

FIGURE 5.33

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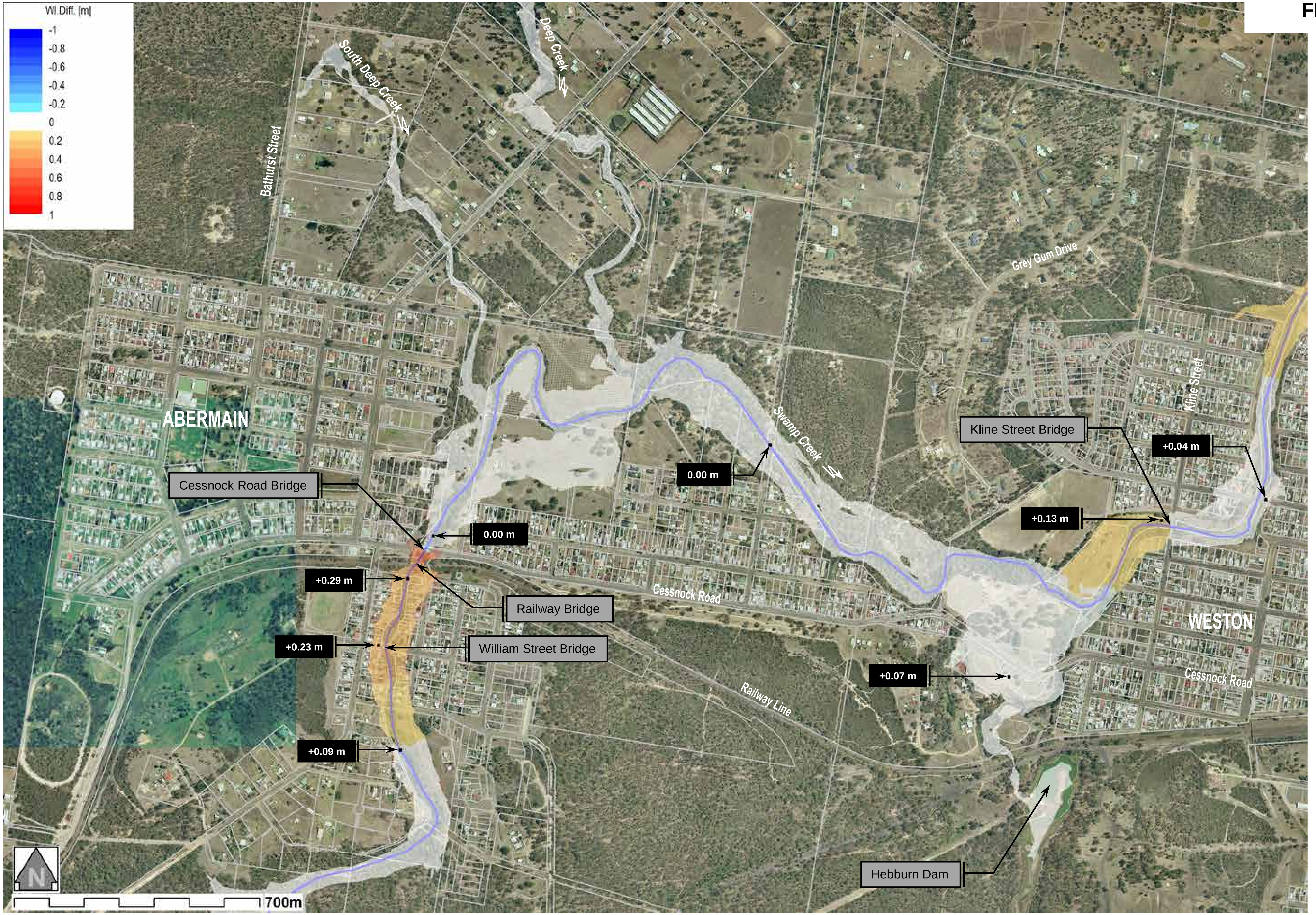
02996nm121112fig42-Impact Block 020yr Weston.doc

IMPACT OF BLOCKAGE AT STRUCTURES ON PEAK 5% AEP FLOOD LEVELS [SHEET 2]



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301015-02996 - Swamp Creek FRMS and Plan
02996nm121112fig43-Impact Block 100yr Abermain.doc

IMPACT OF BLOCKAGE AT STRUCTURES ON PEAK 1% AEP FLOOD LEVELS [SHEET 1]

FIGURE 5.35

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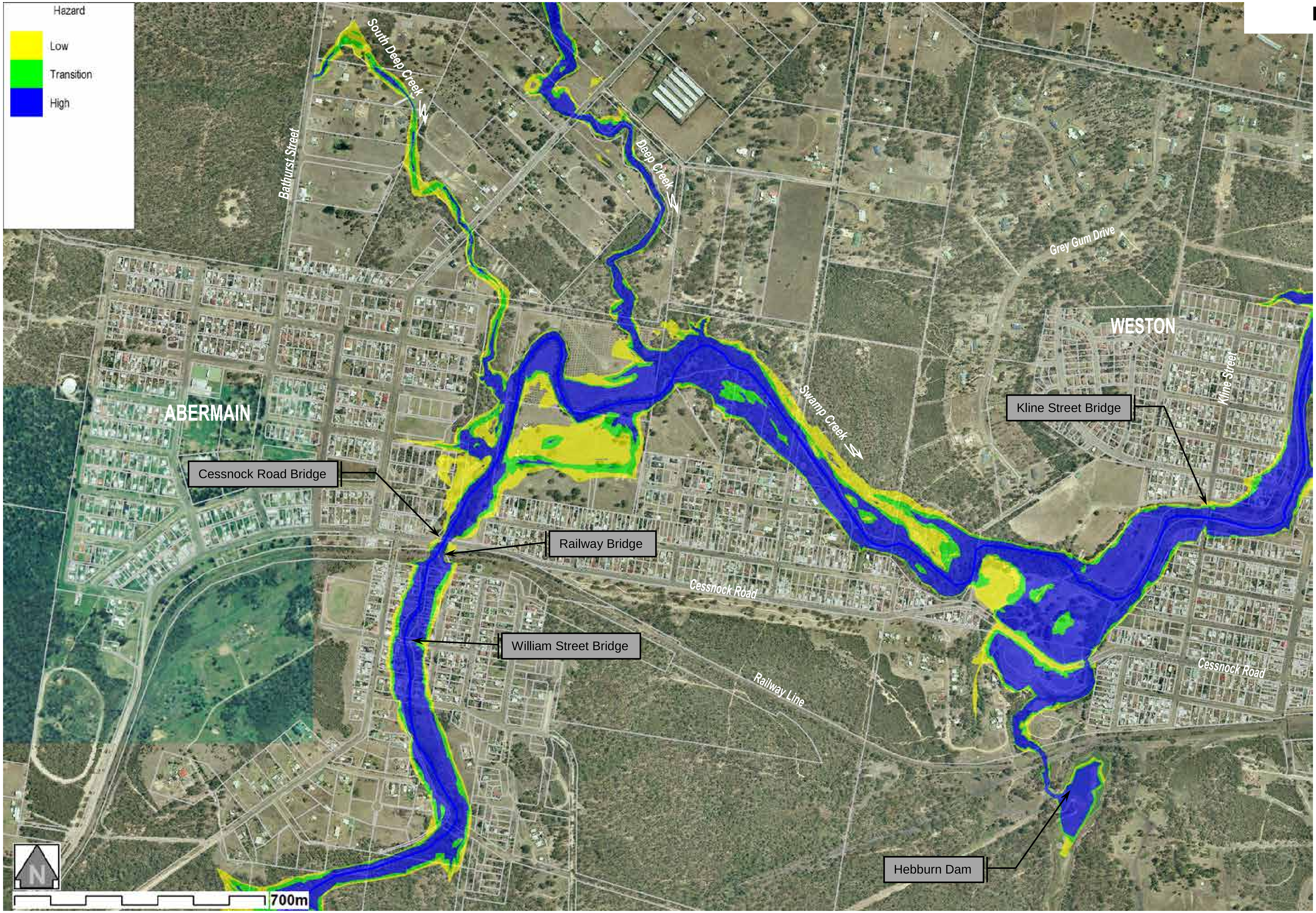
02996nm121112fig44-Impact Block 100yr Weston.doc

IMPACT OF BLOCKAGE AT STRUCTURES ON PEAK 1% AEP FLOOD LEVELS [SHEET 2]

FIGURE 6.1



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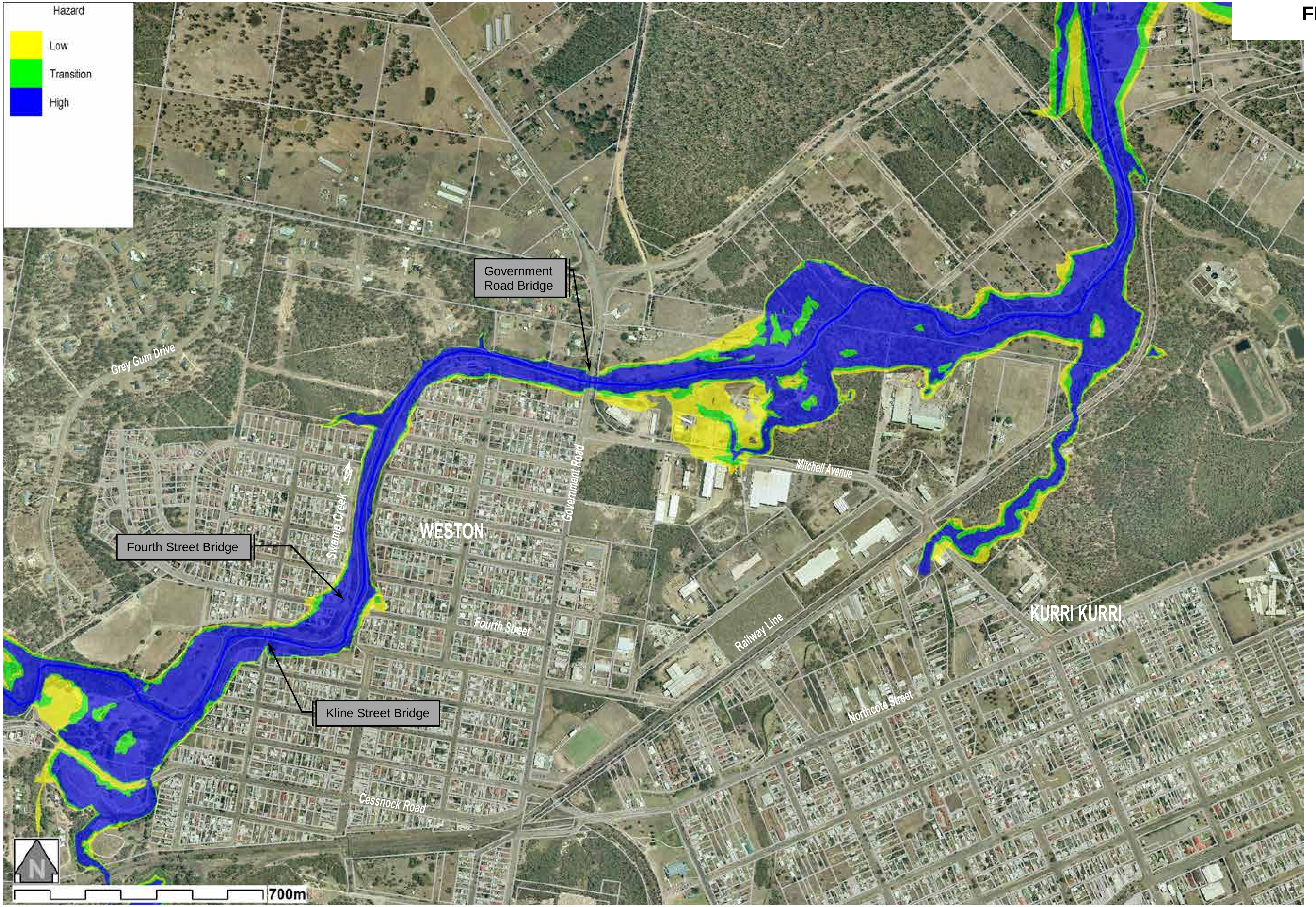
301015-02996 - Swamp Creek FRMS and Plan
02996ja121112fig47-Provisional Flood Hazard 100 Year ARI Abermain.doc

PROVISIONAL FLOOD HAZARD FOR THE 1% AEP EVENT [SHEET 1]

FIGURE 6.2



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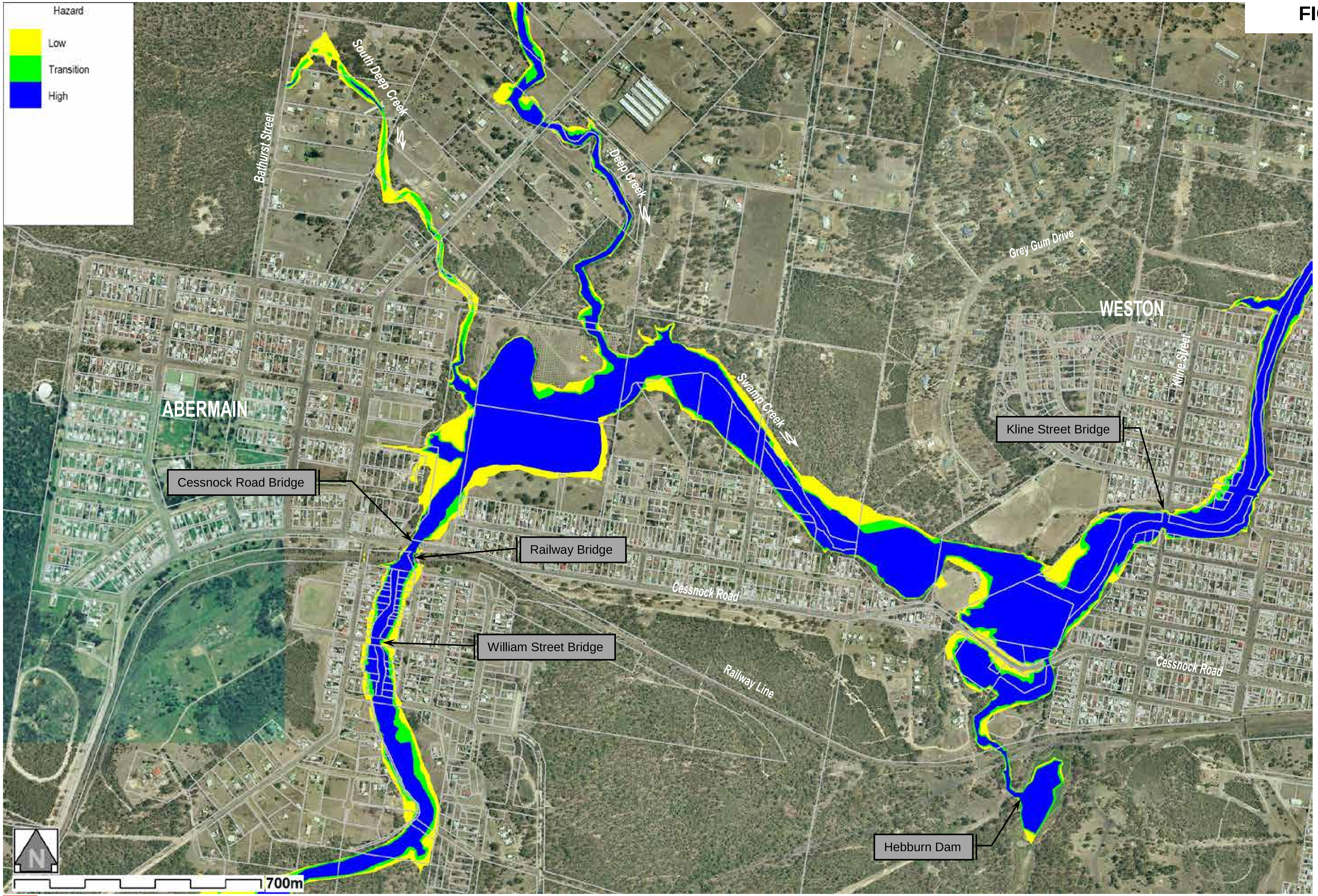
301015-02996 - Swamp Creek FRMS and Plan
02996ja121112fig48-Provisional Flood Hazard 100 Year ARI Weston.doc

PROVISIONAL FLOOD HAZARD
FOR THE 1% AEP EVENT [SHEET 2]

FIGURE 6.3



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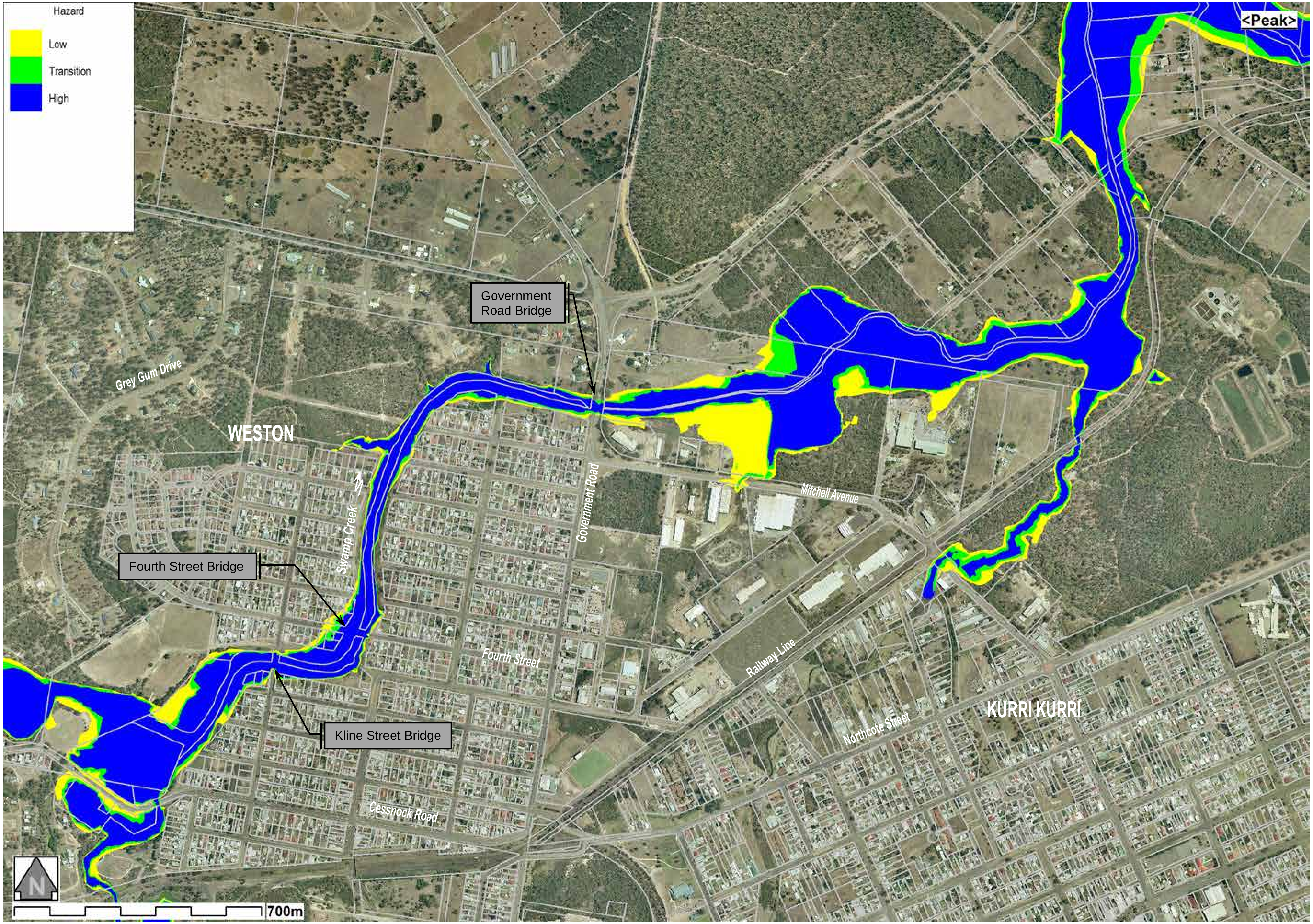
301015-02996 - Swamp Creek FRMS and Plan
02996ja121217fig01-True Flood Hazard 20 Year ARI Abermain.doc

**TRUE FLOOD HAZARD
FOR THE 5% AEP FLOOD [SHEET 1]**

FIGURE 6.4



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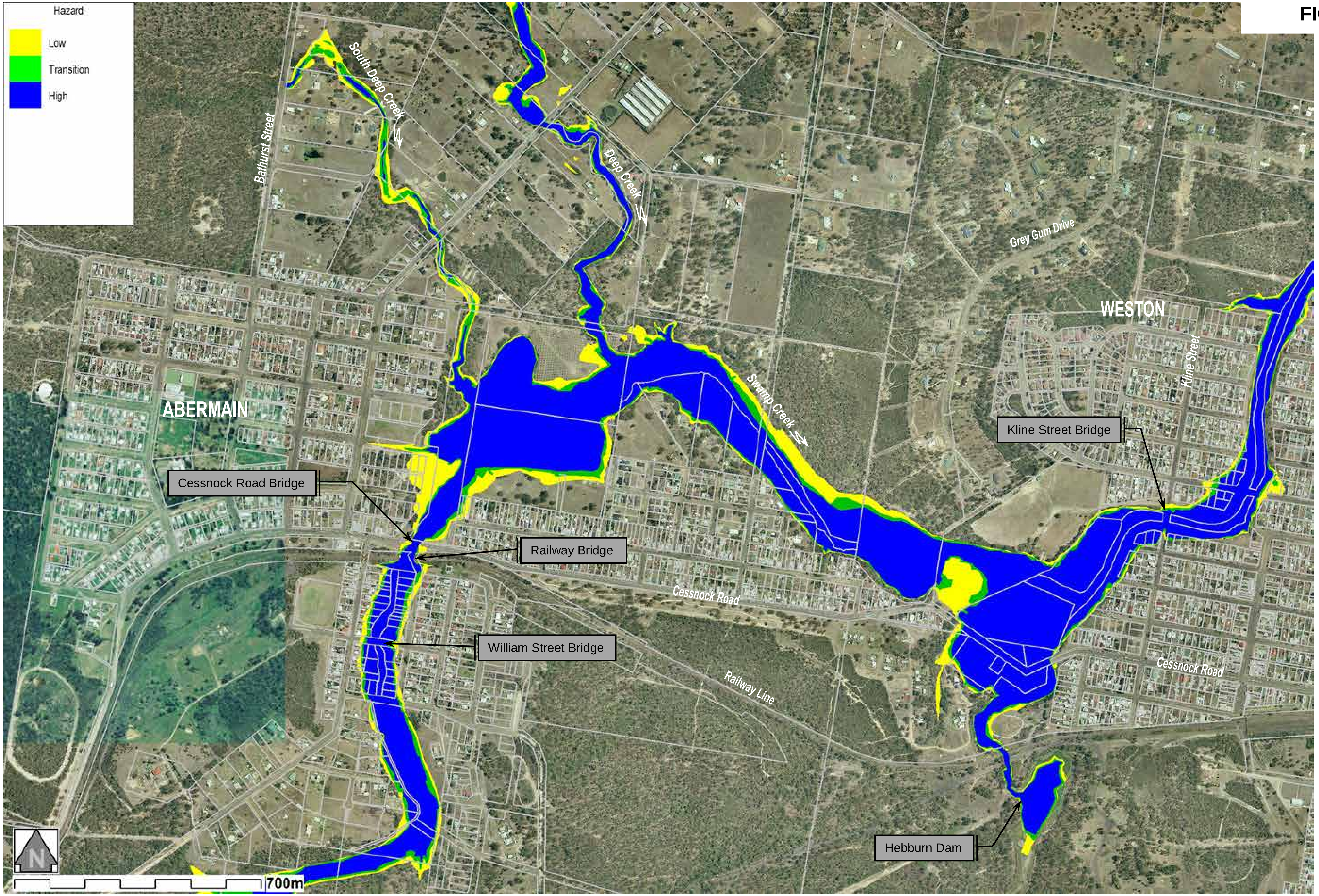
301015-02996 - Swamp Creek FRMS and Plan
02996ja121217fig02-True Flood Hazard 20 Year ARI Weston.doc

TRUE FLOOD HAZARD
FOR THE 5% AEP FLOOD [SHEET 2]

FIGURE 6.5



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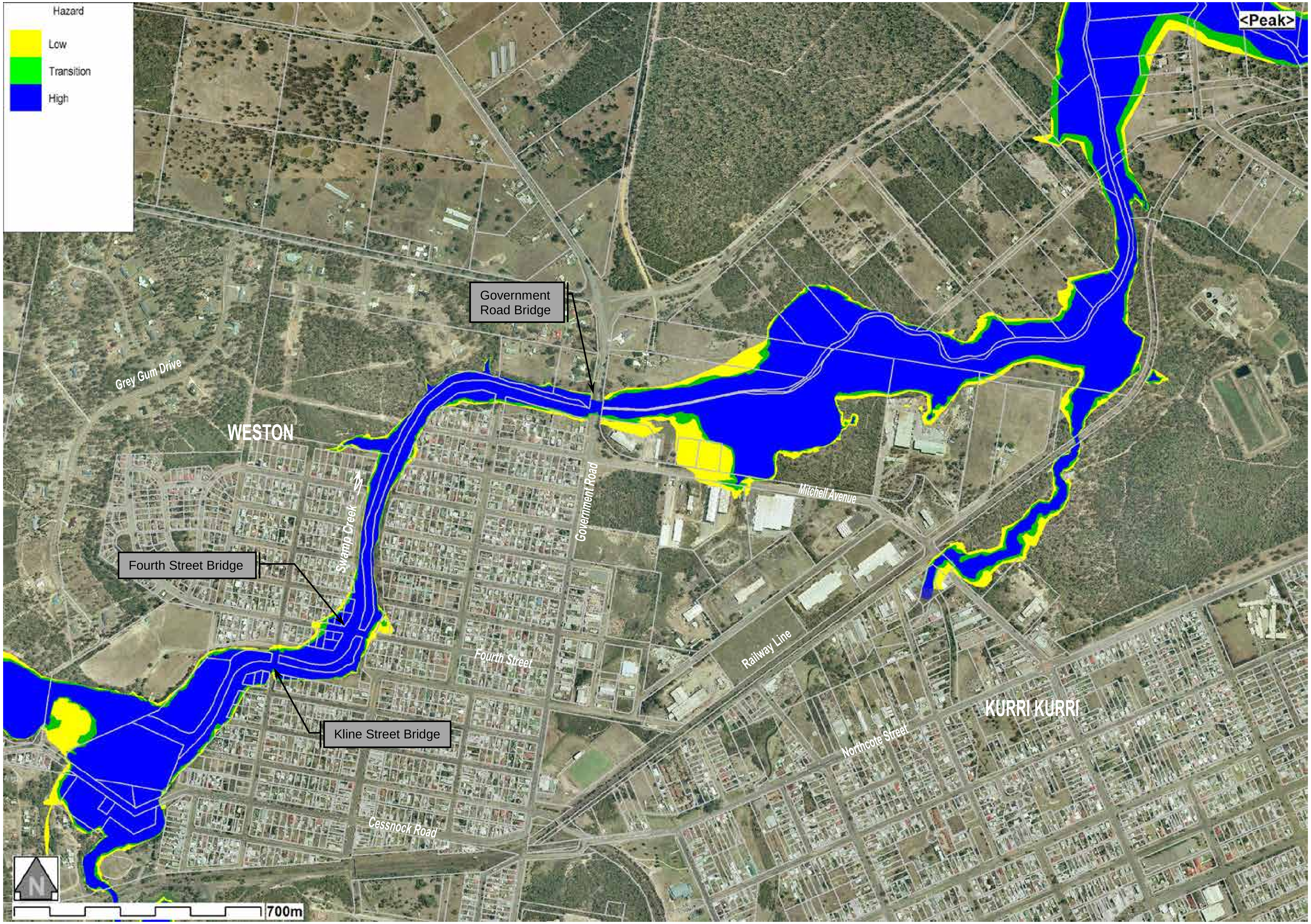
301015-02996 - Swamp Creek FRMS and Plan
02996ja121217fig03-True Flood Hazard 100 Year ARI Abermain.doc

TRUE FLOOD HAZARD FOR THE 1% AEP FLOOD [SHEET 1]

FIGURE 6.6



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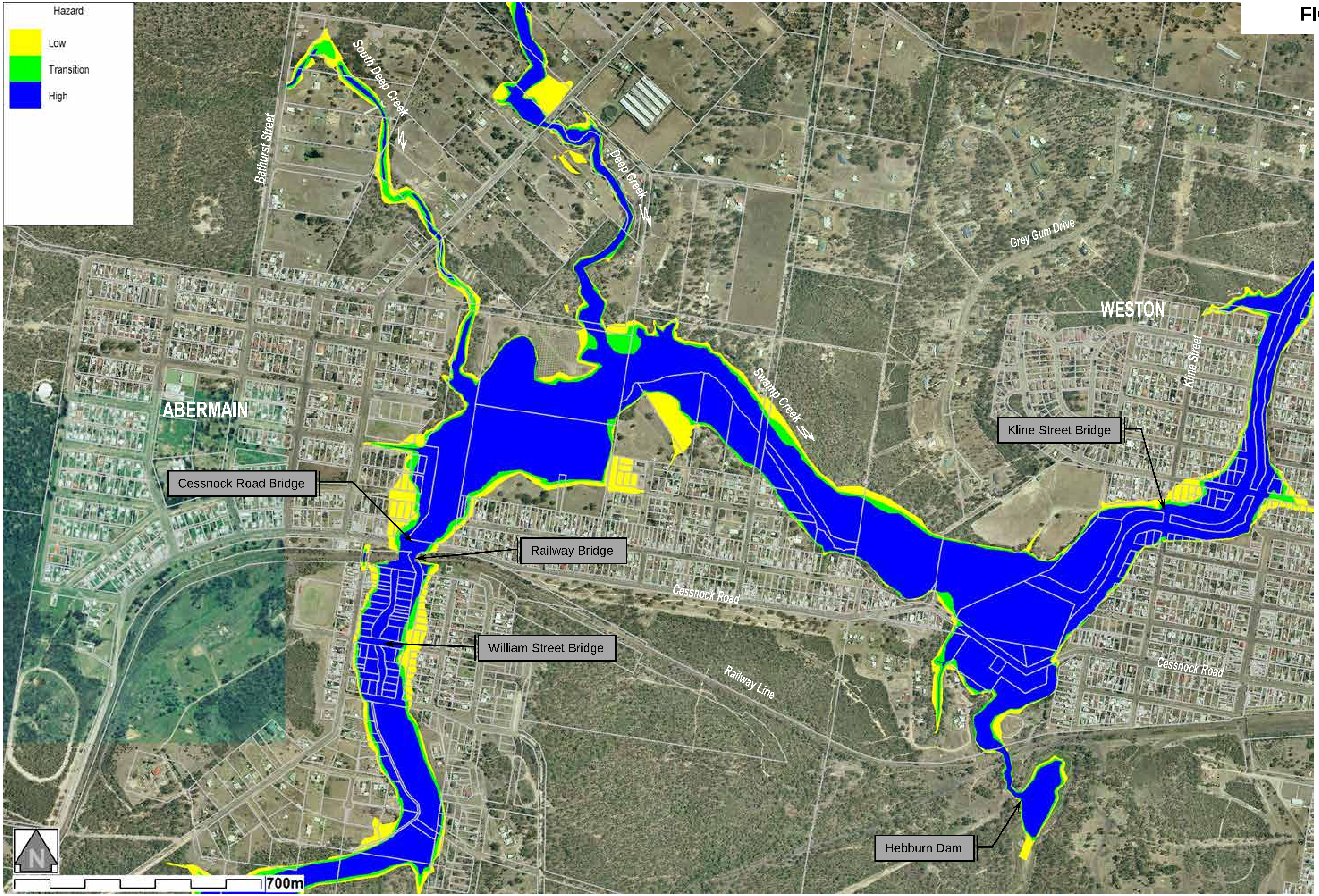
301015-02996 - Swamp Creek FRMS and Plan
02996ja121217fig04-True Flood Hazard 100 Year ARI Weston.doc

TRUE FLOOD HAZARD FOR THE 1% AEP FLOOD [SHEET 2]

FIGURE 6.7



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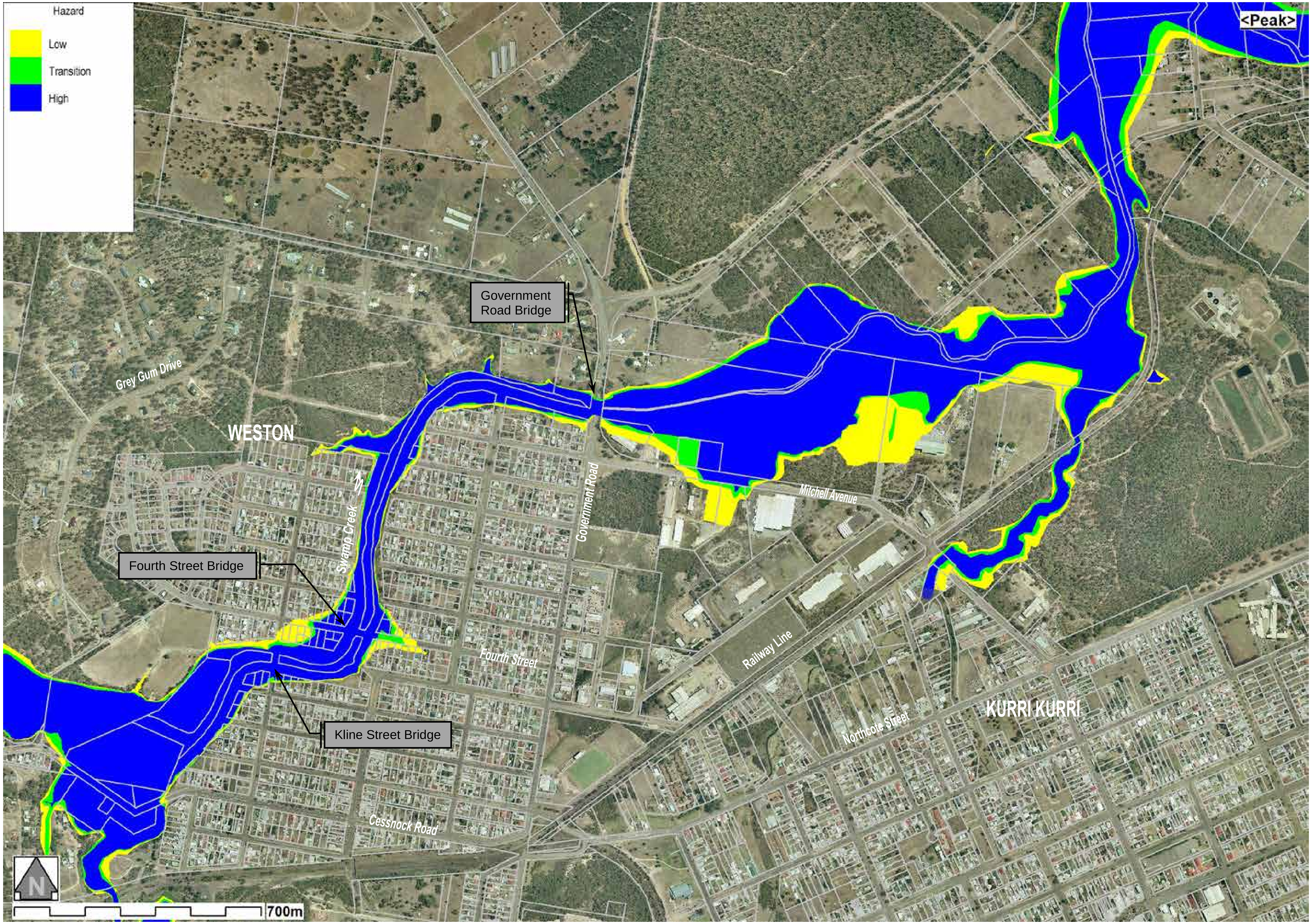
301015-02996 - Swamp Creek FRMS and Plan
02996ja121217fig05-True Flood Hazard 200 Year ARI Abermain.doc

TRUE FLOOD HAZARD FOR THE 0.5% AEP FLOO [SHEET 1]

FIGURE 6.8



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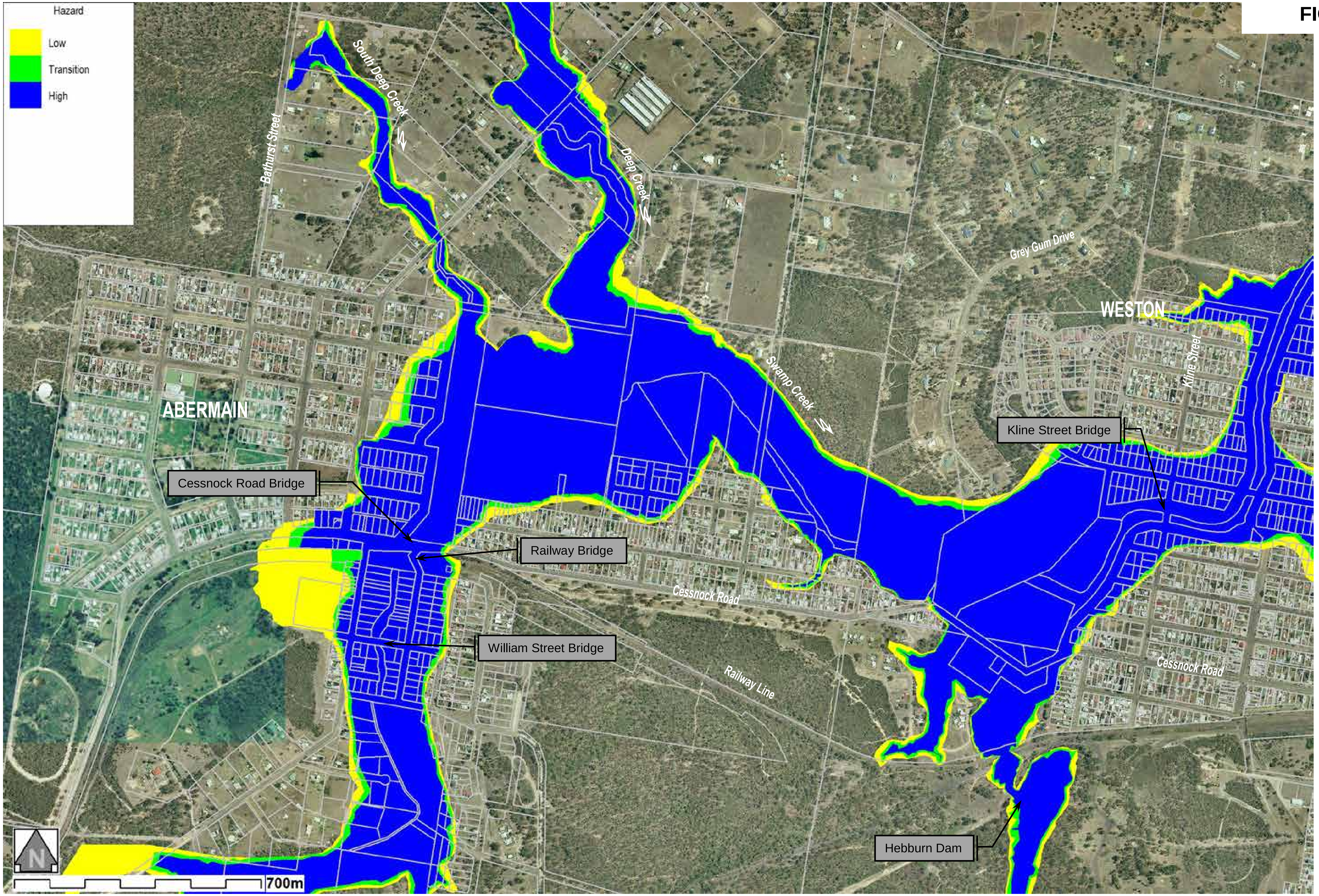
301015-02996 - Swamp Creek FRMS and Plan
02996ja121217fig06-True Flood Hazard 200 Year ARI Weston.doc

TRUE FLOOD HAZARD FOR THE 0.5% AEP FLOOD [SHEET 2]

FIGURE 6.9



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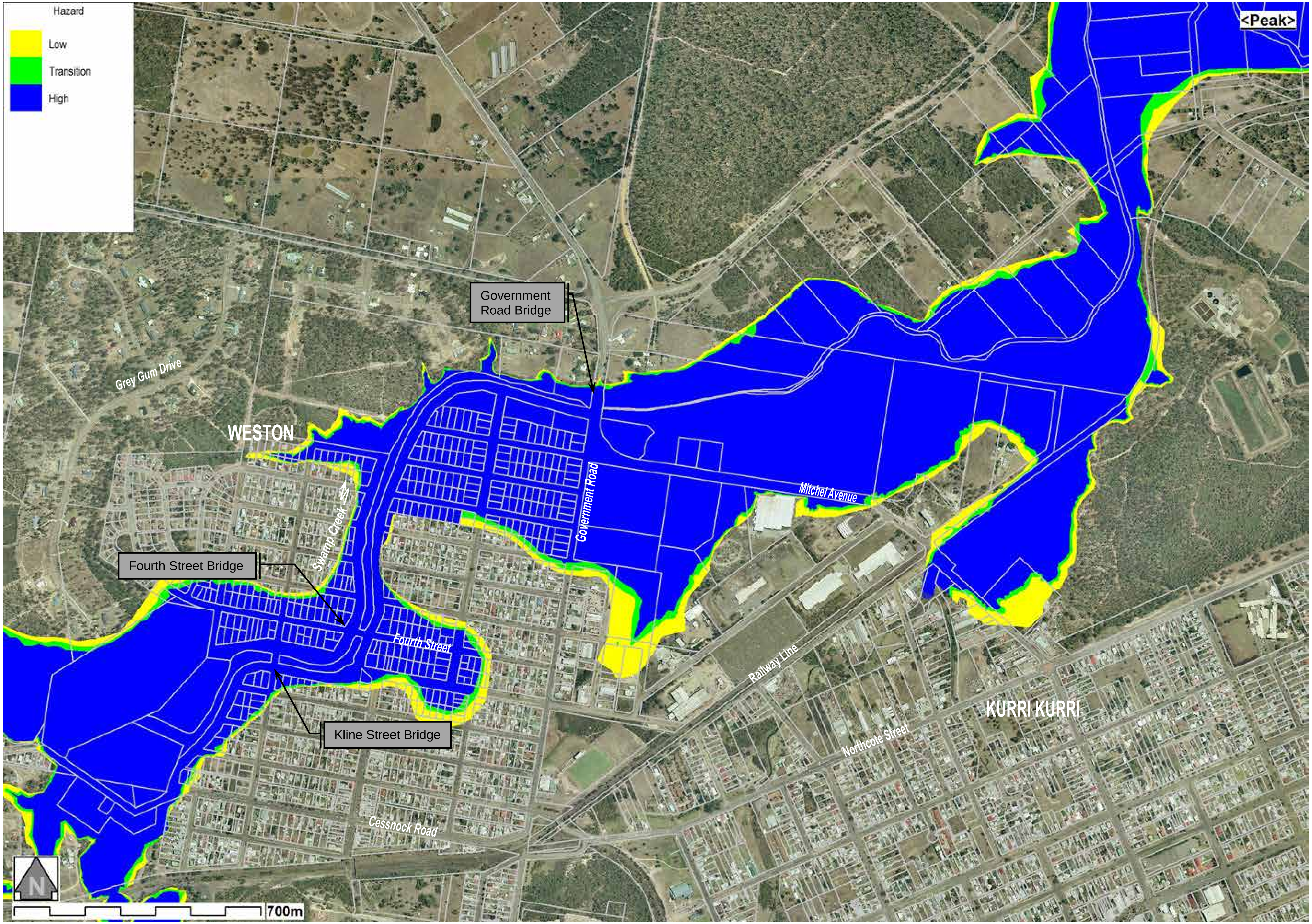
301015-02996 - Swamp Creek FRMS and Plan
02996ja121217fig07-True Flood Hazard PMF Abermain.doc

TRUE FLOOD HAZARD
FOR THE PROBABLE MAXIMUM FLOOD [SHEET 1]

FIGURE 6.10



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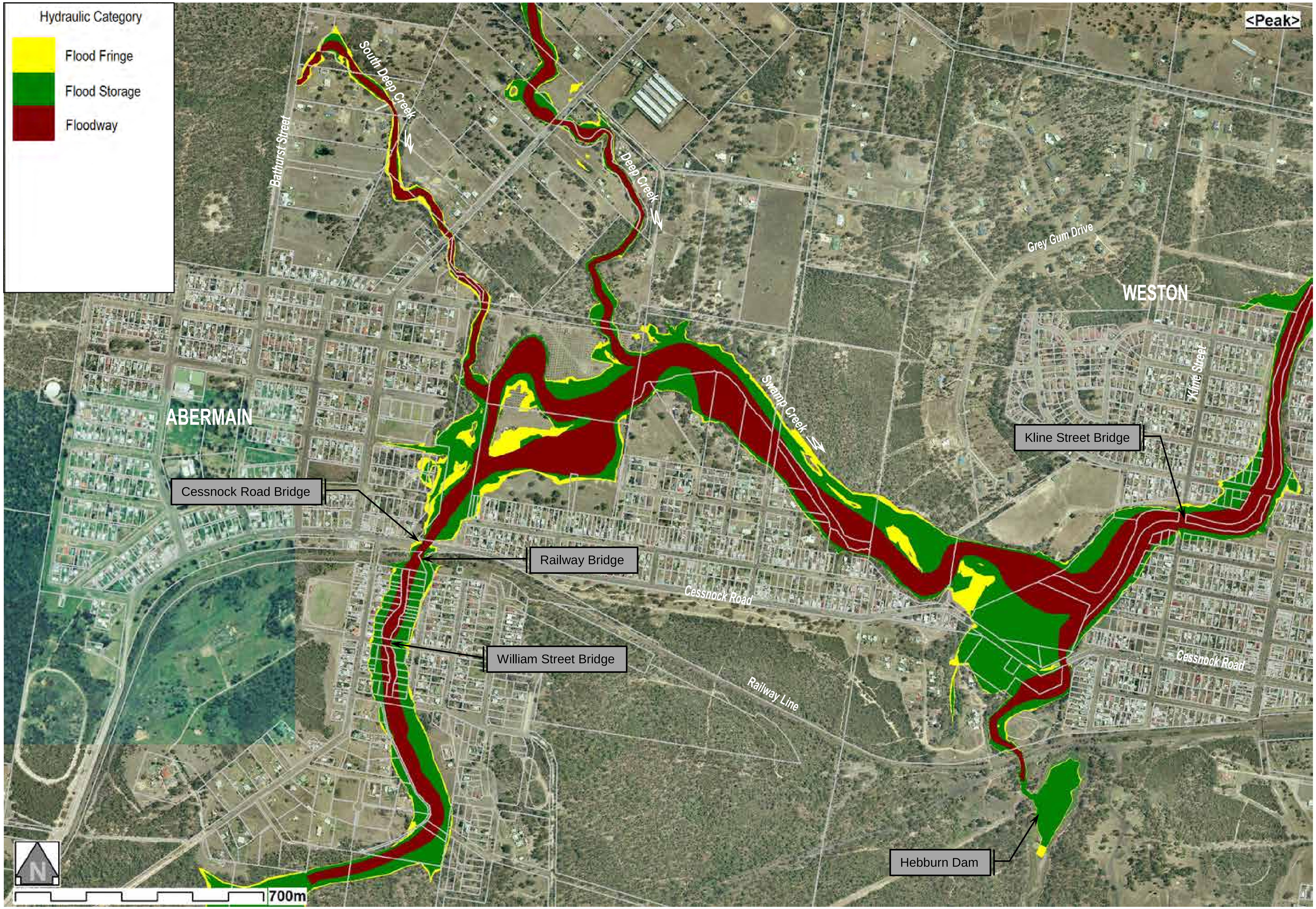
301015-02996 - Swamp Creek FRMS and Plan
02996ja121217fig08-True Flood Hazard PMF Weston.doc

TRUE FLOOD HAZARD
FOR THE PROBABLE MAXIMUM FLOOD [SHEET 2]

FIGURE 7.1



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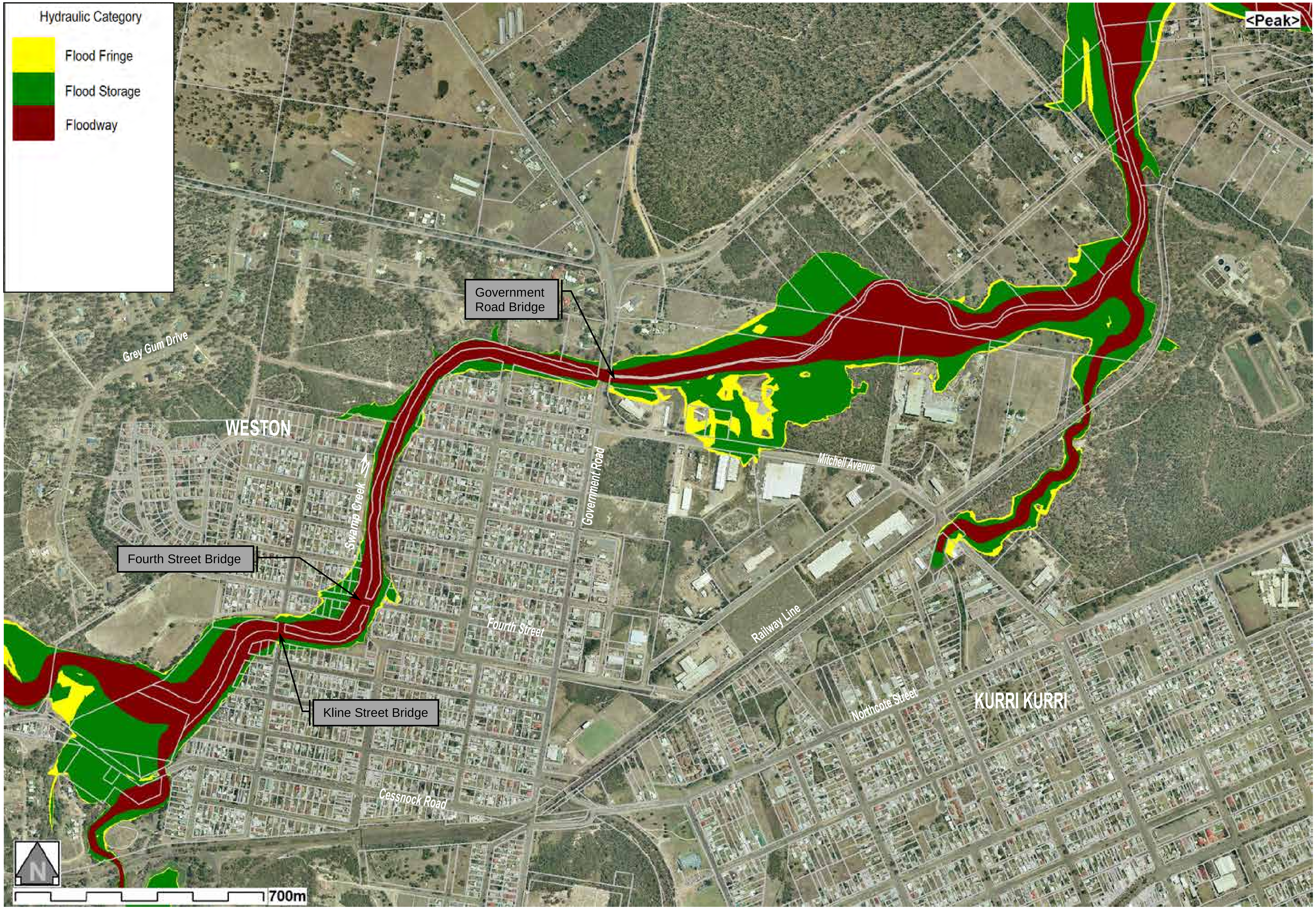
HYDRAULIC CATEGORY MAPPING FOR THE 1% AEP FLOOD [SHEET 1]

FIGURE 7.2



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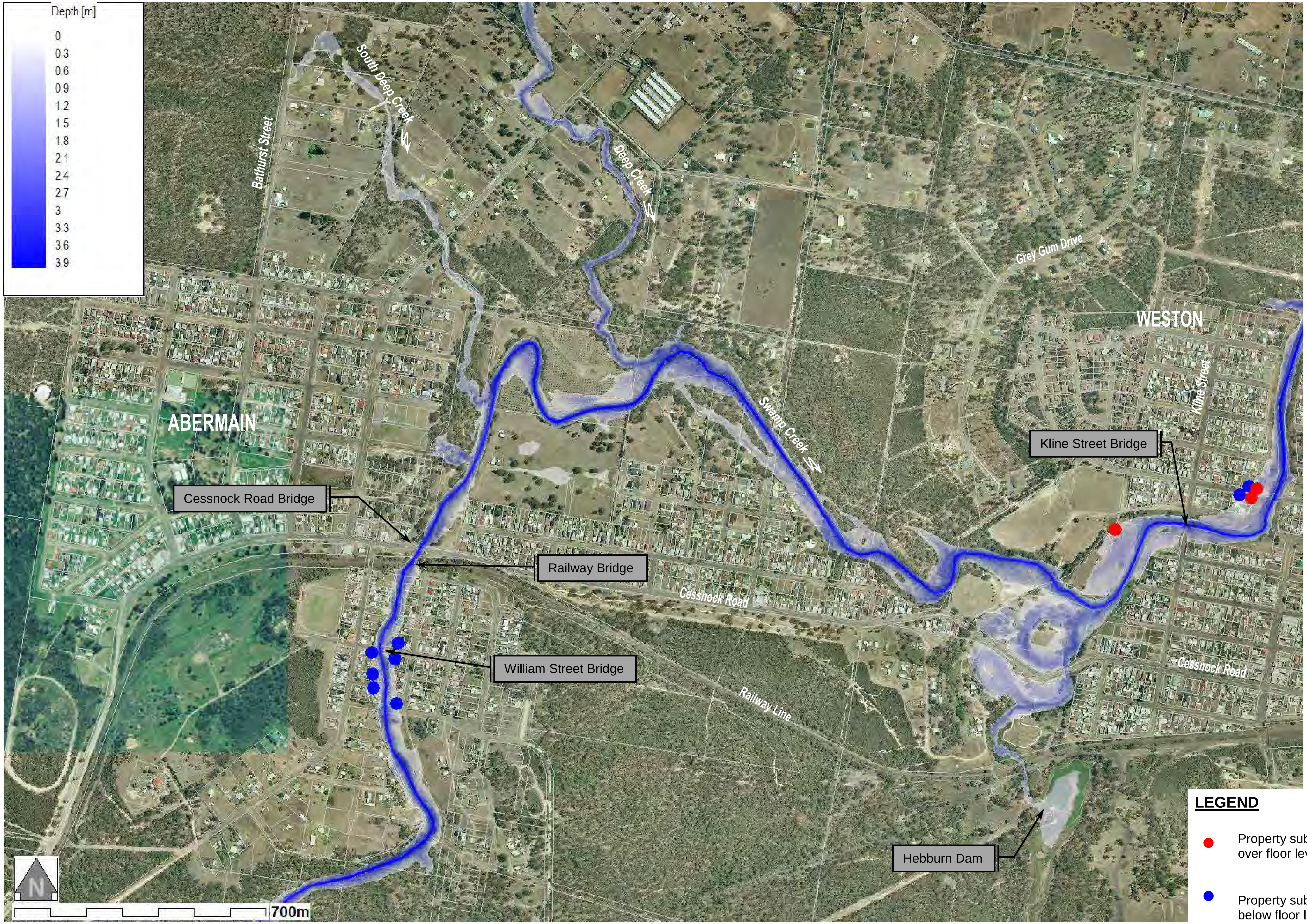
301015-02996 - Swamp Creek FRMS and Plan
02996ja121217fig12-Floodway 100 Year ARI Weston.doc

HYDRAULIC CATEGORY MAPPING FOR THE 1% AEP FLOOD [SHEET 2]

FIGURE 8.1



LEGEND

Property subject to damages over floor level

Property subject to damage below floor level

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301015-02996 - Swamp Creek FRMS and Plan
02996ja121217fig70-Flood Damages 5 Year ARI Abermain.doc

LOCATION OF PROPERTIES SUBJECT TO DAMAGE DURING THE 20% AEP FLOOD [SHEET 1]

FIGURE 8.2

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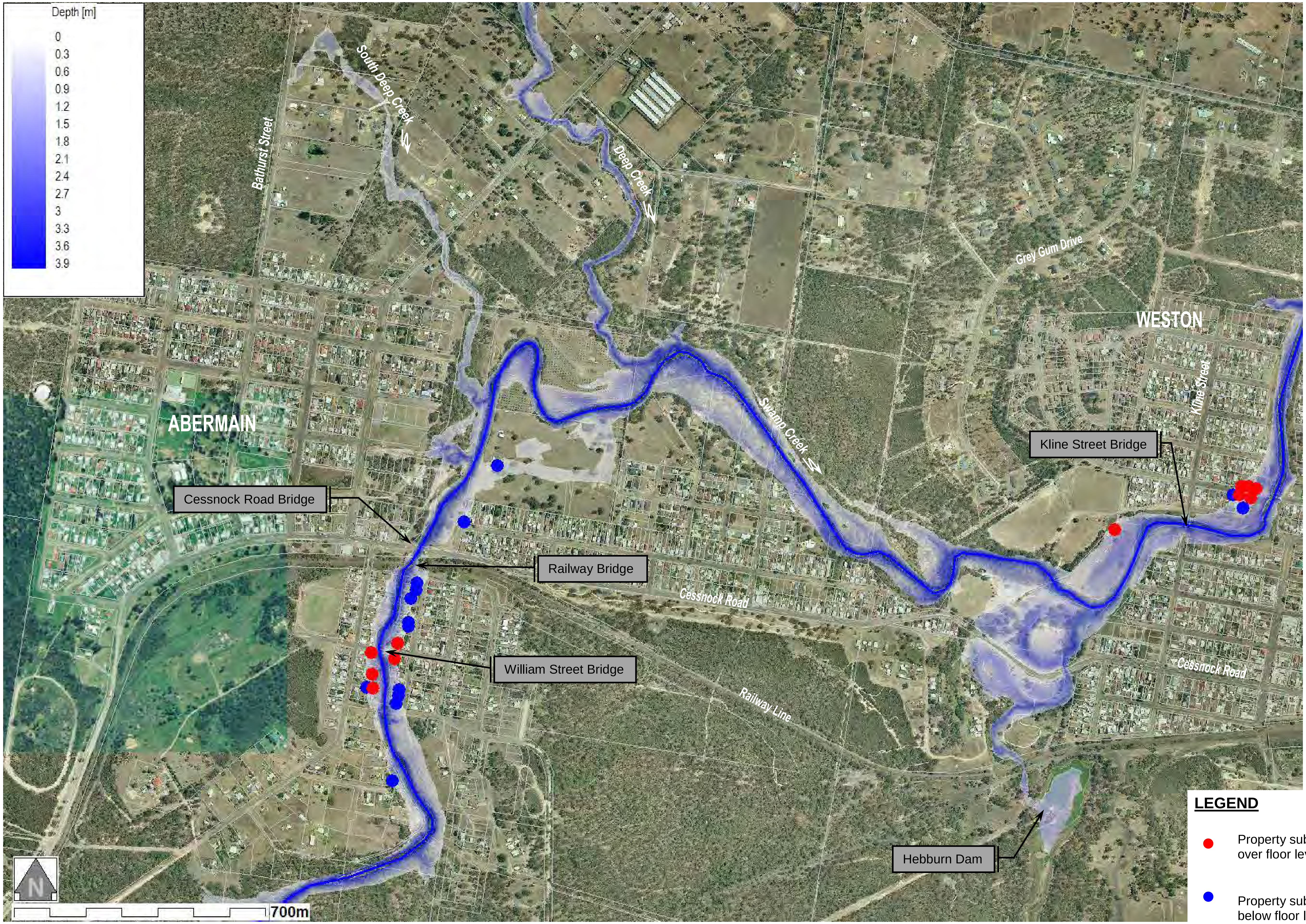
301015-02996 - Swamp Creek FRMS and Plan
02996ja121217figB2-Flood Damages 100 Year ARI.doc

LOCATION OF PROPERTIES SUBJECT TO DAMAGE DURING THE 20% AEP FLOOD [SHEET 2]

FIGURE 8.3



LEGEND

- Property subject to damages over floor level (red)
- Property subject to damage below floor level (blue)

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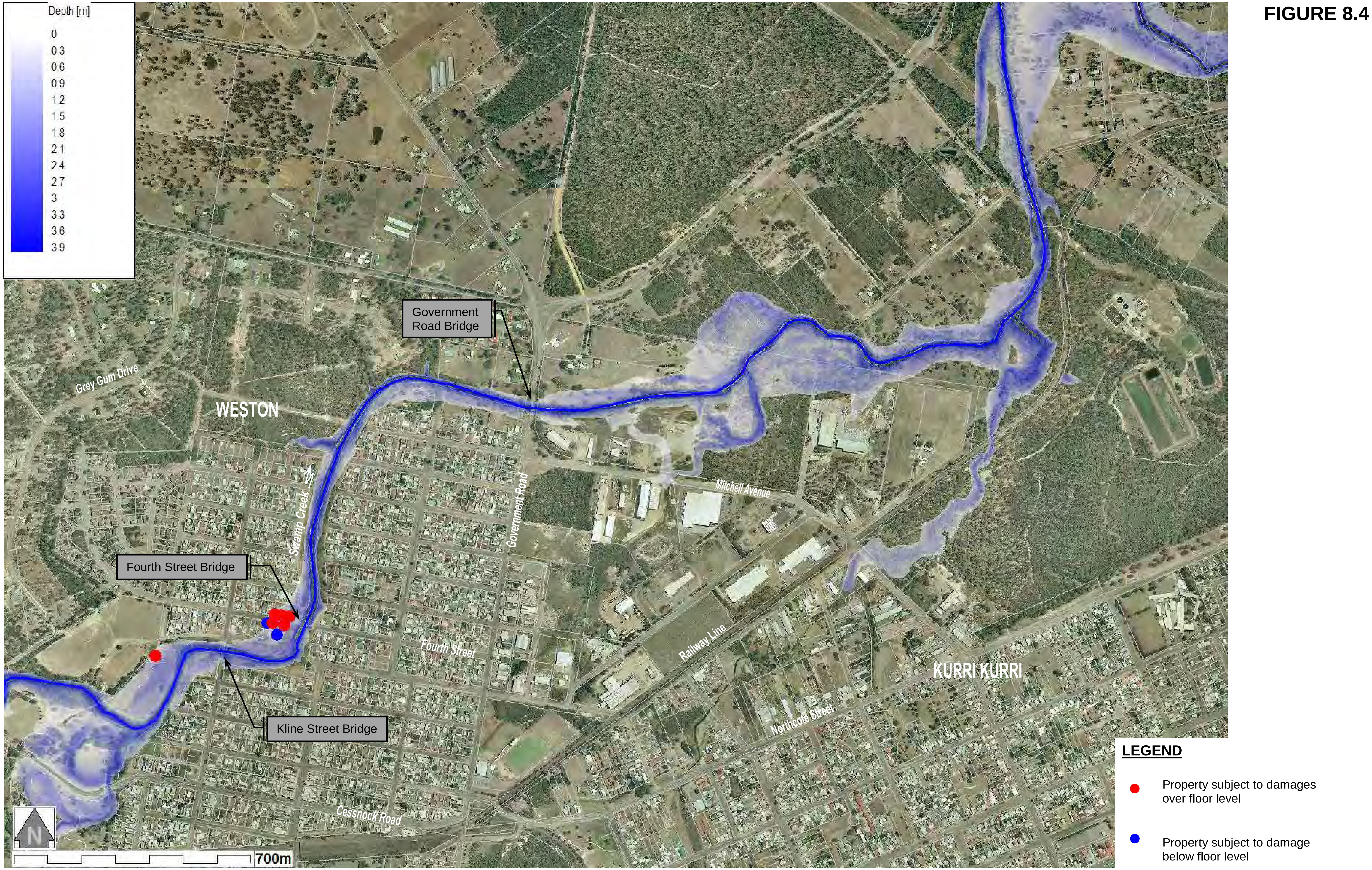
LOCATION OF PROPERTIES SUBJECT TO DAMAGE DURING THE 5% AEP FLOOD [SHEET 1]

FIGURE 8.4



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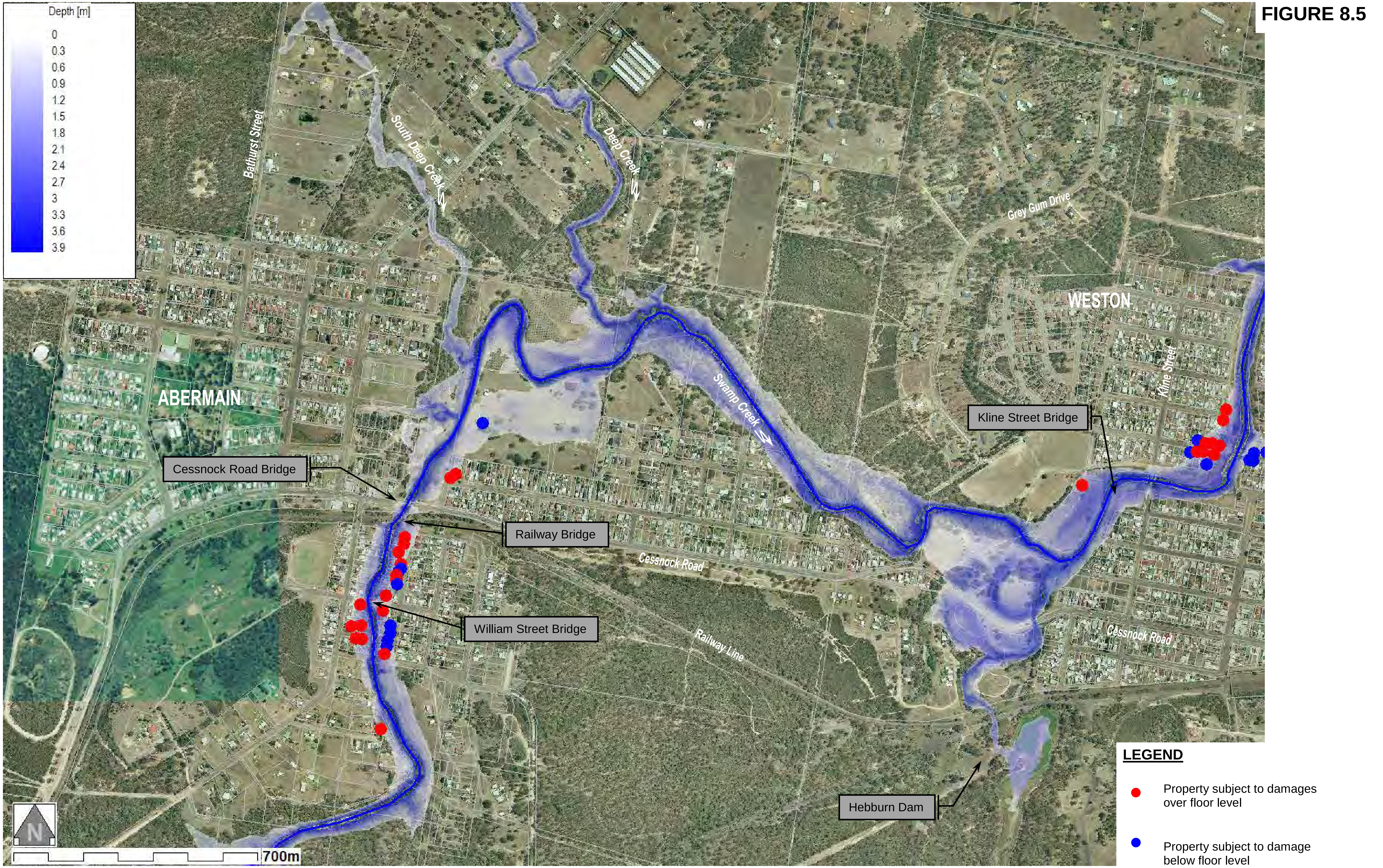
301015-02996 - Swamp Creek FRMS and Plan
02996ja121217fig8.4-Flood Damages 20 Year ARI Weston.doc

LOCATION OF PROPERTIES SUBJECT TO DAMAGE DURING THE 5% AEP FLOOD [SHEET 2]

FIGURE 8.5



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LOCATION OF PROPERTIES SUBJECT TO DAMAGE DURING THE 1% AEP FLOOD [SHEET 1]

301015-02996 - Swamp Creek FRMS and Plan
02996ja121217fig70-Flood Damages 5 Year ARI Abermain.doc

FIGURE 8.6

LEGEND

Property subject to damages over floor level

Property subject to damage below floor level

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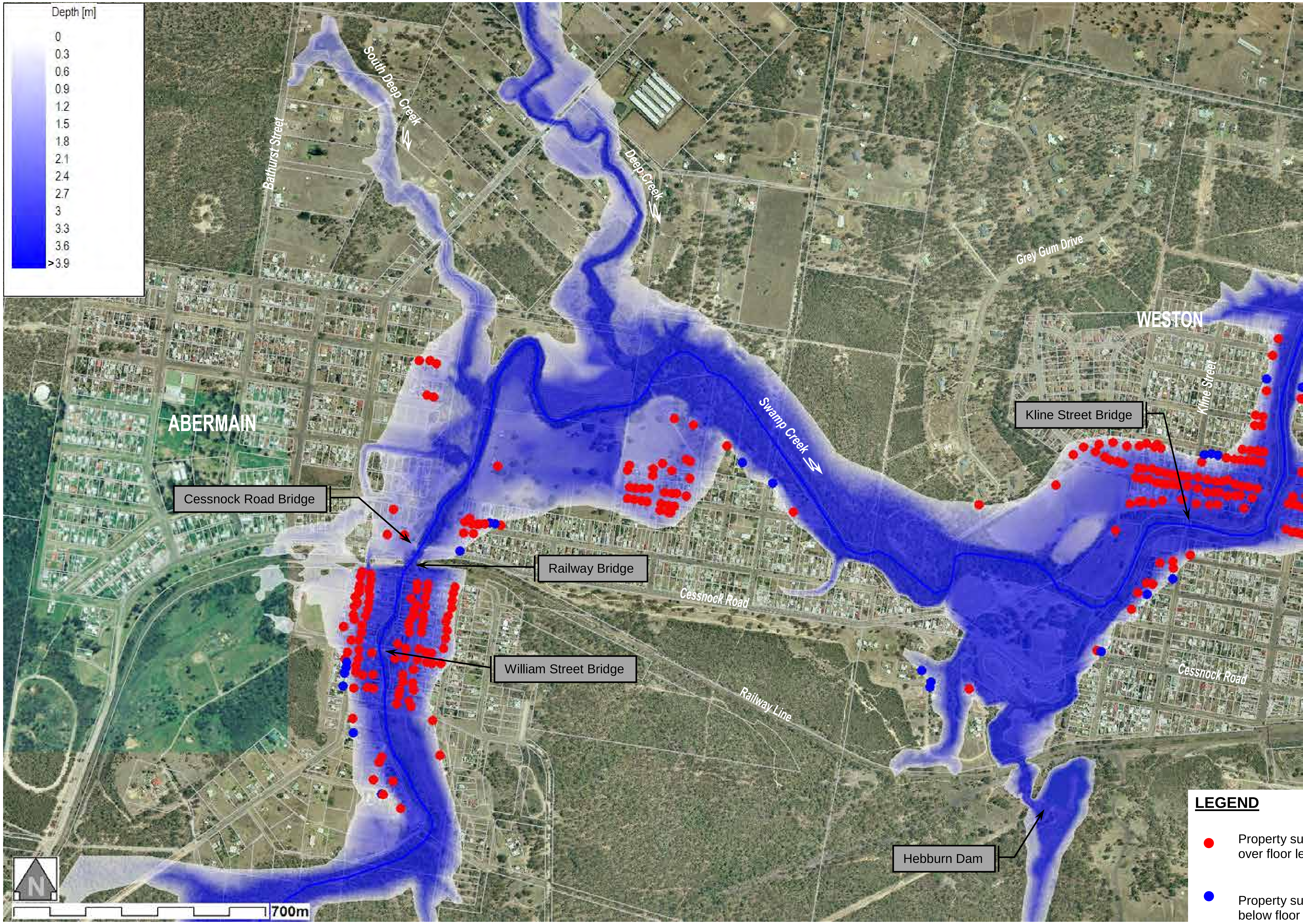
301015-02996 - Swamp Creek FRMS and Plan
02996ja121217figB2-Flood Damages 100 Year ARI.doc

LOCATION OF PROPERTIES SUBJECT TO DAMAGE DURING THE 1% AEP FLOOD [SHEET 2]

FIGURE 8.7



LEGEND

- Property subject to damages over floor level
- Property subject to damage below floor level

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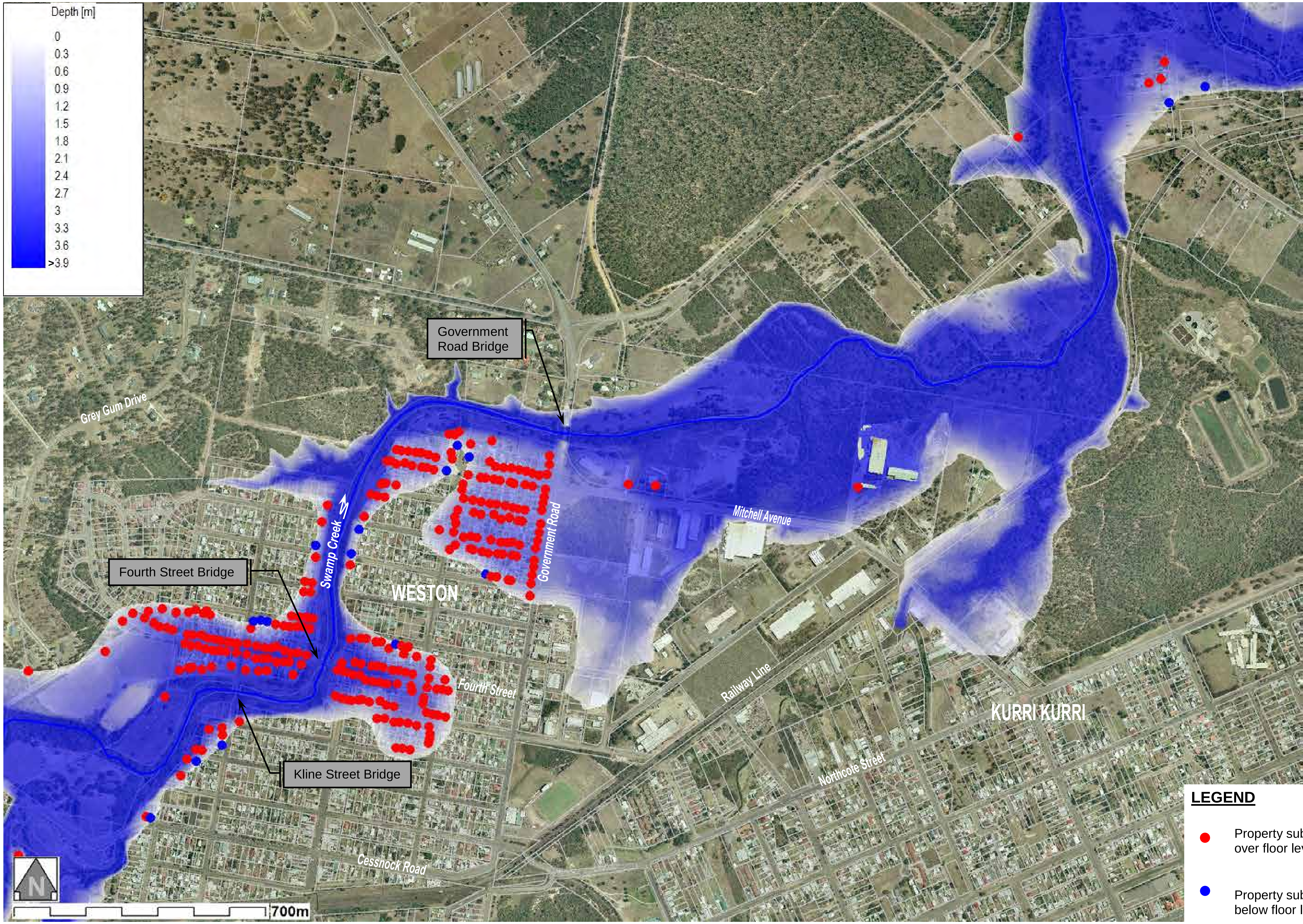
301015-02996 - Swamp Creek FRMS and Plan
02996ja121217fig8.7-Flood Damages PMF Abermain.doc

LOCATION OF PROPERTIES SUBJECT TO DAMAGE DURING THE PROBABLE MAXIMUM FLOOD [SHEET 1]

FIGURE 8.8



LEGEND

- Property subject to damages over floor level (red)
- Property subject to damage below floor level (blue)

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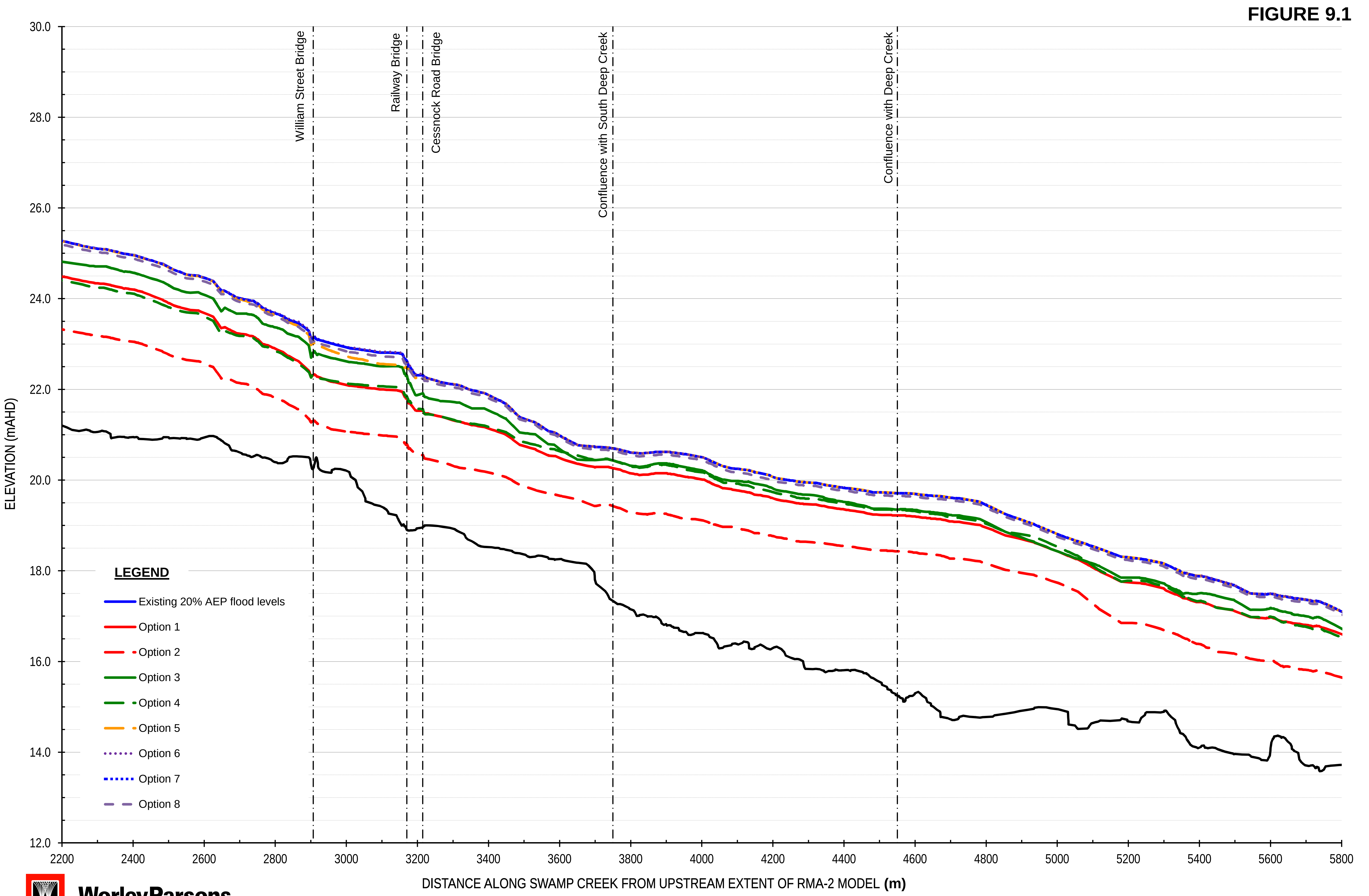
301015-02996 - Swamp Creek FRMS and Plan
02996ja121217fig8.8-Flood Damages PMF Weston.doc

LOCATION OF PROPERTIES SUBJECT TO DAMAGE DURING THE PROBABLE MAXIMUM FLOOD [SHEET 2]



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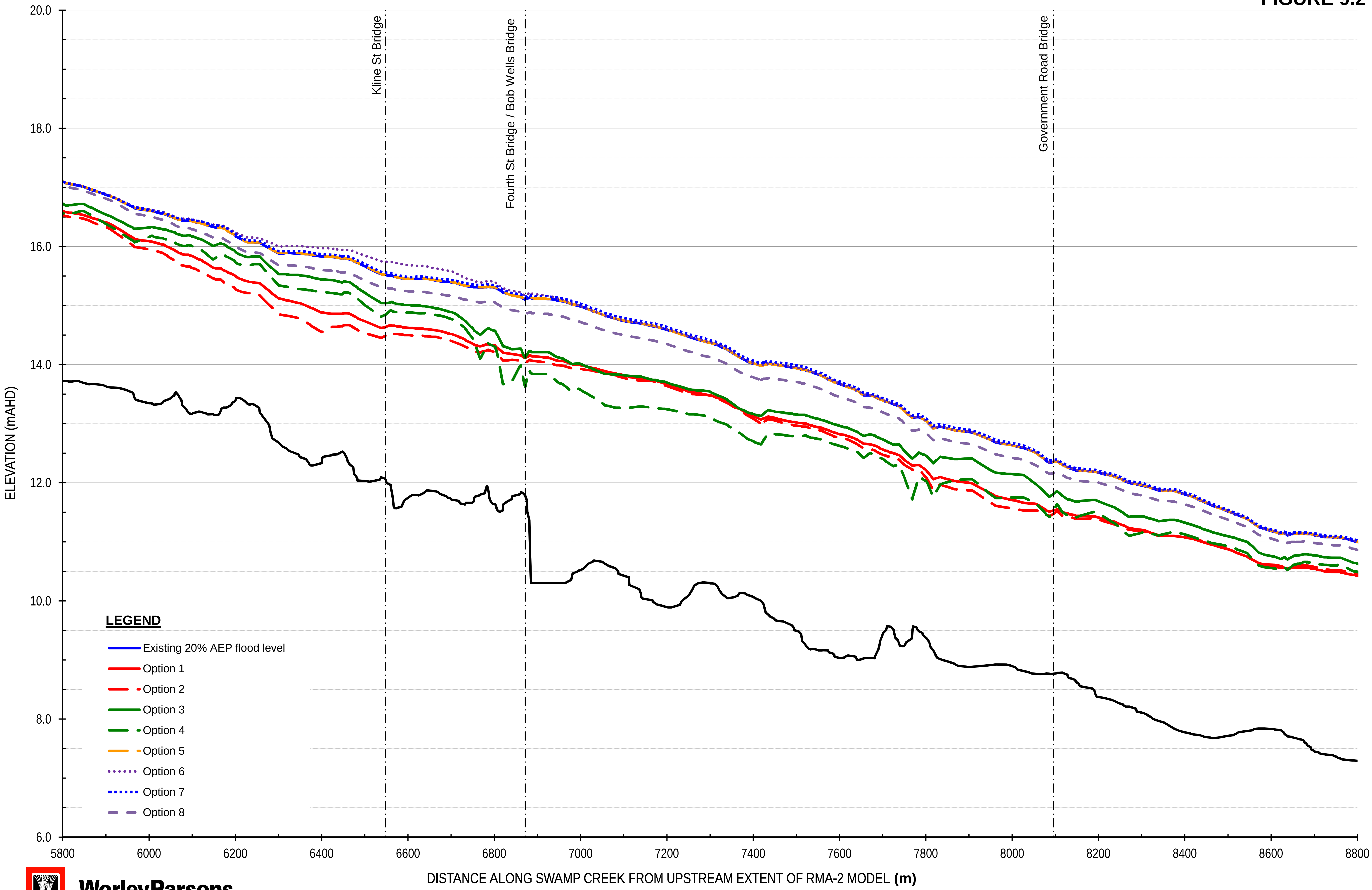
301015-02996 - Swamp Creek FRMS and Plan
fg2996_01ja120921-Calibration WSP.xls

COMPARISON OF FLOOD MITIGATION OPTIONS FOR THE 20% AEP FLOOD [IN THE VICINITY OF ABERMAIN]

FIGURE 9.2



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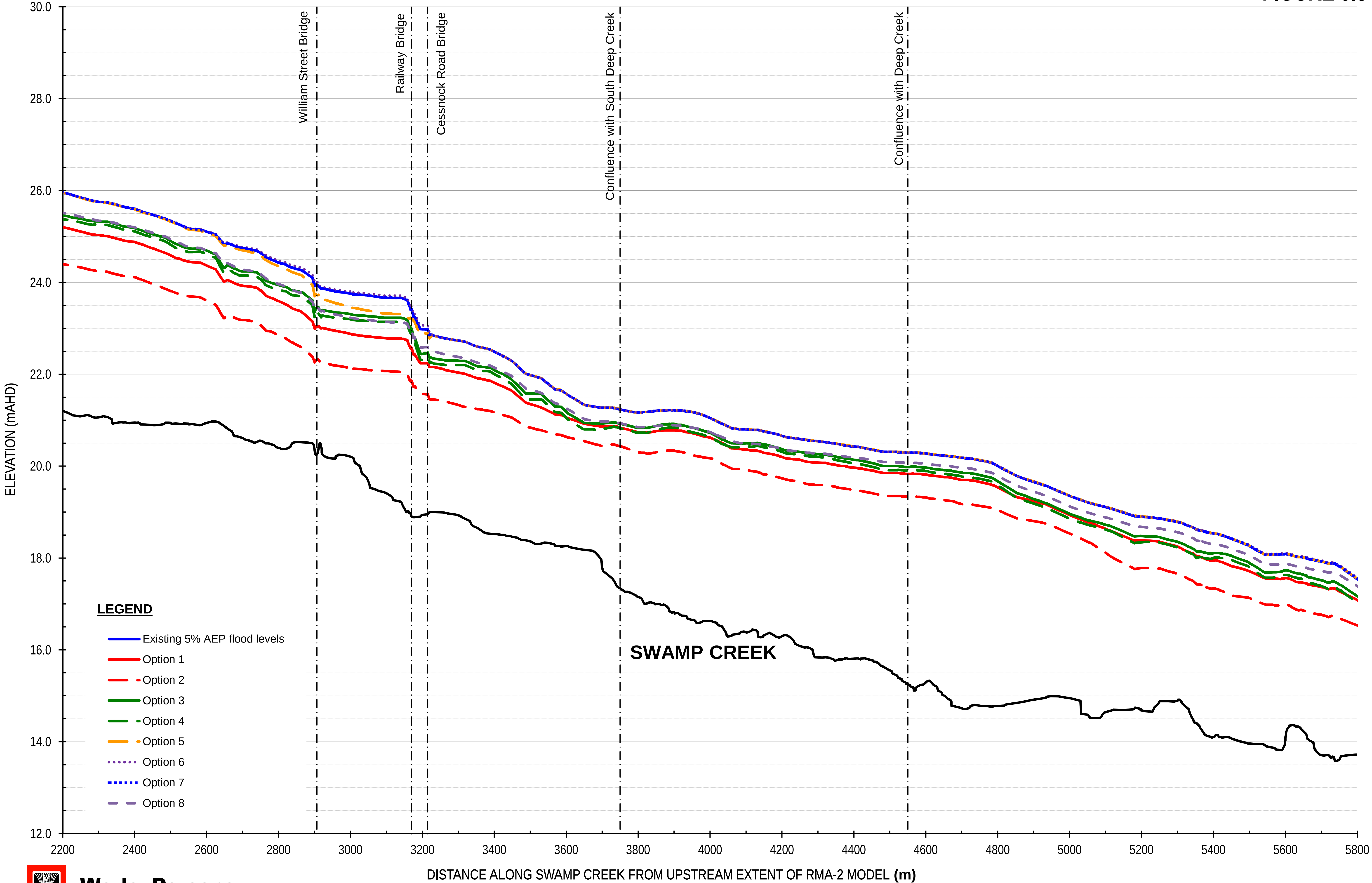
301015-02996 - Swamp Creek FRMS and Plan
fg2996_01ja120921-Calibration WSP.xls

COMPARISON OF FLOOD MITIGATION OPTIONS FOR THE 20% AEP FLOOD [IN THE VICINITY OF WESTON]

FIGURE 9.3



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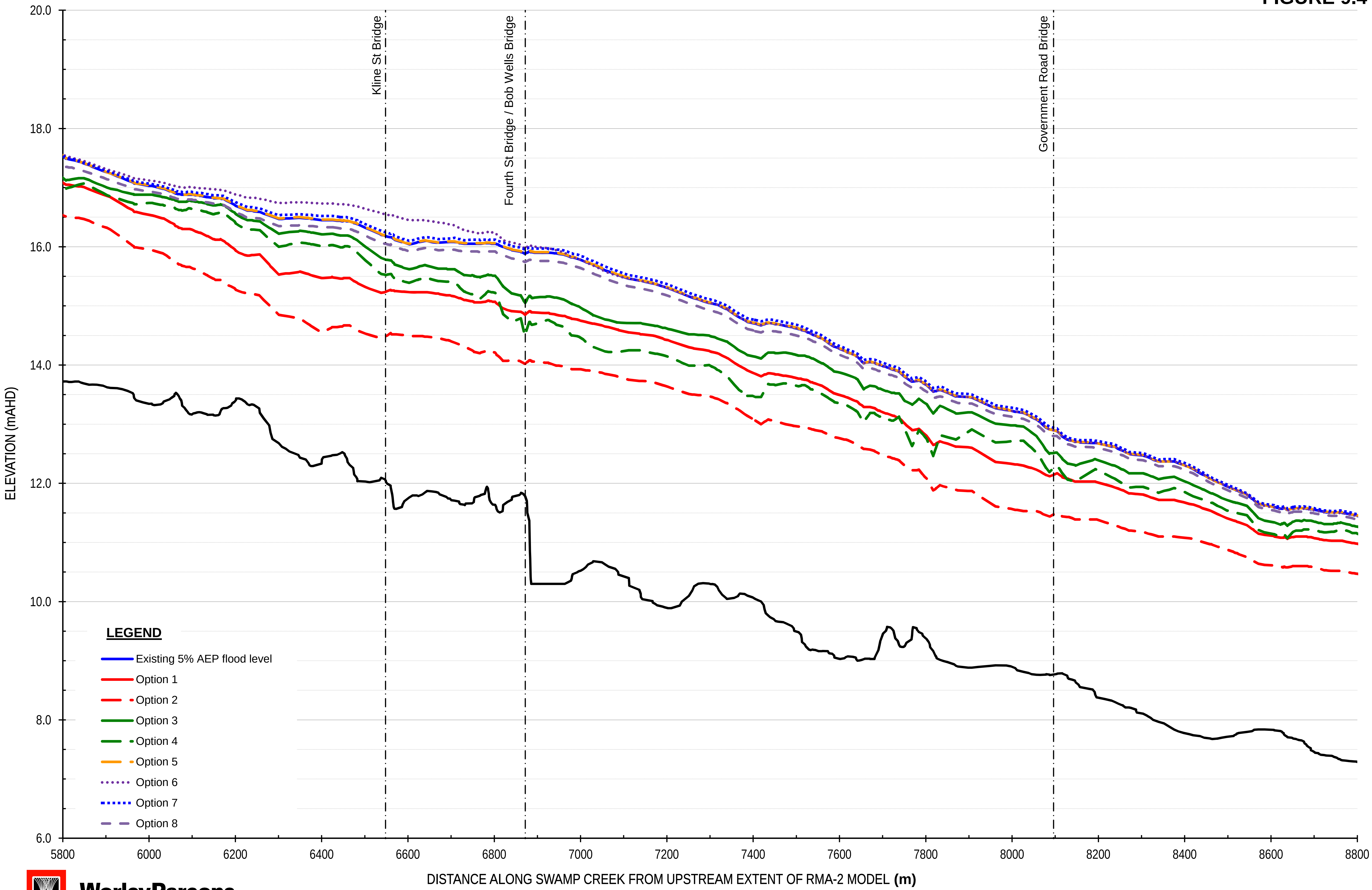
301015-02996 - Swamp Creek FRMS and Plan
fg2996_01ja120921-Calibration WSP.xls

COMPARISON OF FLOOD MITIGATION OPTIONS FOR THE 5% AEP EVENT [IN THE VICINITY OF ABERMAIN]

FIGURE 9.4



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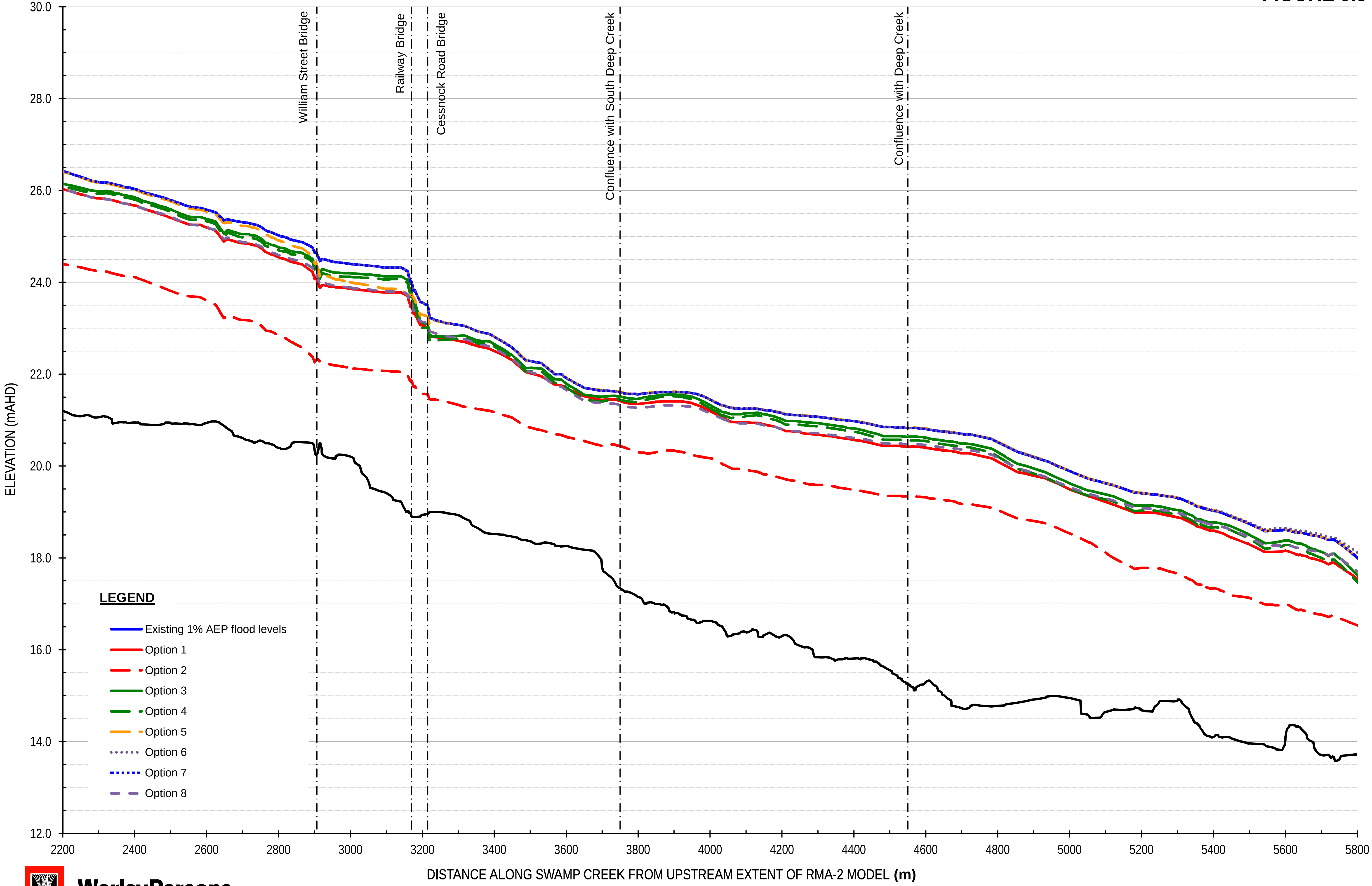
301015-02996 - Swamp Creek FRMS and Plan
fg2996_01ja120921-Calibration WSP.xls

COMPARISON OF FLOOD MITIGATION OPTIONS FOR THE 5% AEP EVENT
[IN THE VICINITY OF WESTON]

FIGURE 9.5



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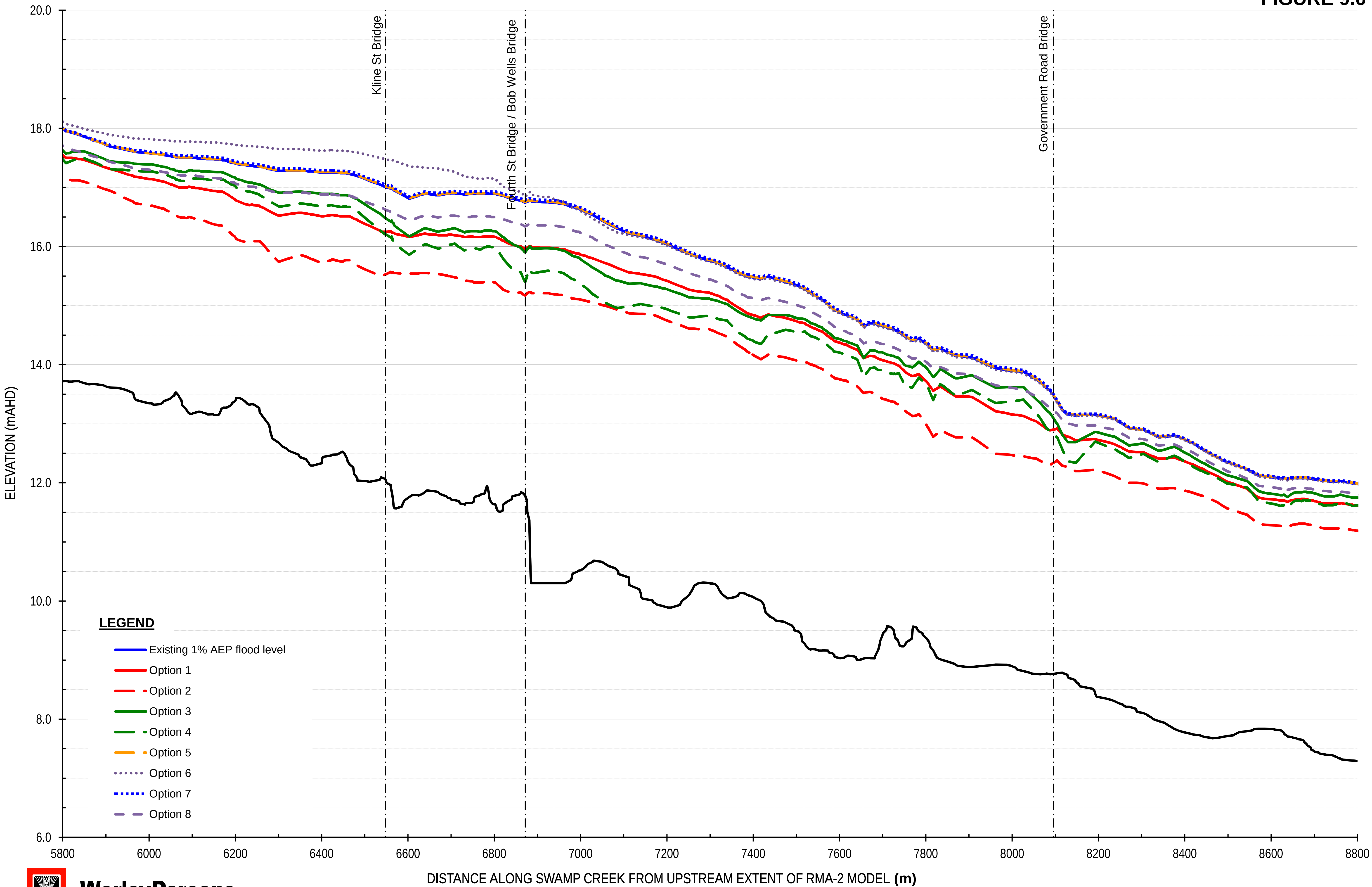
301015-02996 - Swamp Creek FRMS and Plan
fg2996_01ja120921-Calibration WSP.xls

COMPARISON OF FLOOD MITIGATION OPTIONS FOR THE 1% AEP EVENT [IN THE VICINITY OF ABERMAIN]



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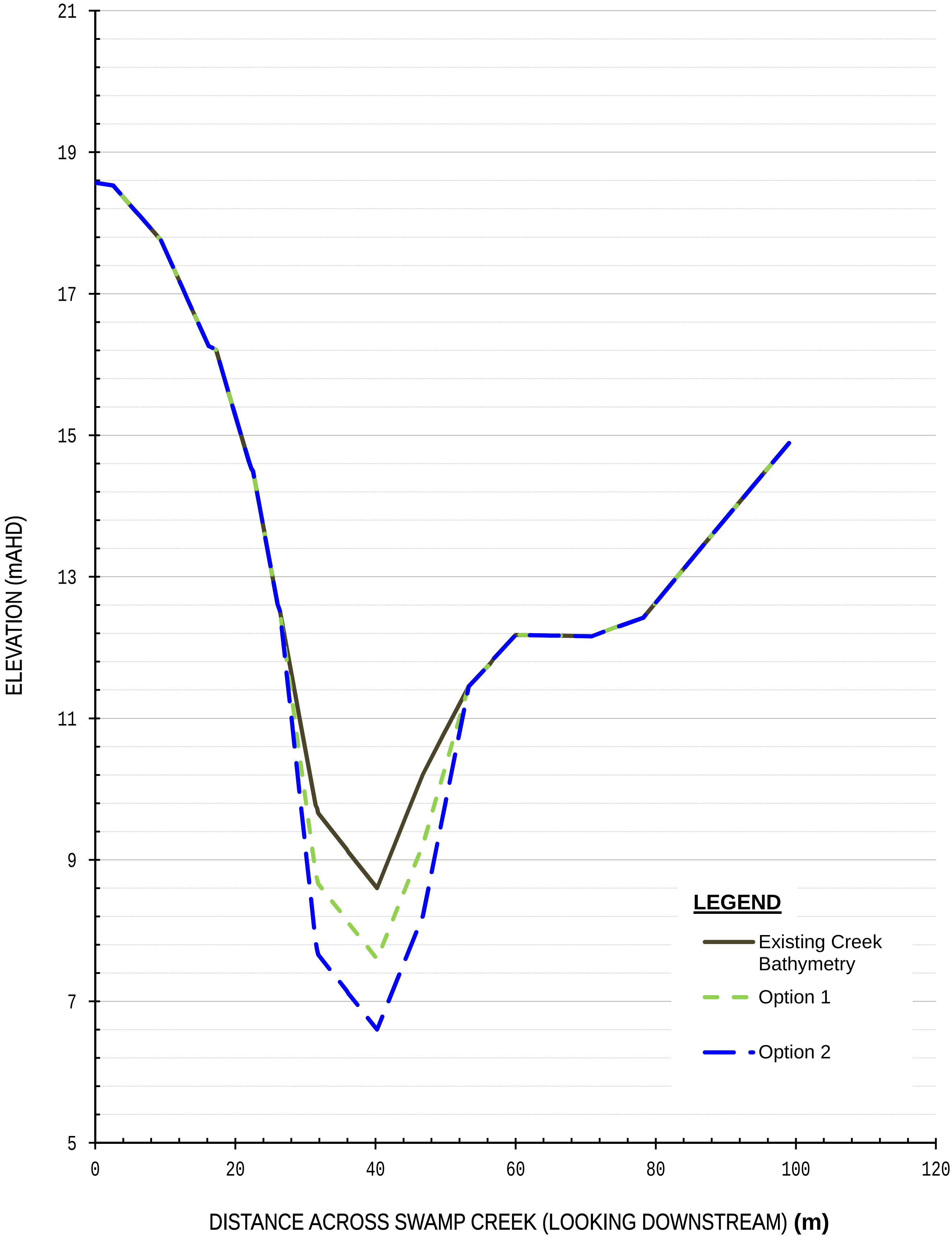
301015-02996 - Swamp Creek FRMS and Plan
fg2996_01ja120921-Calibration WSP.xls

COMPARISON OF FLOOD MITIGATION OPTIONS FOR THE 1% AEP EVENT [IN THE VICINITY OF WESTON]

FIGURE 9.7



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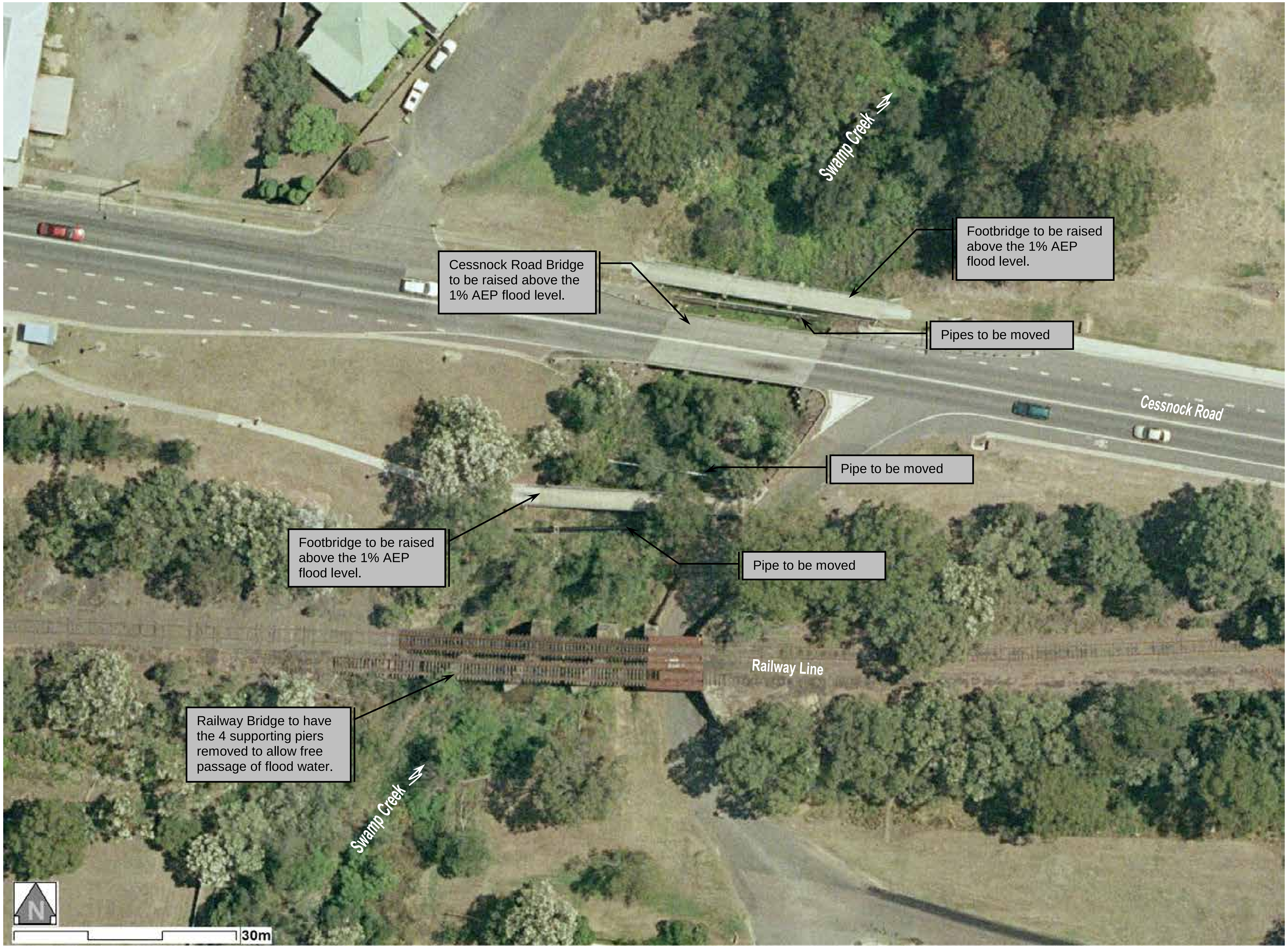
301015-02996 - Swamp Creek FRMS and Plan
02996ja121129_cross-section Comparisons.xlsx

CHANNEL EXCAVATION OPTIONS

FIGURE 9.8



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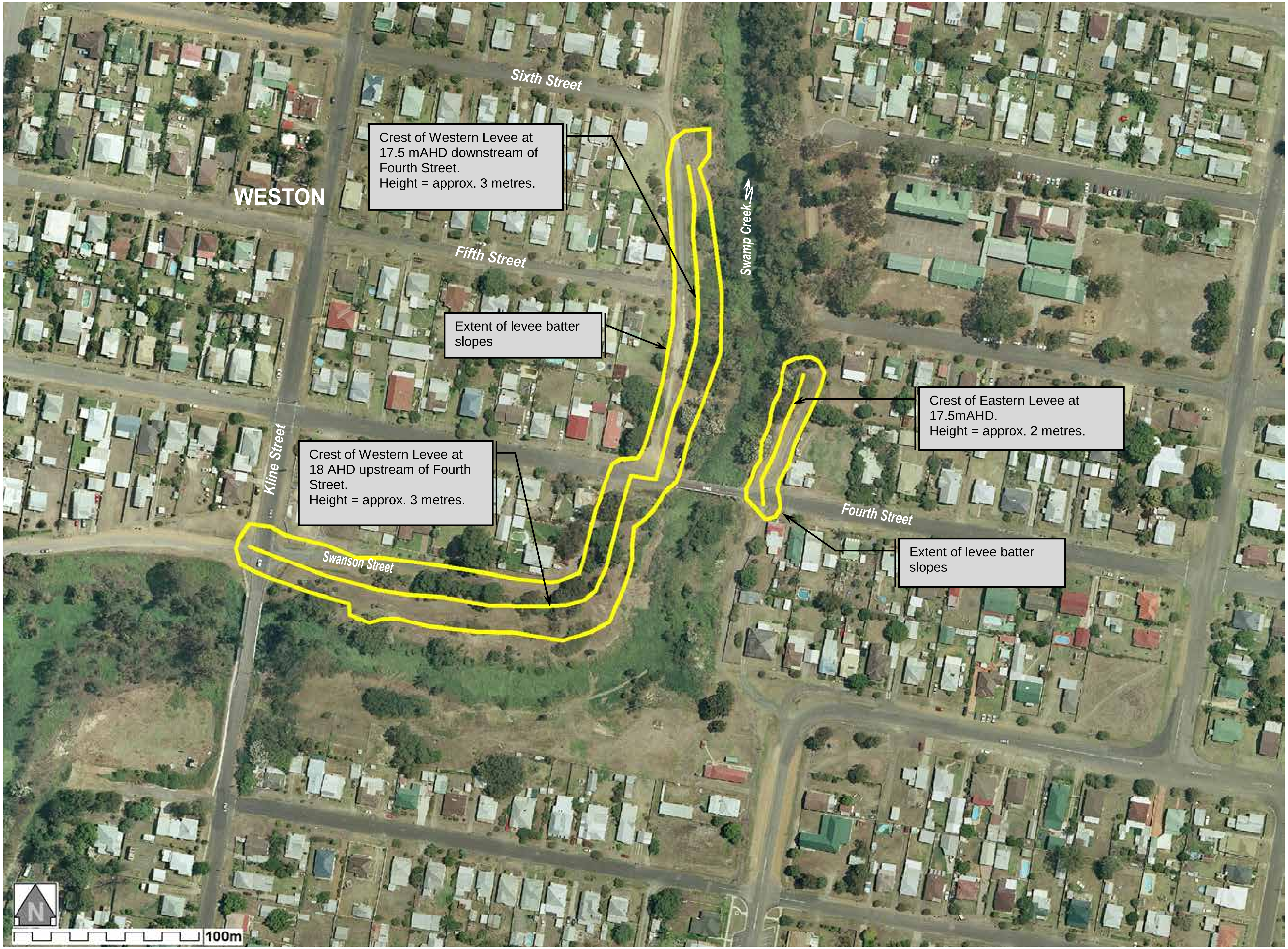
OPTION 5
BRIDGES AND PIPES TO BE MODIFIED AT ABERMAIN

FIGURE 9.9



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301015-02996 - Swamp Creek FRMS and Plan
02996ja130220figNN-Option 5 Schematic.doc

OPTION 6
CONSTRUCTION OF LEVEE SYSTEM AT WESTON

FIGURE 9.10

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301015-02996 - Swamp Creek FRMS and Plan
02996ja130221figNN-Option 8 Schematic.doc

SCHEMATIC OF OPTION 7A
HEBBURN RESERVOIR WEIR UPGRADE

FIGURE 9.11

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02996ja130221figNN-Option 8 Schematic.doc

SCHEMATIC OF OPTION 7B
HEBBURN RESERVOIR UPGRADE

FIGURE 9.12

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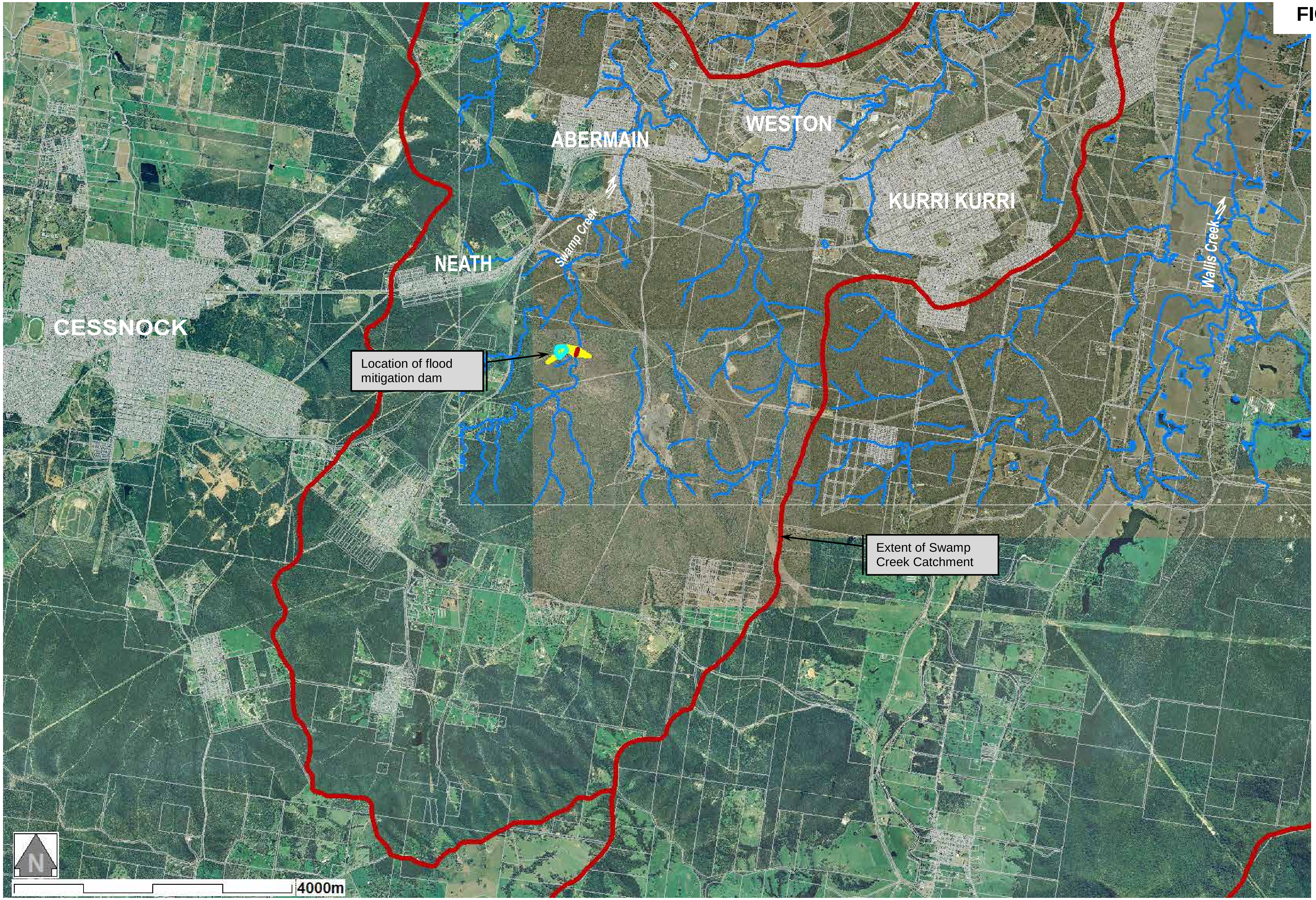
301015-02996 - Swamp Creek FRMS and Plan
02996ja130221figNN-Option 8 Schematic.doc

SCHEMATIC OF OPTION 7C
HEBBURN RESERVOIR UPGRADE



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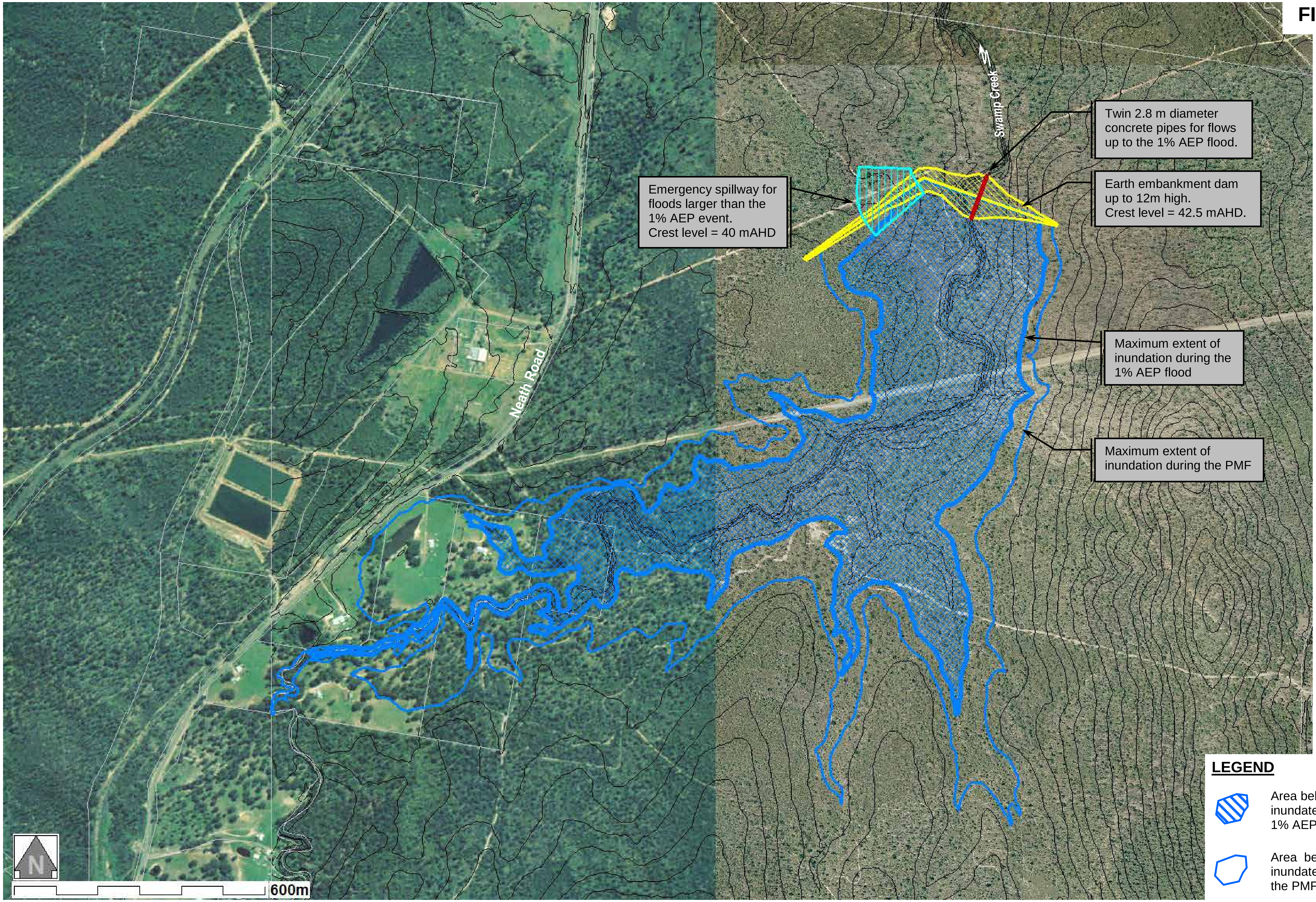
OPTION 8
LOCATION OF POTENTIAL FLOOD MITIGATION DAM

FIGURE 9.14



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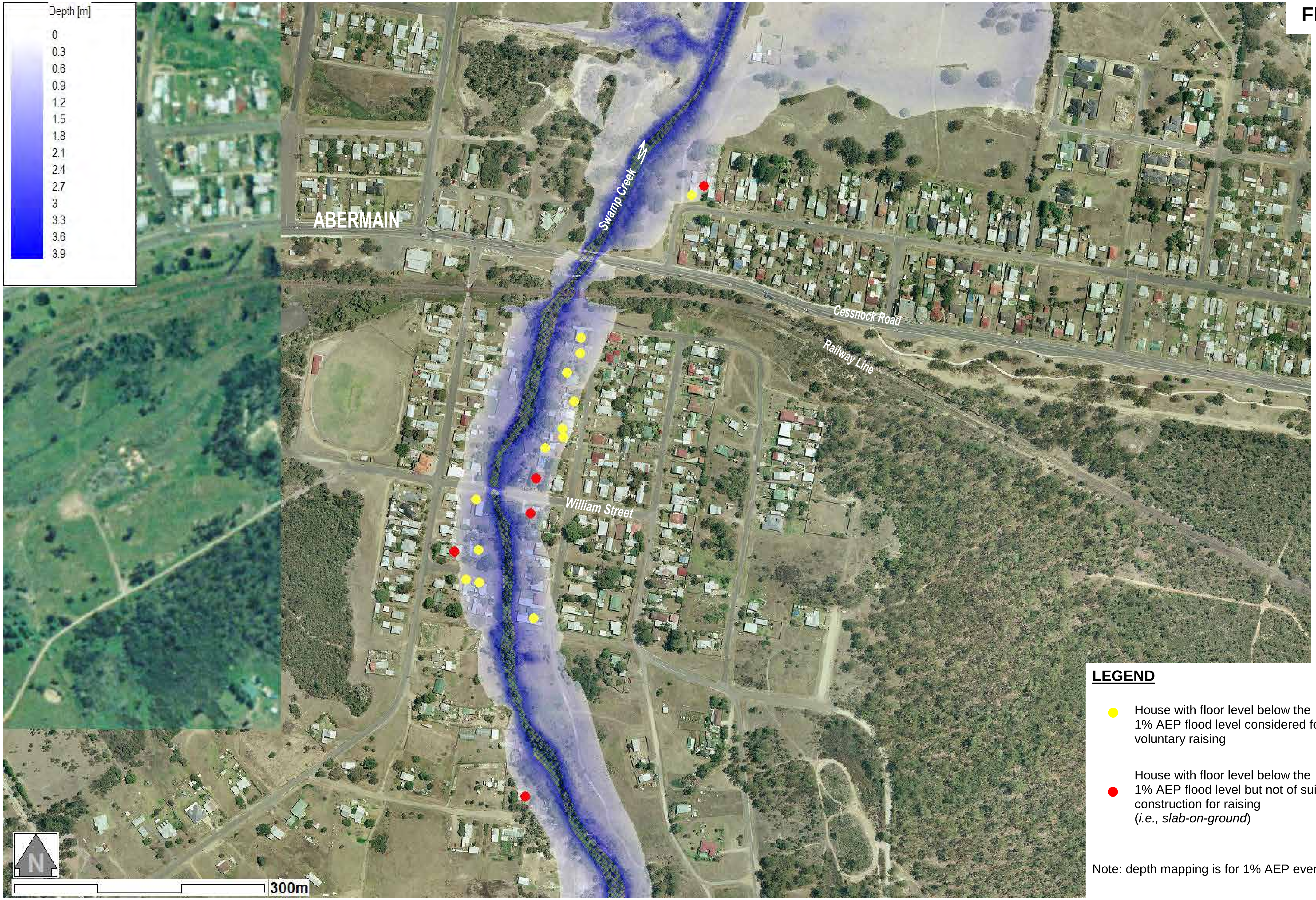
301015-02996 - Swamp Creek FRMS and Plan
02996ja130221fig9.14-Option 8 Inundation.doc

OPTION 8
FLOOD MITIGATION DAM CONCEPT



LEGEND

- House with floor level below the 1% AEP flood level considered for voluntary raising (yellow dot)
- House with floor level below the 1% AEP flood level but not of suitable construction for raising (*i.e., slab-on-ground*) (red dot)

Note: depth mapping is for 1% AEP event

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02996ja130226fig9.15-Option 9 & 10 Schematic Abermain.doc

OPTION 9
VOLUNTARY HOUSE RAISING [ABERMAIN]

FIGURE 9.16

LEGEND

- House with floor level below the 1% AEP flood level considered for voluntary raising
- House with floor level below the 1% AEP flood level but not of suitable construction for raising (*i.e., slab-on-ground*)

Note: depth mapping is for 1% AEP event

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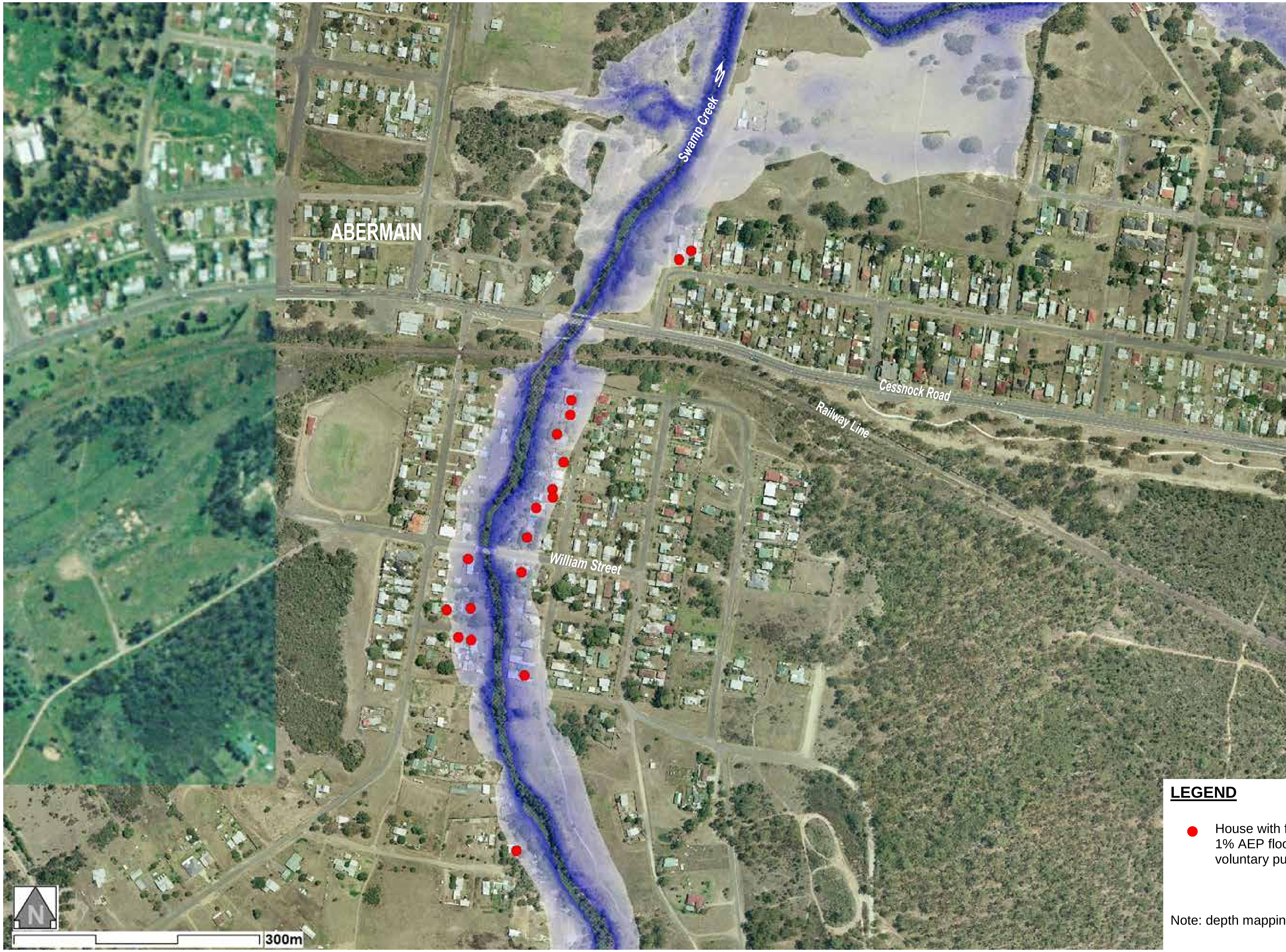
OPTION 9
VOLUNTARY HOUSE RAISING [WESTON]

FIGURE 9.17



LEGEND

● House with floor level below the 1% AEP flood level considered for voluntary purchase

Note: depth mapping is for 1% AEP event

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301015-02996 - Swamp Creek FRMS and Plan
02996ja130226fig9.15-Option 9 & 10 Schematic Abermain.doc

OPTION 10
VOLUNTARY HOUSE PURCHASE [ABERMAIN]

FIGURE 9.18

LEGEND

● House with floor level below the 1% AEP flood level considered for voluntary raising or purchase

Note: depth mapping is for 1% AEP event

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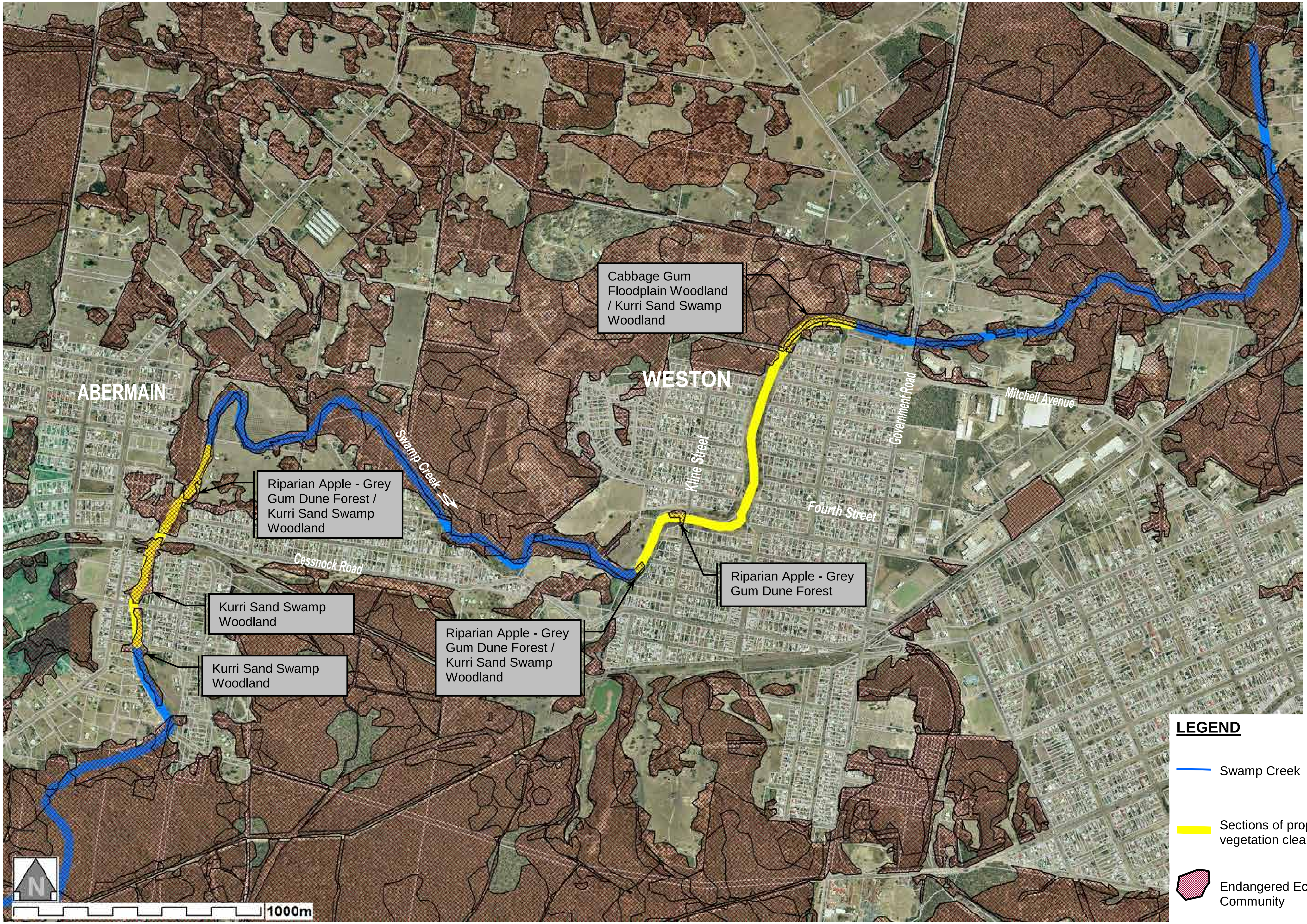
02996ja130226fig9.16-Option 9 & 10 Schematic Weston.doc

OPTION 10
VOLUNTARY HOUSE PURCHASE [WESTON]

FIGURE 9.19



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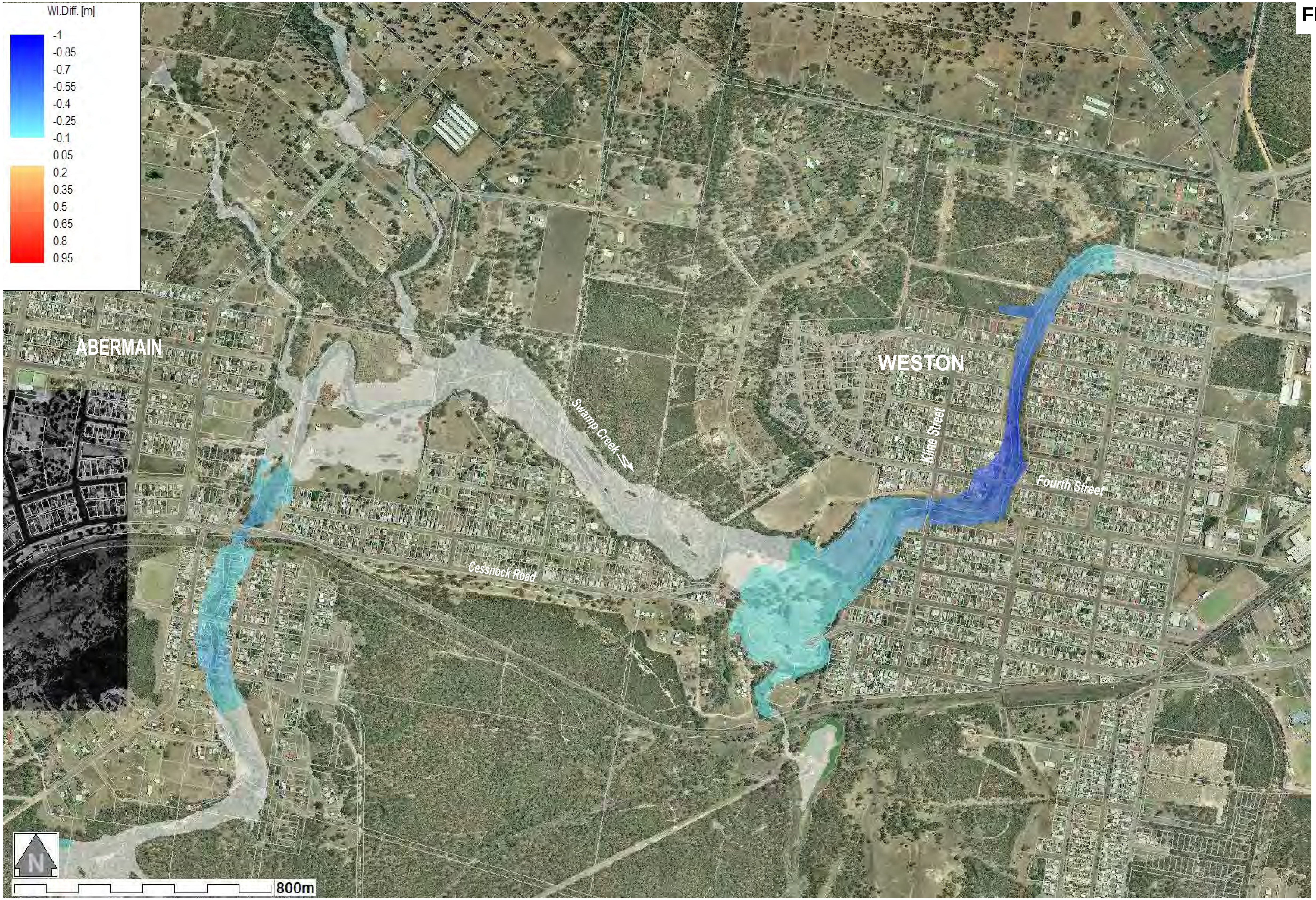
301015-02996 - Swamp Creek FRMS and Plan
02996ja130321fig9.19-Option S1 Schematic.doc

OPTION S1
TARGETED VEGETATION CLEARING

FIGURE 9.20



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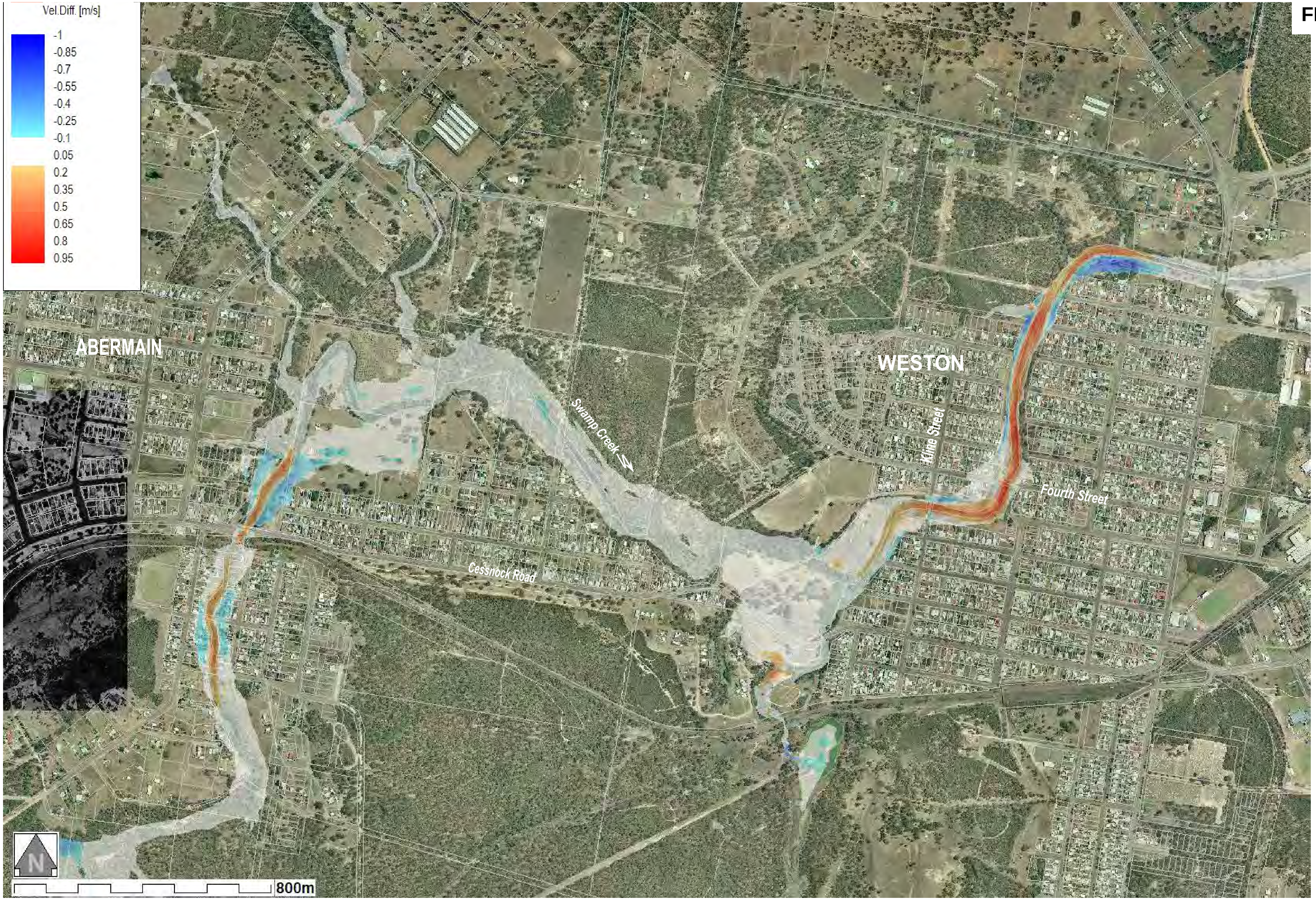
OPTION S1
REDUCTION IN 1% AEP FLOOD LEVELS

FIGURE 9.21



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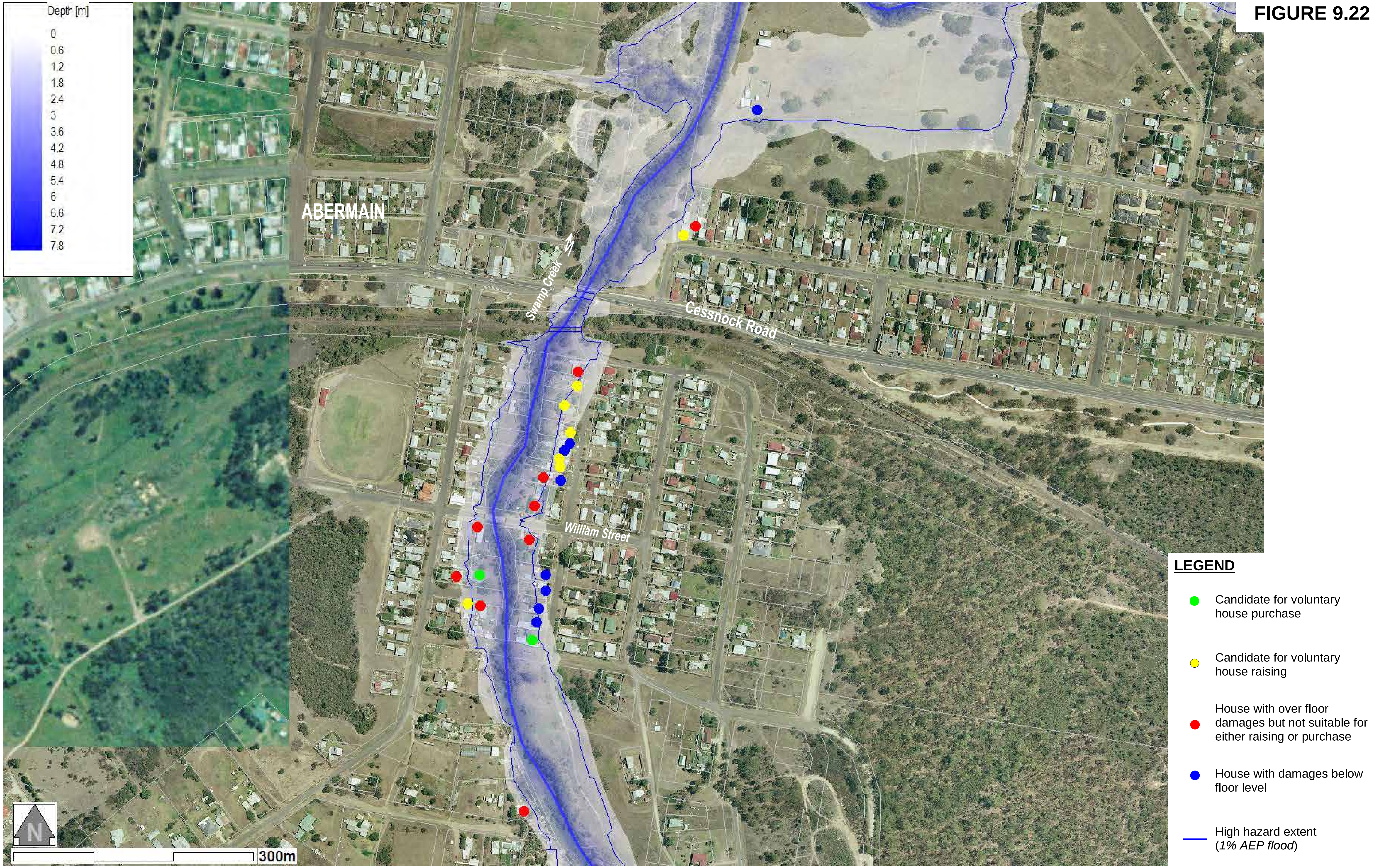
301015-02996 - Swamp Creek FRMS and Plan
02996ja130220figNN-Option 5 Schematic.doc

OPTION S1
CHANGE IN 1% AEP FLOW VELOCITIES

FIGURE 9.22



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301015-02996 - Swamp Creek FRMS and Plan
02996ja130321fig9.20-Preferred Option 2 Schematic Abermain.doc

OPTION S2
VOLUNTARY HOUSE RAISING AND PURCHASE [ABERMAIN]

FIGURE 9.23

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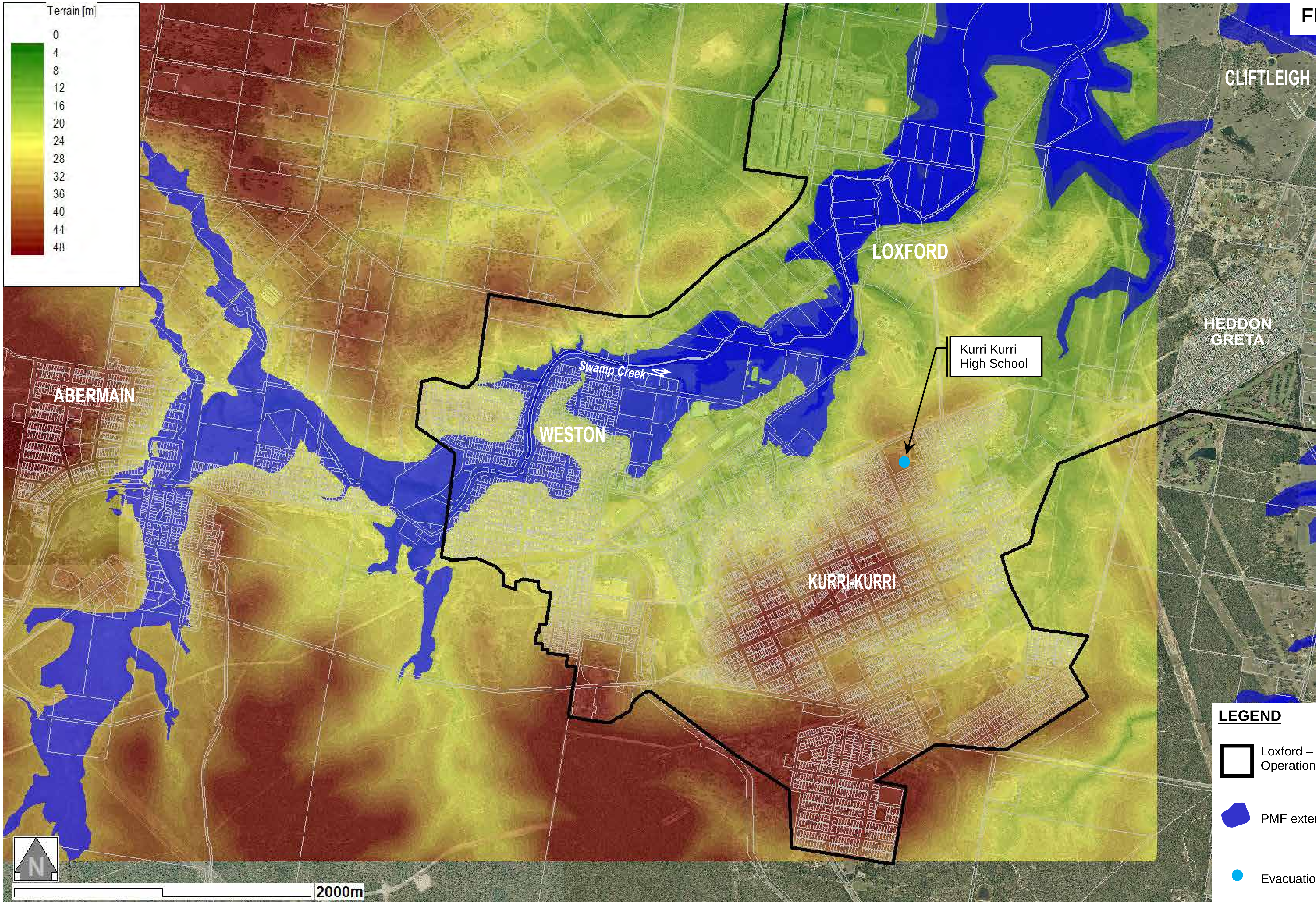
02996ja130220figNN-Option 5 Schematic.doc

OPTION S2
VOLUNTARY HOUSE RAISING AND PURCHASE [WESTON]

FIGURE 10.1



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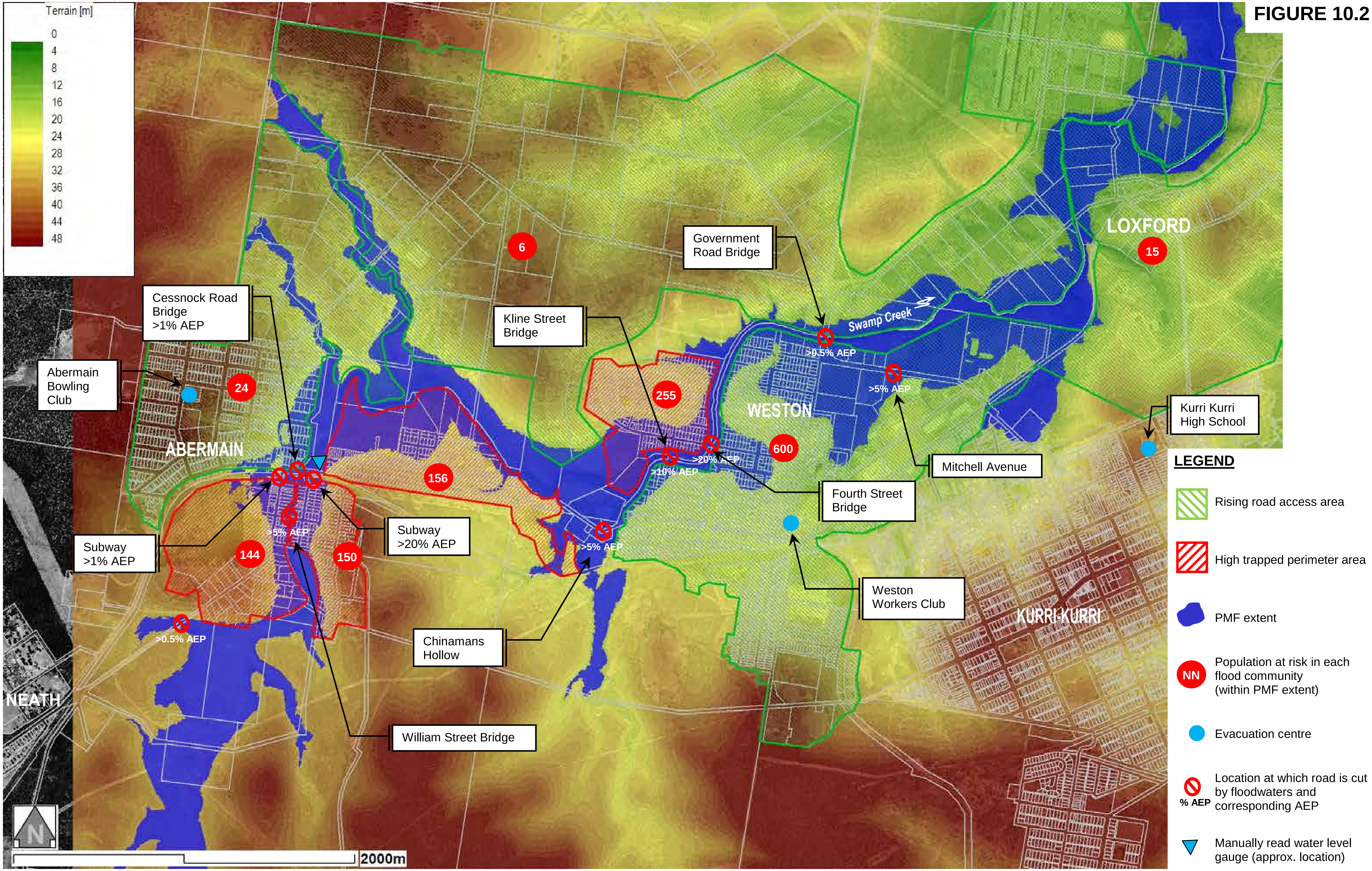
EXISTING FLOOD EMERGENCY RESPONSE FOR HUNTER RIVER FLOODING

FIGURE 10.2



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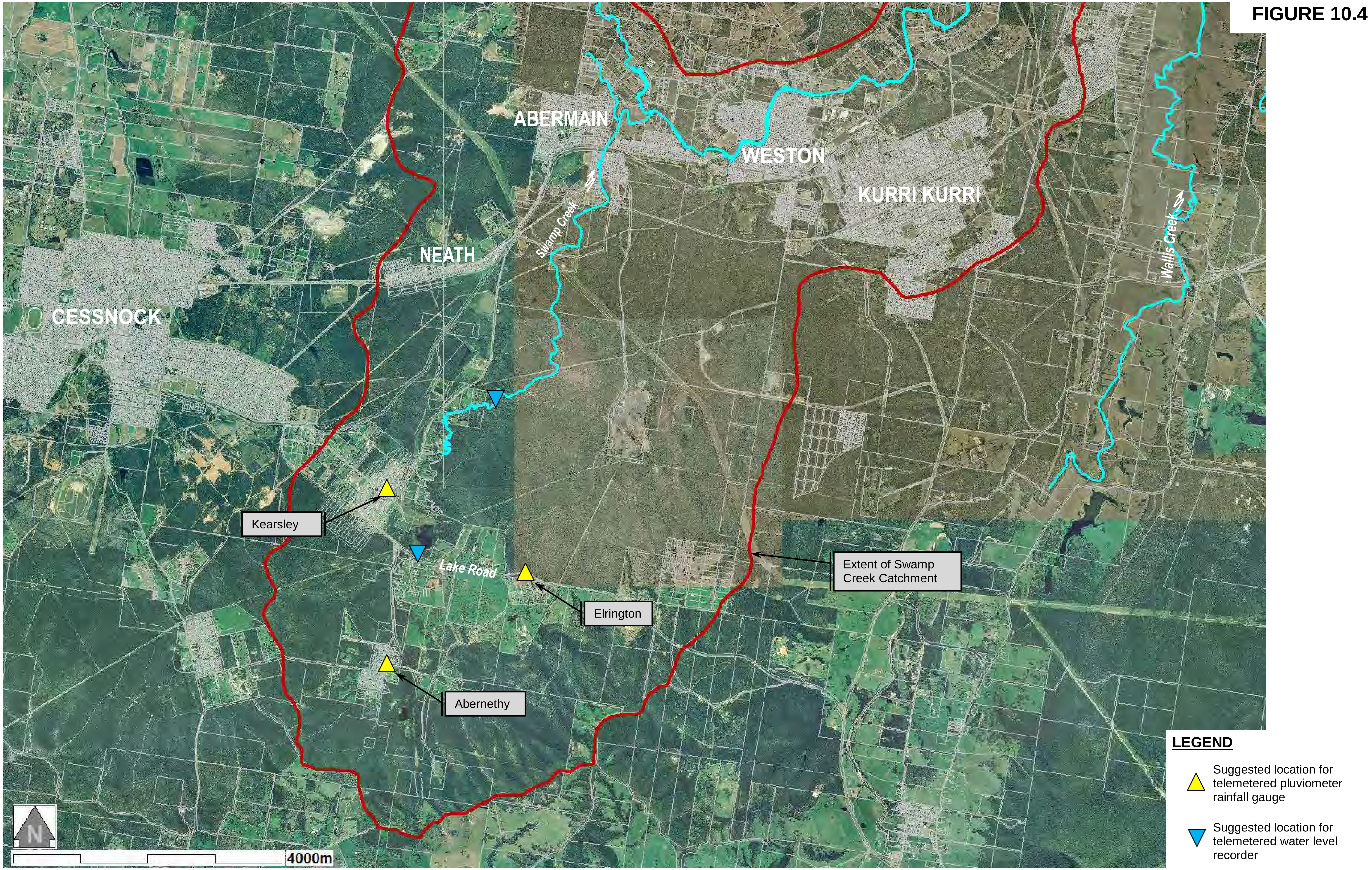
301015-02996 - Swamp Creek FRMS and Plan
02996ja130322fig10.2-Flood managment communities.doc

EMERGENCY RESPONSE MANAGEMENT FOR LOCAL CATCHMENT FLOODING



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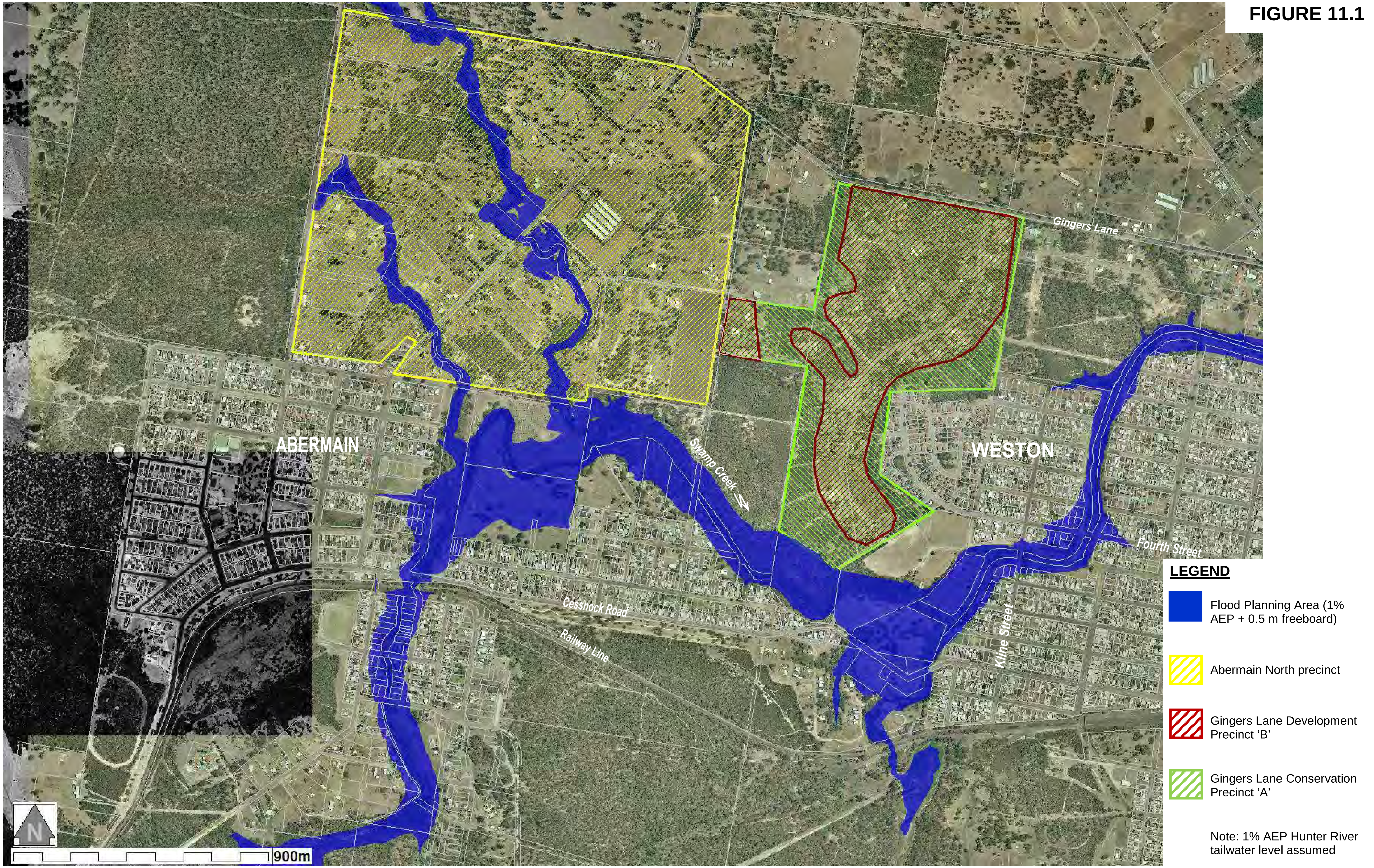
RECOMMENDED FLOOD WARNING SYSTEM FOR ABERMAIN AND WESTON

FIGURE 11.1



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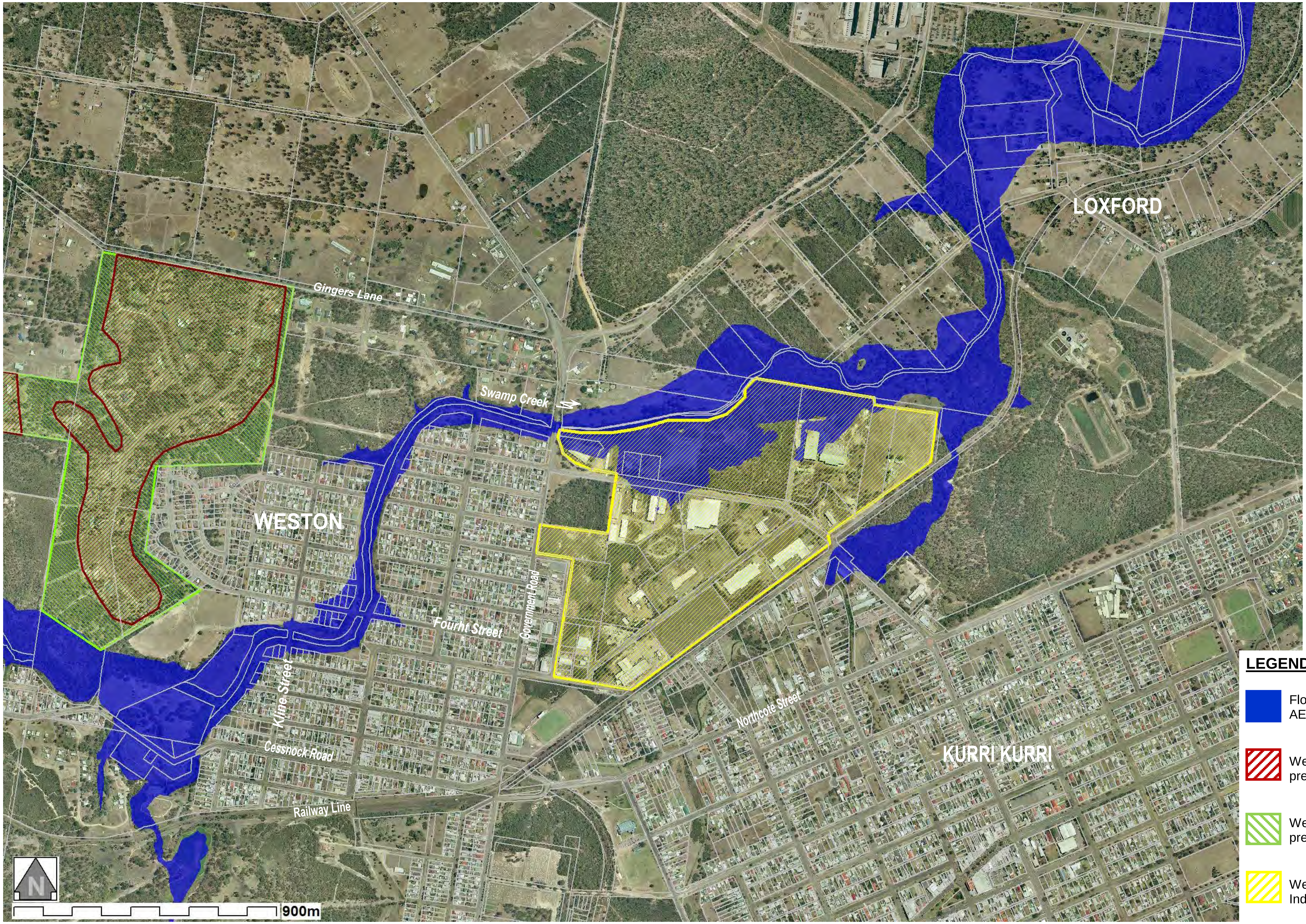
FLOOD PLANNING AREA [ABERMAIN]

FIGURE 11.2



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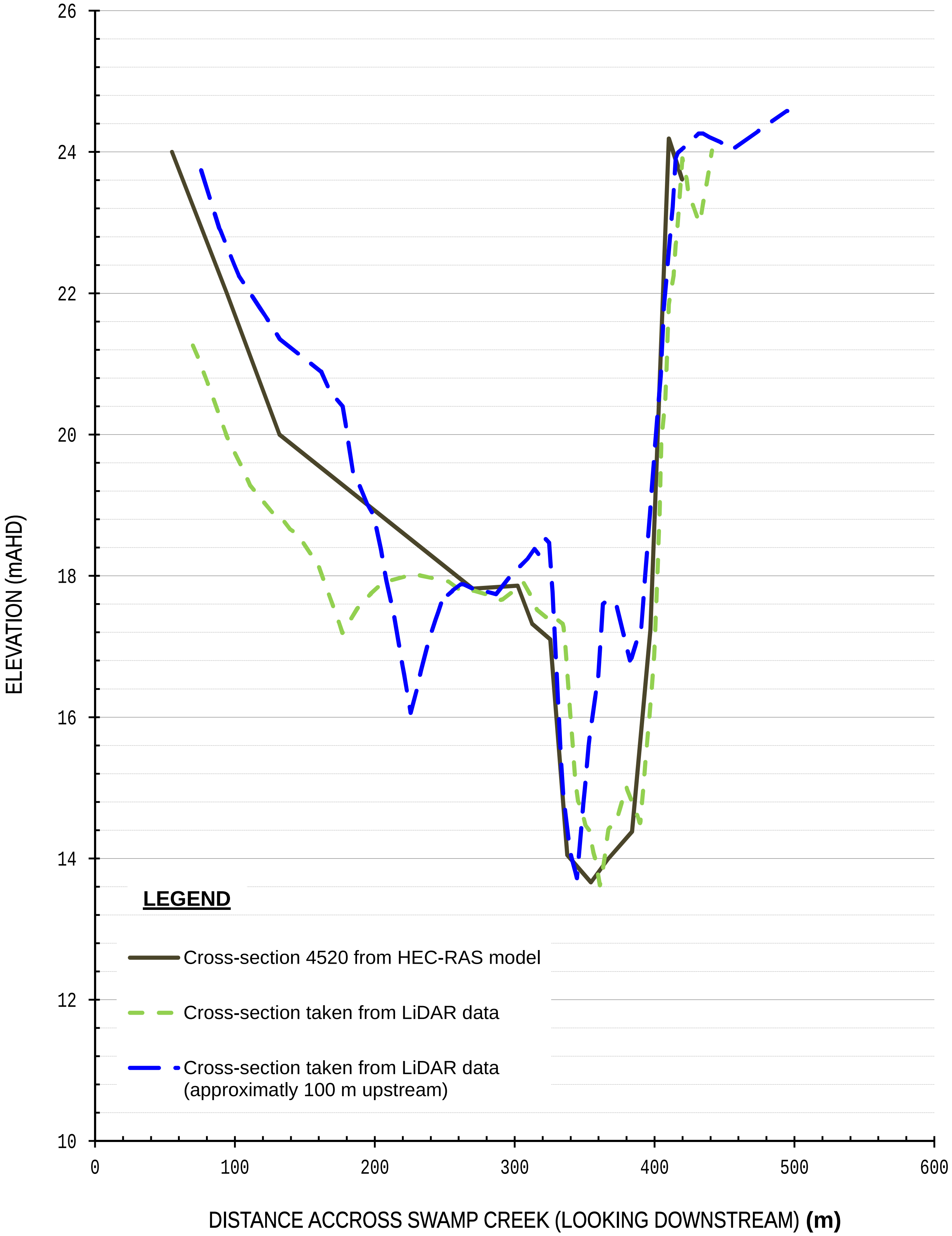
FLOOD PLANNING AREA [WESTON]

Appendix A – Comparison of Creek Bathymetry

FIGURE A1



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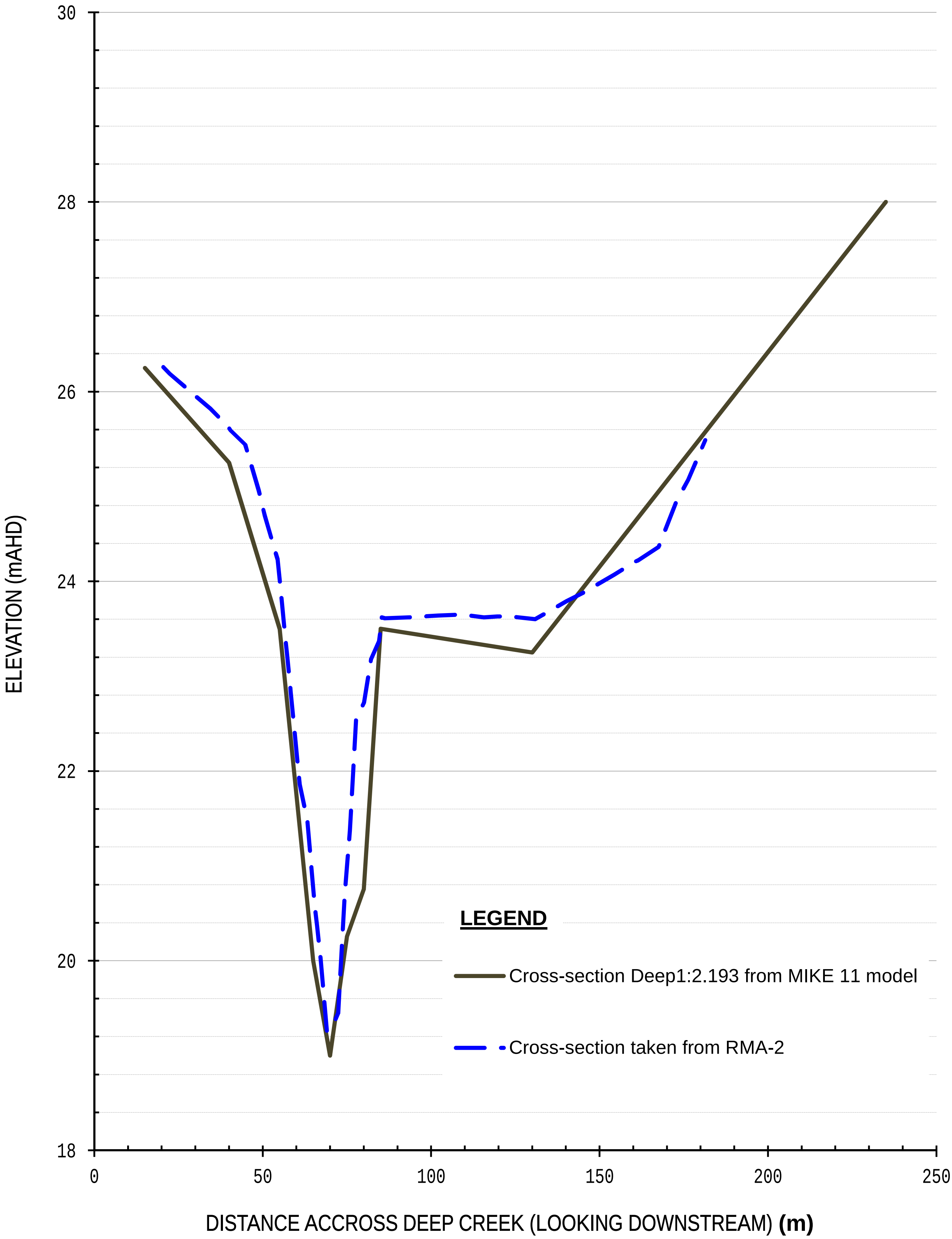
301015-02996 - Swamp Creek FRMS and Plan
02996ja121129_Appendix_A_Cross-section

COMPARISON OF CROSS-SECTIONS IN SWAMP CREEK

FIGURE A2



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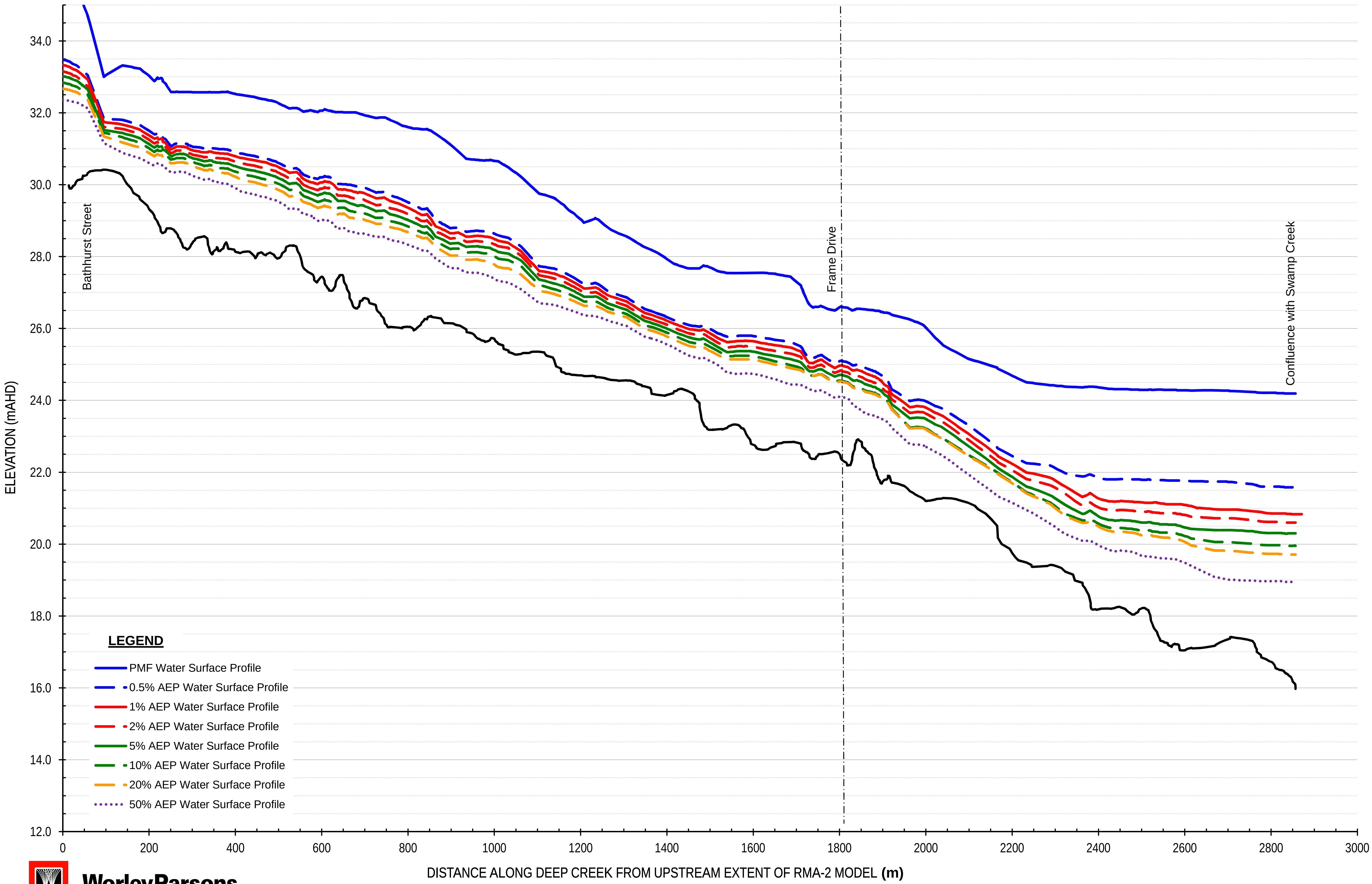
301015-02996 - Swamp Creek FRMS and Plan
02996ja121129_Appendix_A_Cross-section

COMPARISON OF CROSS-SECTIONS IN DEEP CREEK

Appendix B – Design Flood Level Profiles for Deep Creek and South Deep Creek

FIGURE B1



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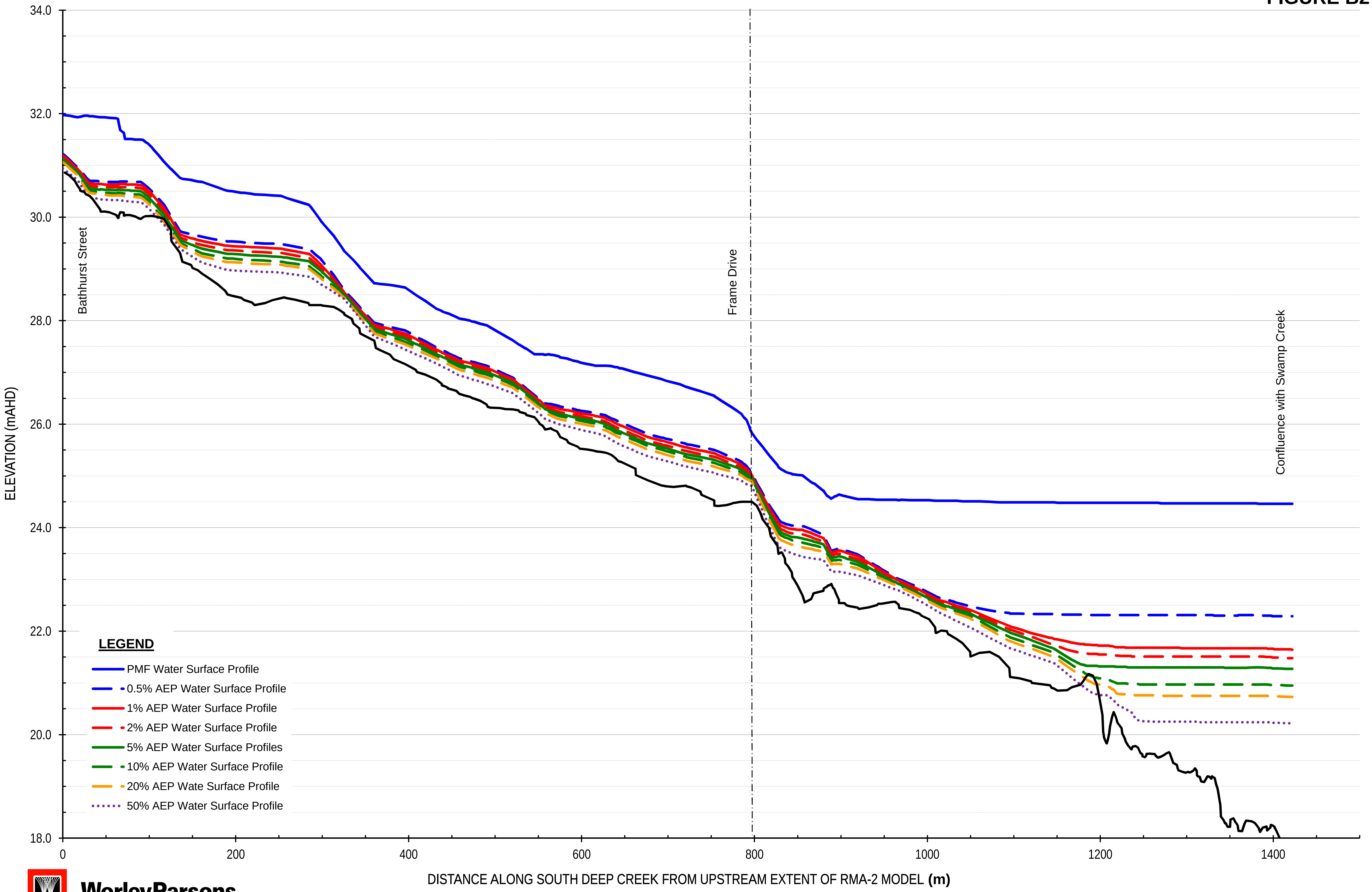
301015-02996 - Swamp Creek FRMS and Plan
fg2996_01ja120921- WSP Figures.xls

DESIGN FLOOD PROFILES ALONG DEEP CREEK

FIGURE B2



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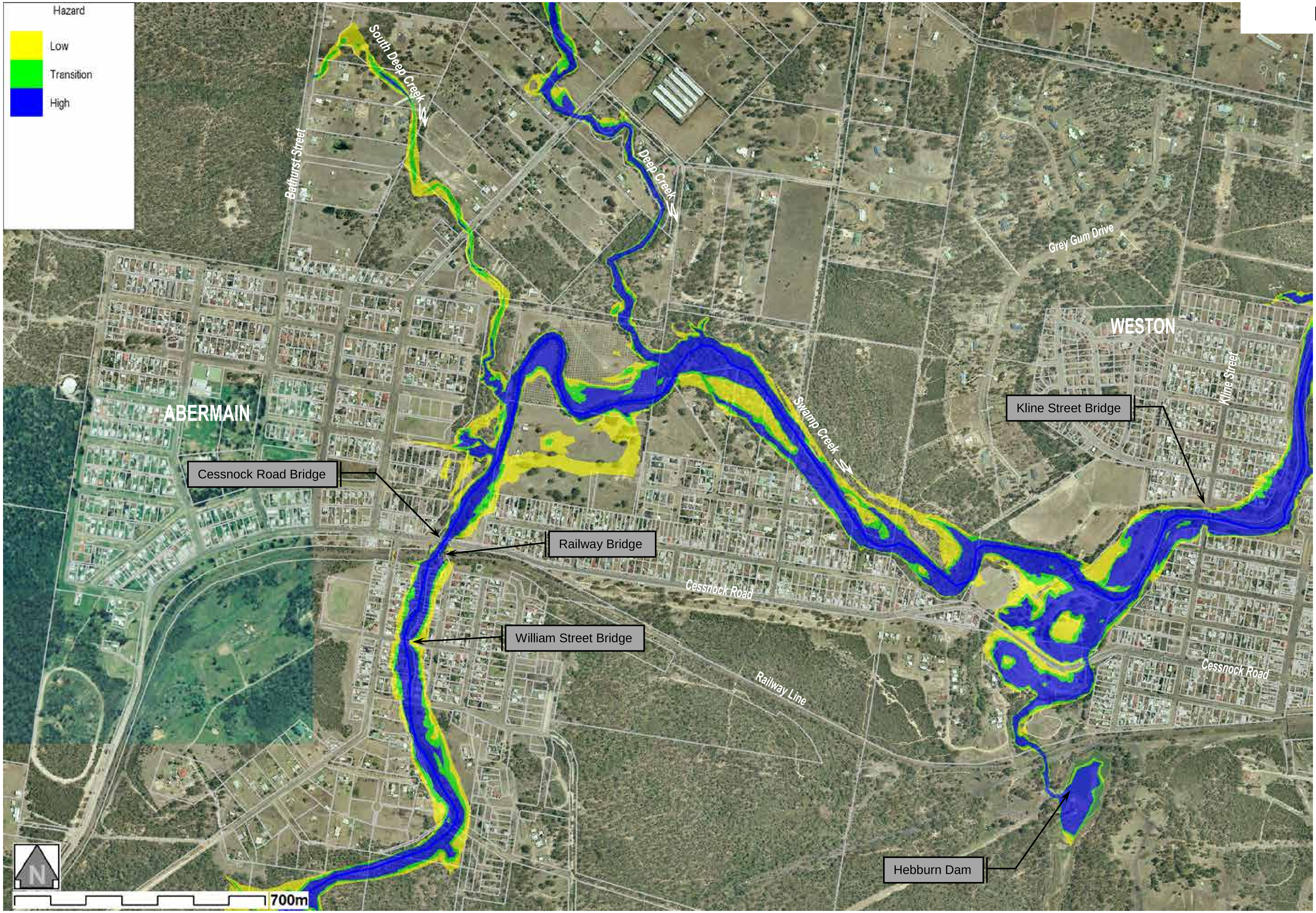
301015-02996 - Swamp Creek FRMS and Plan
fg2996_01ja120921- WSP Figures.xls

DESIGN FLOOD PROFILES
ALONG SOUTH DEEP CREEK

Appendix C – Provisional Flood Hazard Mapping for the 5%, 0.5% events and PMF

FIGURE C1



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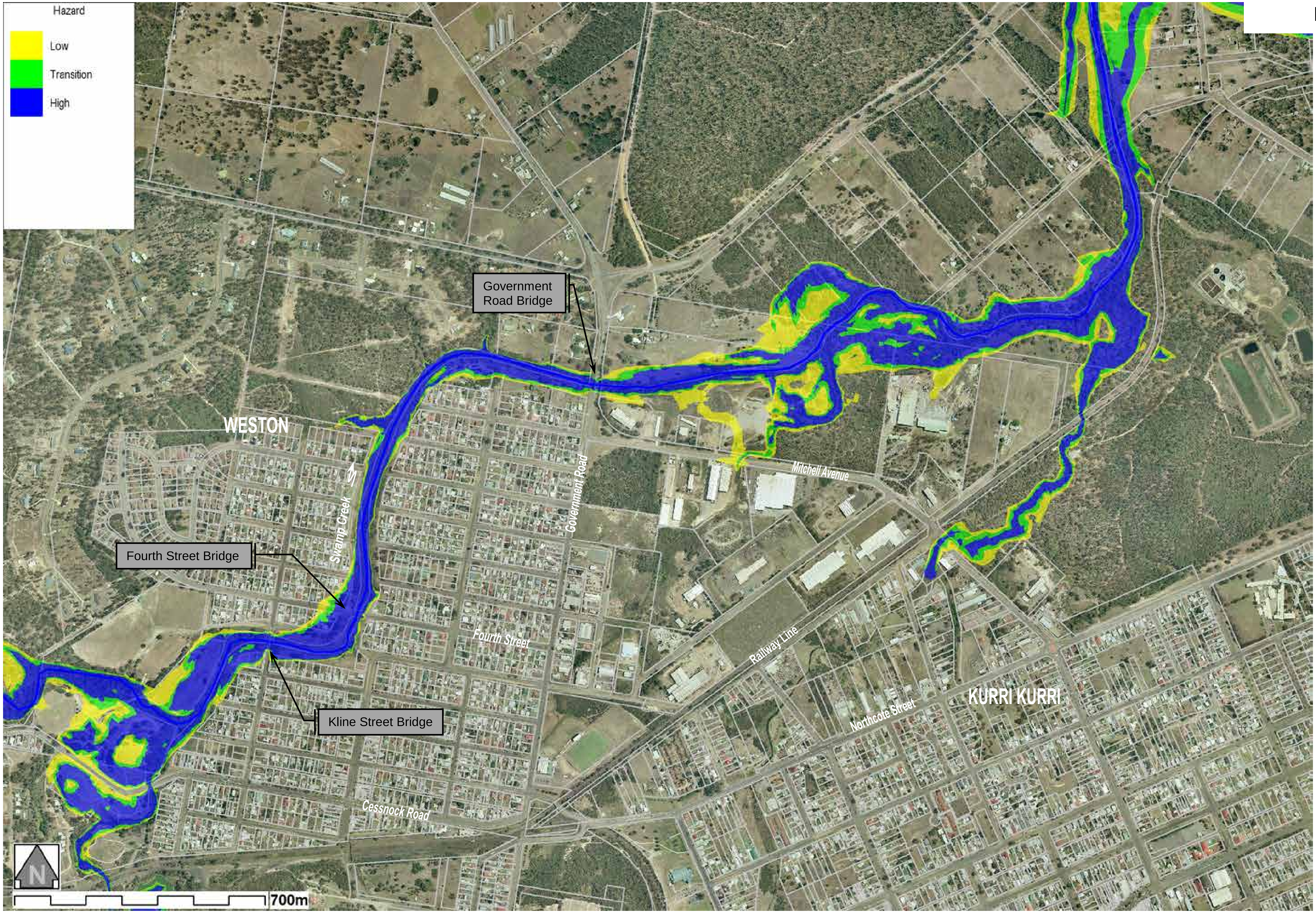
301015-02996 - Swamp Creek FRMS and Plan
02996ja121112fig45-Provisional Flood Hazard 20 Year ARI Abermain.doc

PROVISIONAL FLOOD HAZARD
5 % AEP [SHEET 1]

FIGURE C2



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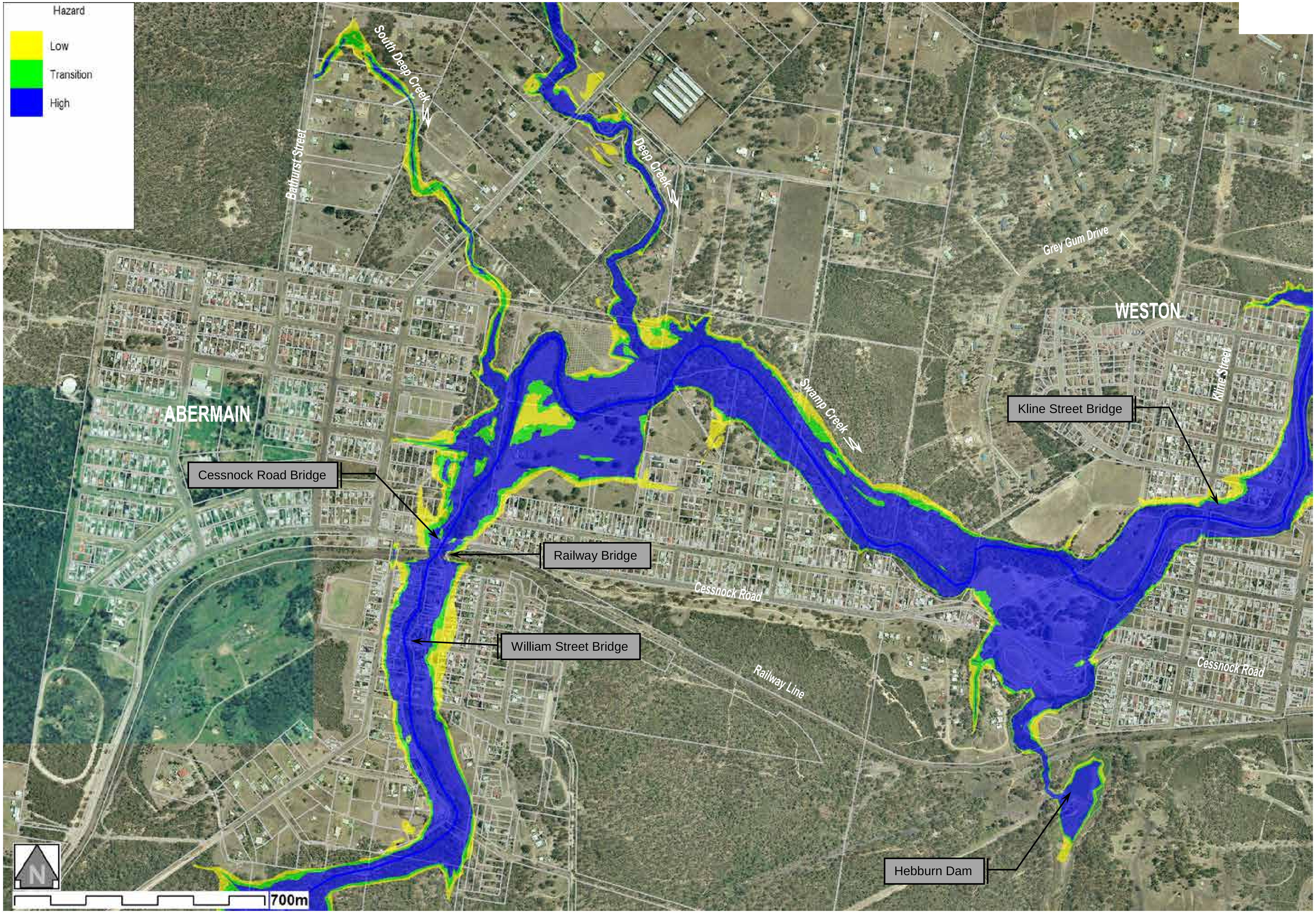
301015-02996 - Swamp Creek FRMS and Plan
02996ja121112fig46-Provisional Flood Hazard 20 Year ARI Weston.doc

PROVISIONAL FLOOD HAZARD
5% AEP [SHEET 2]

FIGURE C3



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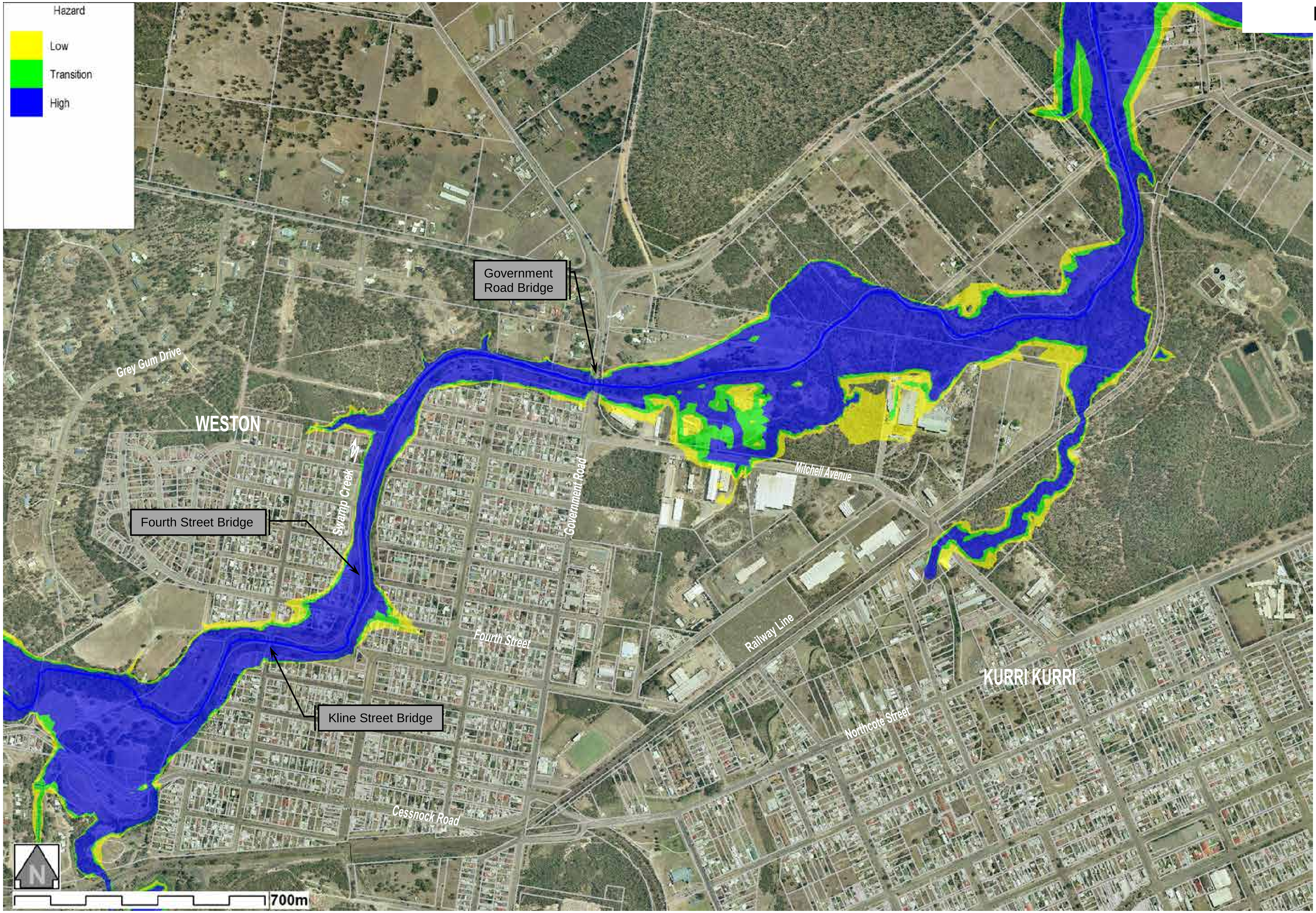
301015-02996 - Swamp Creek FRMS and Plan
02996ja121112figC3-Provisional Flood Hazard 200 Year ARI Abermain.doc

PROVISIONAL FLOOD HAZARD
0.5% AEP [SHEET 1]

FIGURE C4



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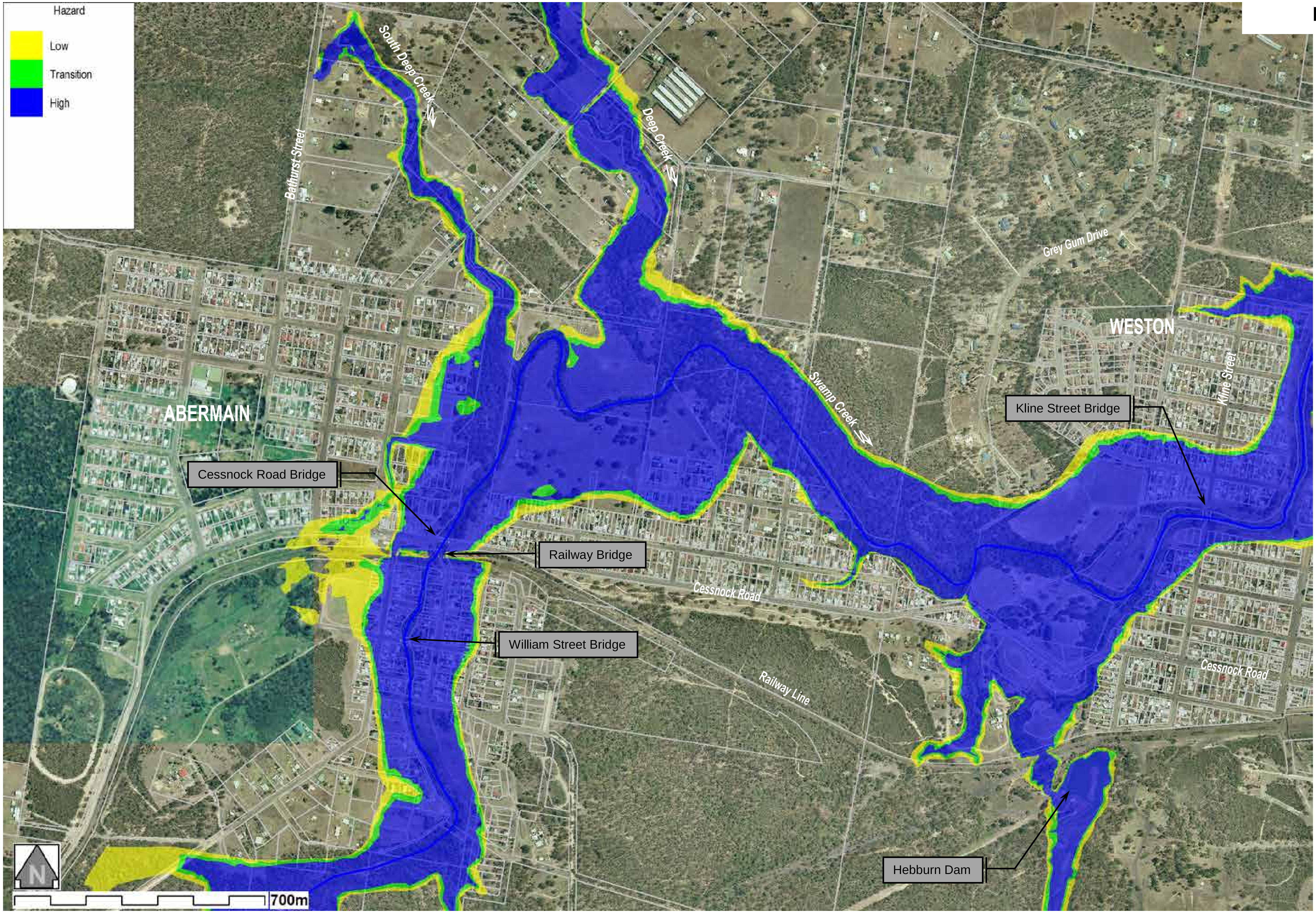
301015-02996 - Swamp Creek FRMS and Plan
02996ja121112fig50-Provisional Flood Hazard 200 Year ARI Weston.doc

PROVISIONAL FLOOD HAZARD
0.5% AEP [SHEET 2]

FIGURE C5



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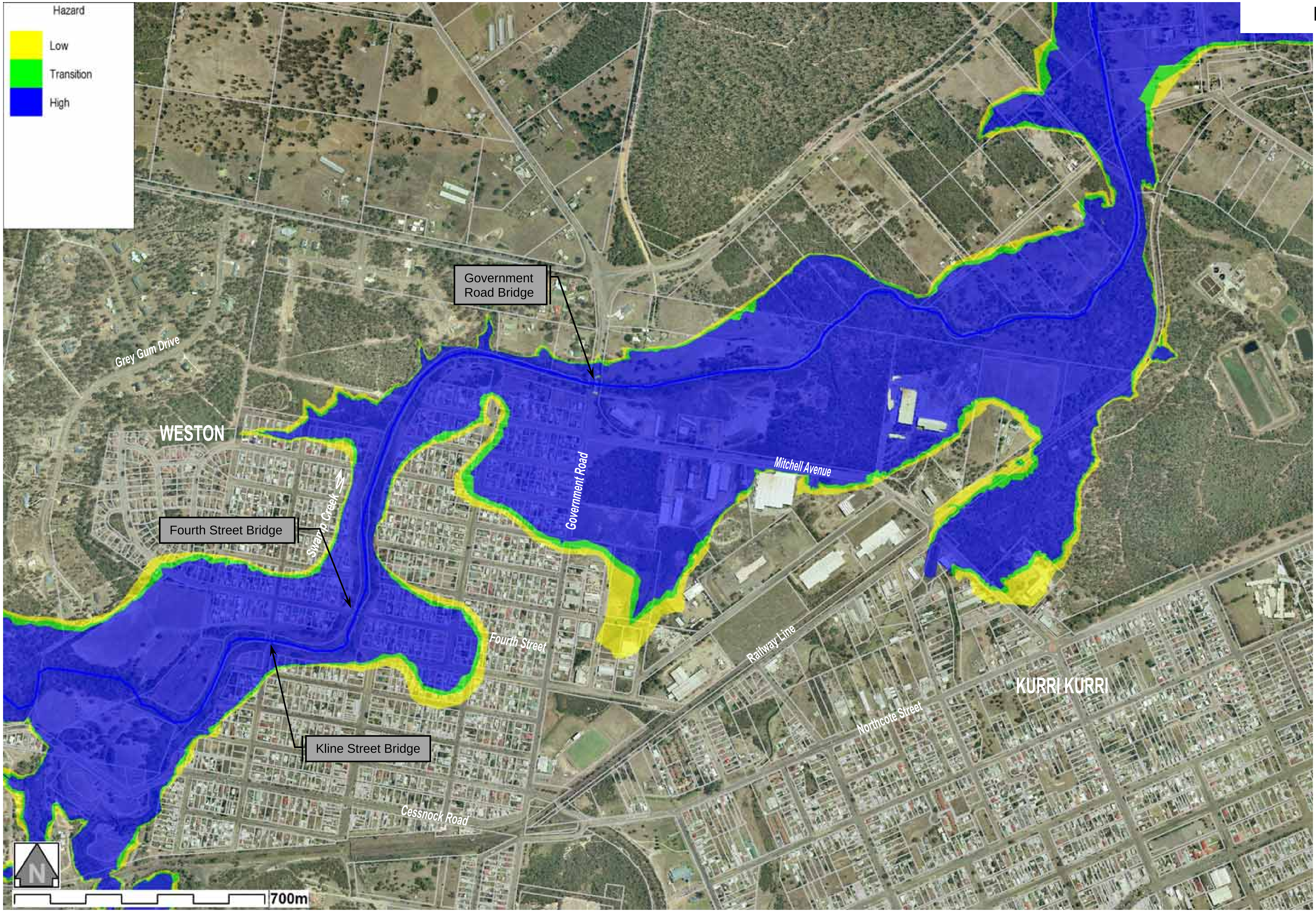
301015-02996 - Swamp Creek FRMS and Plan
02996ja121112fig51-Provisional Flood Hazard PMF Abermain.doc

PROVISIONAL FLOOD HAZARD
PROBABLE MAXIMUM FLOOD [SHEET 1]

FIGURE C6



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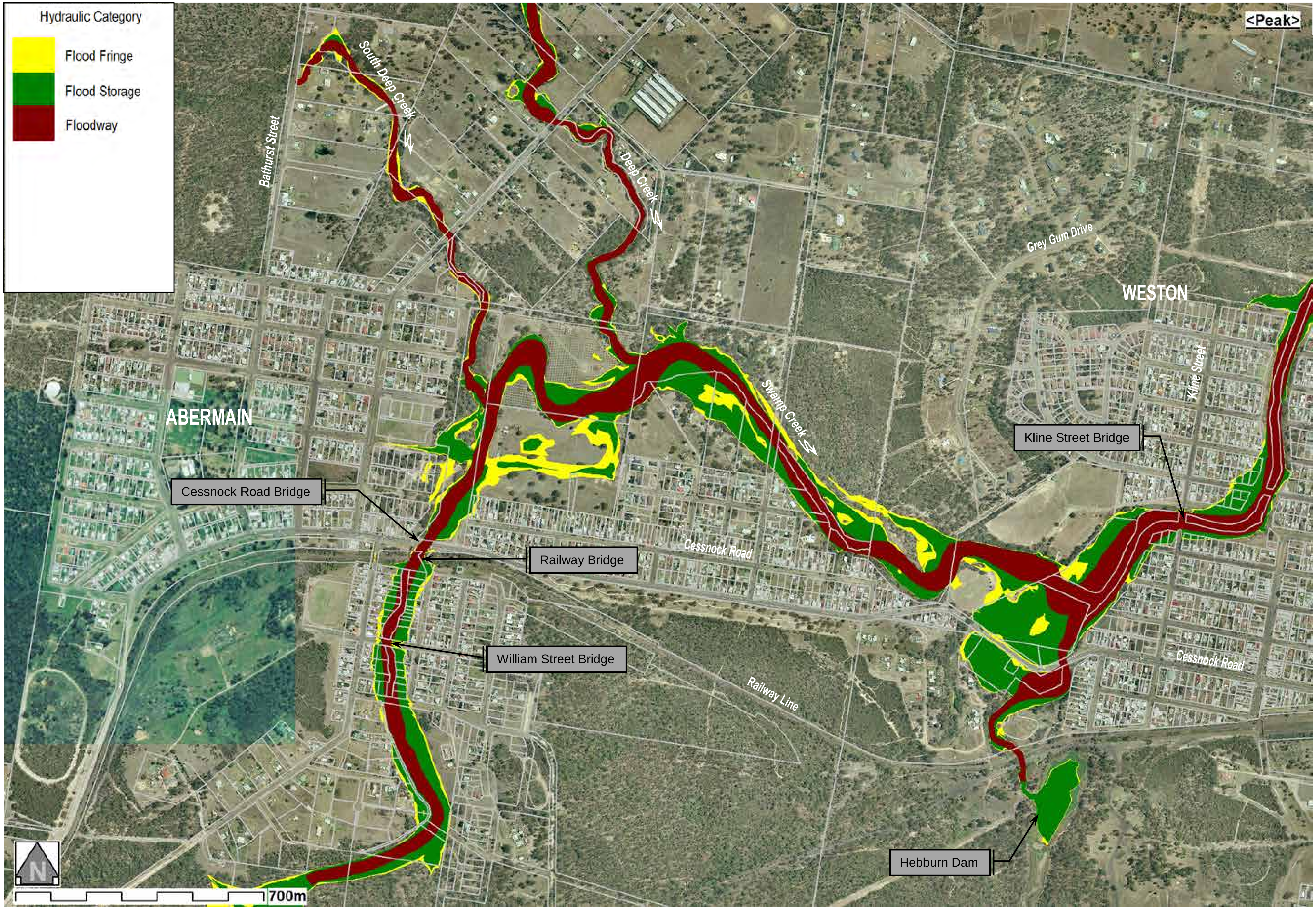
301015-02996 - Swamp Creek FRMS and Plan
02996ja121112fig52-Provisional Flood Hazard PMF Weston.doc

PROVISIONAL FLOOD HAZARD
PROBABLE MAXIMUM FLOOD [SHEET 2]

Appendix D – Hydraulic Category Mapping for the 5%, 0.5% AEP events and PMF

FIGURE D1



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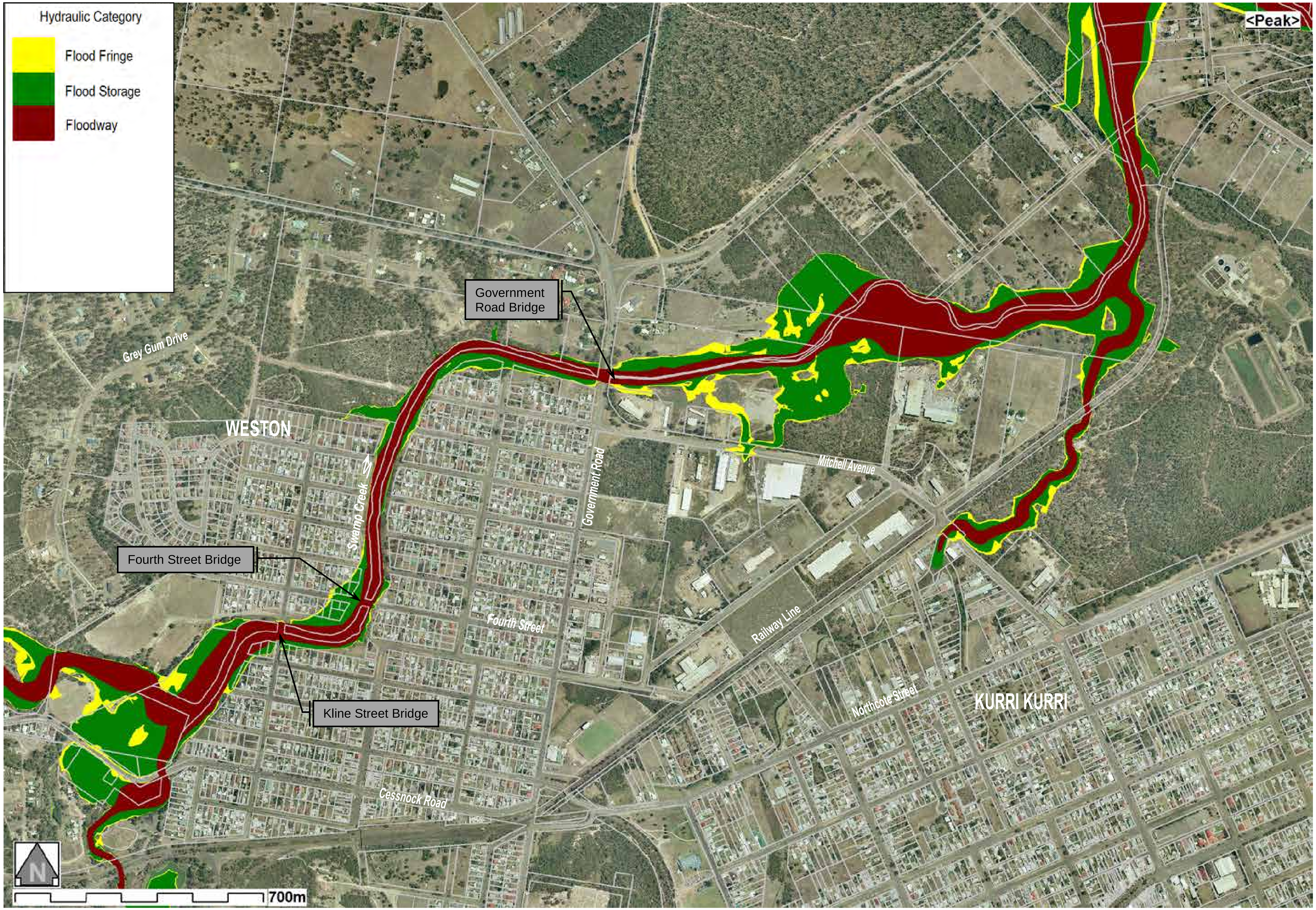
301015-02996 - Swamp Creek FRMS and Plan
02996ja121217fig09-Floodway 20 Year ARI Abermain.doc

HYDRAULIC CATEGORY MAPPING FOR THE 5% AEP FLOOD [SHEET 1]

FIGURE D2



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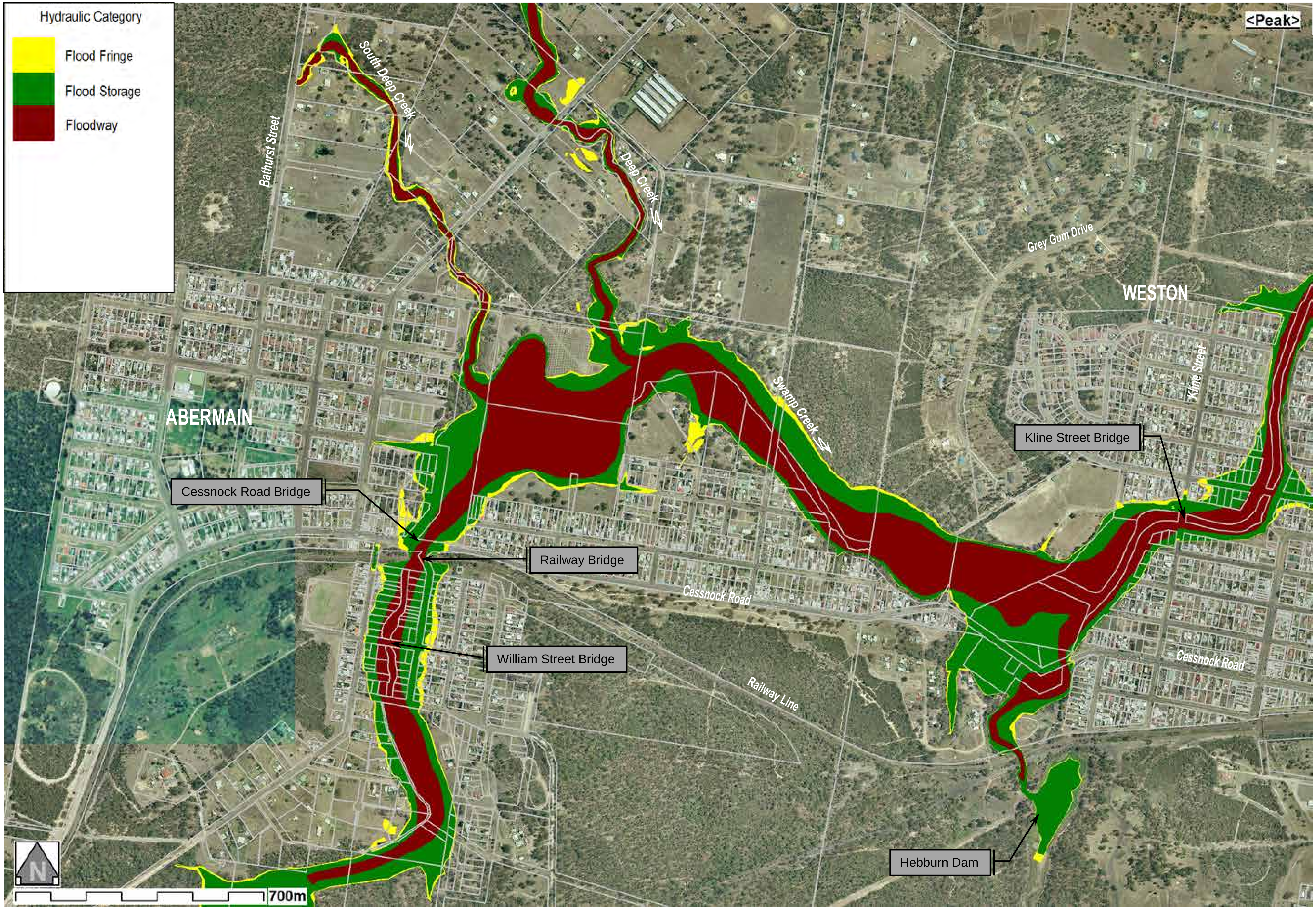
301015-02996 - Swamp Creek FRMS and Plan
02996ja121217fig10-Floodway 20 Year ARI Weston.doc

HYDRAULIC CATEGORY MAPPING FOR THE 5% AEP FLOOD [SHEET 2]

FIGURE D3



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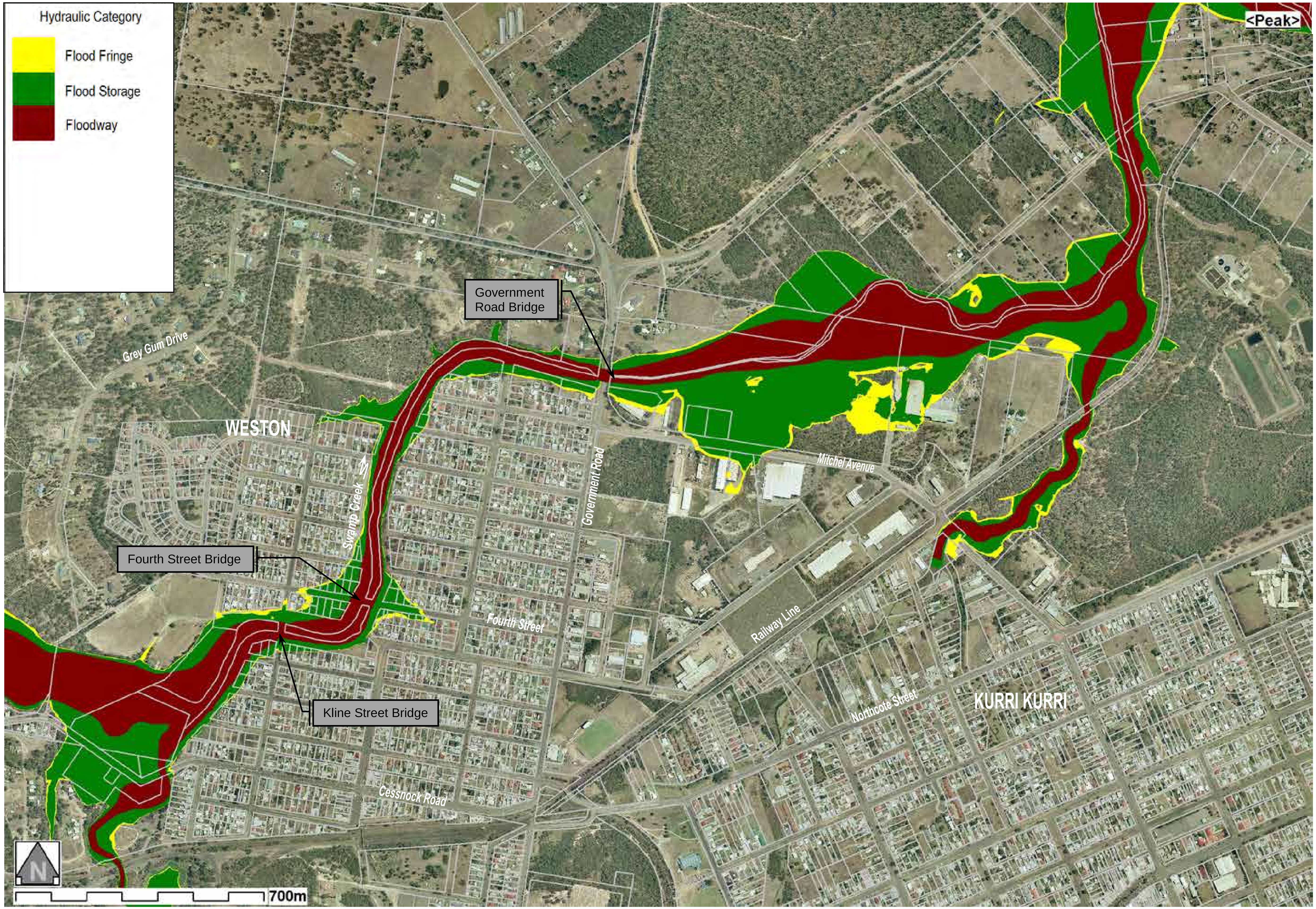
HYDRAULIC CATEGORY MAPPING FOR THE 0.5% AEP FLOOD [SHEET 1]

FIGURE D4



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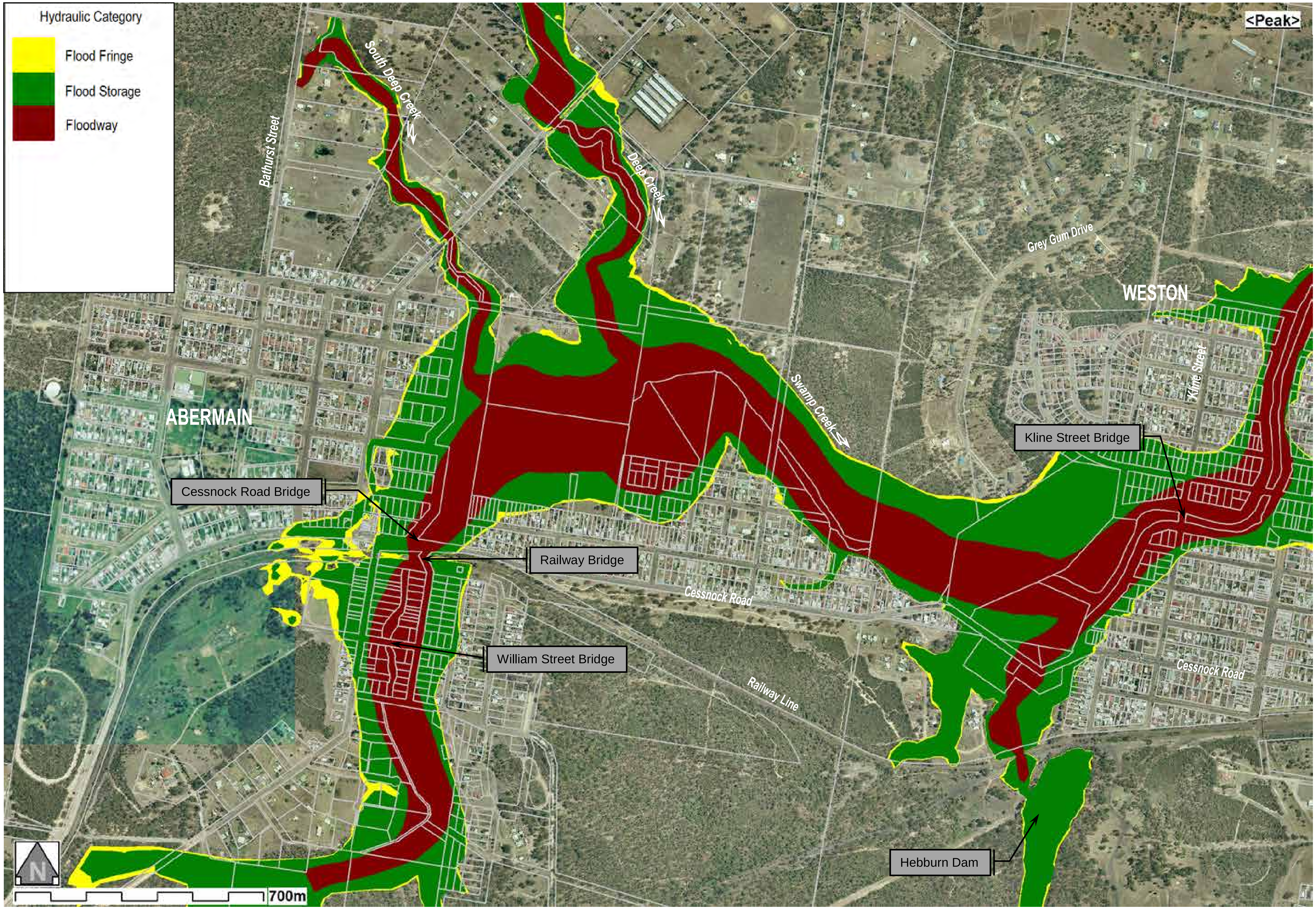
301015-02996 - Swamp Creek FRMS and Plan
02996ja121217fig14-Floodway 200 Year ARI Weston.doc

HYDRAULIC CATEGORY MAPPING FOR THE 0.5% AEP FLOOD [SHEET 2]

FIGURE D5



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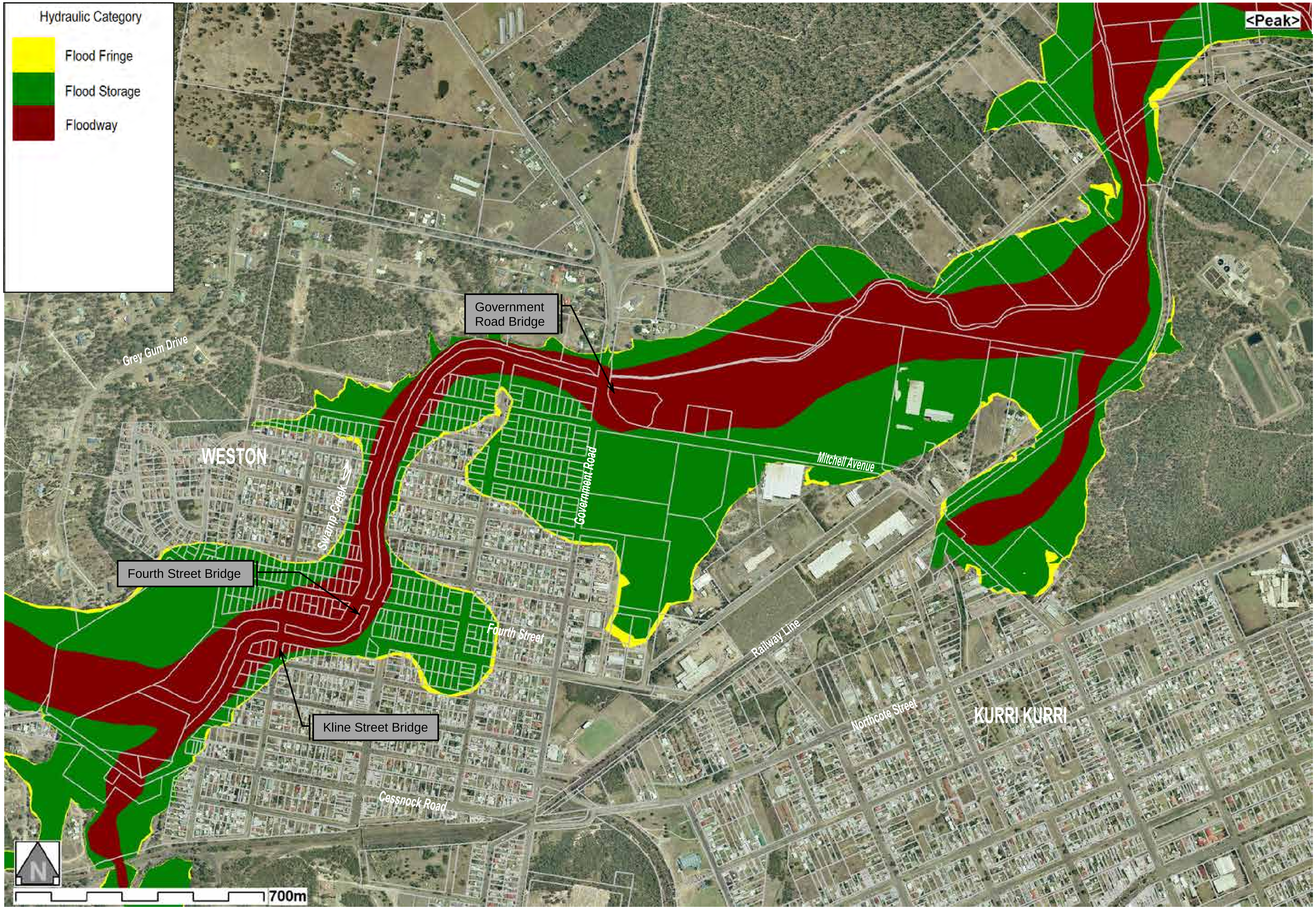
301015-02996 - Swamp Creek FRMS and Plan
02996ja121217fig15-Floodway PMF Abermain.doc

HYDRAULIC CATEGORY MAPPING FOR THE PROBABLE MAXIMUM FLOOD [SHEET 1]

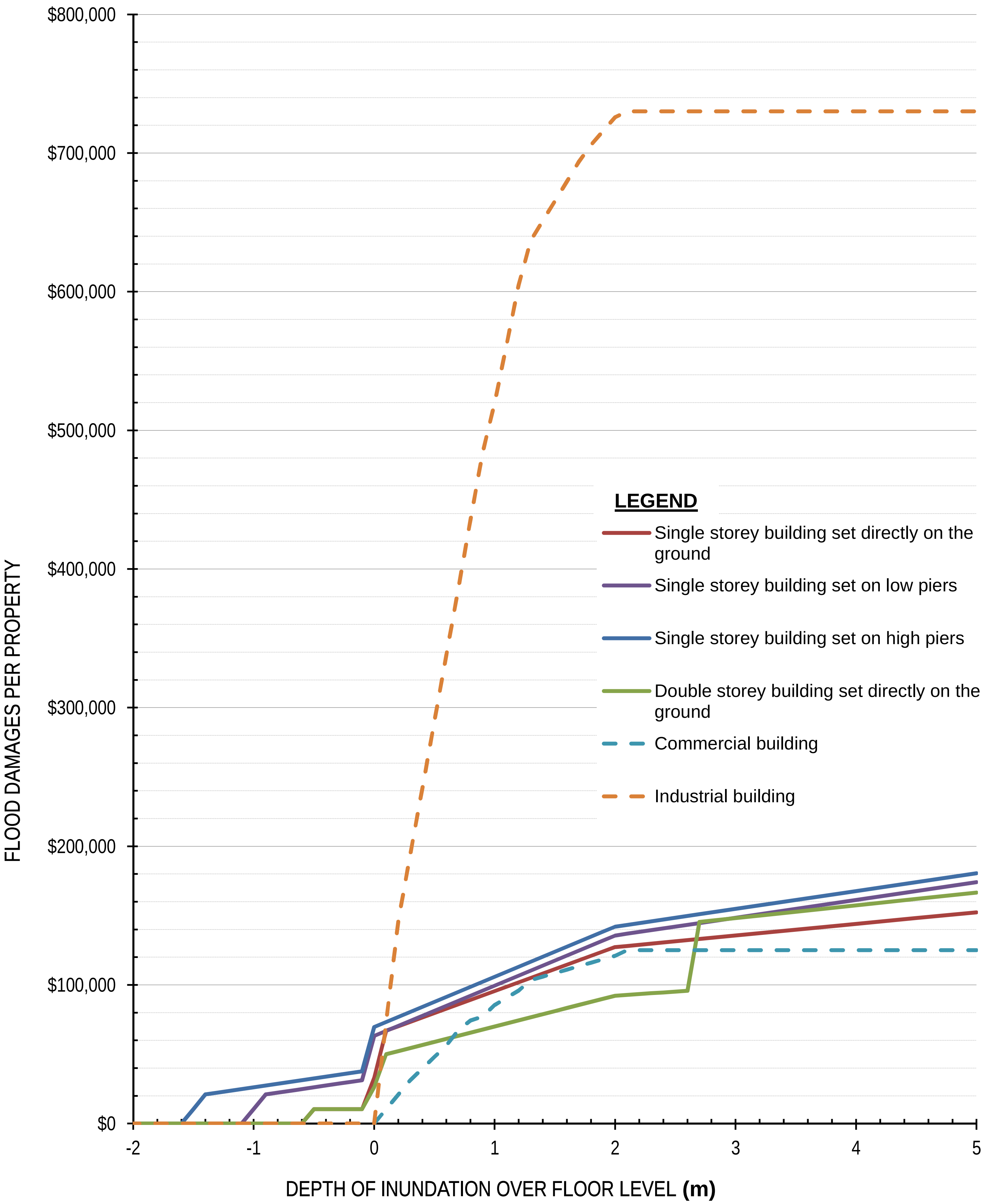
FIGURE D6



HYDRAULIC CATEGORY MAPPING FOR THE PROBABLE MAXIMUM FLOOD [SHEET 2]

Appendix E – Stage-Damage Curves

FIGURE E1



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301015-02996 - Swamp Creek FRMS and Plan
ResidentialDamageCurve.xlsx

ADOPTED STAGE DAMAGE CURVES FOR SWAMP CREEK

Appendix F – Cost Estimates for Flood Mitigation Options

APPENDIX F1: Cost Estimate for Option 1 (Excavate Channel 1m Deep)

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Rev	Description	Orig	Review	Worley-Parsons Approval	Date
0	Issued for Information	WJH	CRT		18/02/2013
		W Honour	Reviewer	Approver	

Disclaimer
This cost estimate is based on WorleyParsons' experience and judgement as a firm of practising professional engineers familiar with the construction industry. This cost estimate can NOT be guaranteed as we have no control over Contractor's prices, market forces and competitive bids from tenderers. This cost estimate excludes authority approval fees.

Note: Wherever possible, cost estimates are based on Rawlinsons Australian Construction Handbook Edition 30, 2012

Item	Description	Quantity	Rate	Unit	Cost
1	Preliminaries				
	- equipment mobilisation and site establishment	1	5	%	528,918
	- site clearing	418,830	1.00	sqm	418,830
	- tree removal	1,900	150	No.	285,000
	- tree disposal	1,900	120	t	228,000
	- coffer dams (to undertake works in 1km sections)	10	30,000	item	300,000
	- low flow piping (1km, to be reused for each section)	1,000	260	m	260,000
2	Exacavation				
	- excavation of channel bed	288,504	7.35	cum	2,120,504
	- cartage of excess material (assume 20km)	288,504	11.40	cum	3,288,946
	- disposal of excess material (assume to be used on another project)	663,559	-	t	-
3	Surface Treatment and Landscaping				
	- trim excavation to batter	276,330	3.25	sqm	898,073
	- jute mat	418,830	2.00	sqm	837,660
	- grass seed, including maintenance	41.9	8,150	ha	341,346
4	Bridge Works				
	- extend road bridge footings to lowered bed level	5	200,000	item	1,000,000
	- extend rail bridge footings to lowered bed level	1	300,000	item	300,000
	- extend foot bridge footings to lowered bed level	2	50,000	item	100,000
5	Traffic Management				
	- based on 30 days per bridge crossing	100	2,000	day	200,000
6	Site Disestablishment				
	- including clean up	1	5	%	528,918
				SUB-TOTAL (SYDNEY)	11,636,195
				CESSNOCK AREA FACTOR (+4%)	12,101,643
	Additional				
	- design, survey, geotechnical, environmental and construction management	1	10	%	1,210,164
	- contingencies	1	20	%	2,420,329
				TOTAL (INCL. CONTINGENCY)	15,732,000

APPENDIX F2: Cost Estimate for Option 2 (Excavate Channel 2m Deep)

WorleyParsons
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Rev	Description	Orig	Review	Worley-Parsons Approval	Date
0	Issued for Information	WJH	CRT		18/02/2013
		W Honour	Reviewer	Approver	

Disclaimer
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Note: Wherever possible, cost estimates are based on Rawlinsons Australian Construction Handbook Edition 30, 2012

Item	Description	Quantity	Rate	Unit	Cost
1	Preliminaries				
	- equipment mobilisation and site establishment	1	5	%	849,004
	- site clearing	418,830	1.00	sqm	418,830
	- tree removal	1,900	150	No.	285,000
	- tree disposal	1,900	120	t	228,000
	- coffer dams (to undertake works in 1km sections)	10	30,000	item	300,000
	- low flow piping (1km, to be reused for each section)	1,000	260	m	260,000
2	Exacavation				
	- excavation of channel bed	590,462	7.35	cum	4,339,896
	- cartage of excess material (assume 20km)	590,462	11.40	cum	6,731,267
	- disposal of excess material (assume to be used on another project)	1,358,063	-	t	-
3	Surface Treatment and Landscaping				
	- trim excavation to batter	276,330	3.25	sqm	898,073
	- jute mat	418,830	2.00	sqm	837,660
	- grass seed, including maintenance	41.9	8,150	ha	341,346
4	Bridge Works				
	- extend road bridge footings to lowered bed level	5	300,000	item	1,500,000
	- extend rail bridge footings to lowered bed level	1	400,000	item	400,000
	- extend foot bridge footings to lowered bed level	2	70,000	item	140,000
5	Traffic Management				
	- based on 30 days per bridge crossing	150	2,000	day	300,000
6	Site Disestablishment				
	- including clean up	1	5	%	849,004
			SUB-TOTAL (SYDNEY)		18,678,079
			CESSNOCK AREA FACTOR (x1.04)		19,425,202
	Additional				
	- design, survey, geotechnical, environmental and construction management	1	10	%	1,942,520
	- contingencies	1	20	%	3,885,040
			TOTAL (INCL. CONTINGENCY)		25,253,000

APPENDIX F3: Cost Estimate for Option 3 (Channel Clearing)

WorleyParsons
resources & energy

Rev	Description	Orig	Review	Worley-Parsons Approval	Date
0	Issued for Information	WJH W Honour	CRT Reviewer	Approver	18/02/2013

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Note: Wherever possible, cost estimates are based on Rawlinsons Australian Construction Handbook Edition 30, 2012

Item	Description	Quantity	Rate	Unit	Cost
1	Preliminaries				
	- equipment mobilisation and site establishment	1	5	%	133,542
	- site clearing	418,830	1.00	sqm	418,830
	- tree removal	1,900	150	No.	285,000
	- tree disposal	1,900	120	t	228,000
	- coffer dams (to undertake works in 1km sections)	10	30,000	item	300,000
	- low flow piping (1km, plus allowance for reuse for each section)	1,000	260	m	260,000
2	Surface Treatment and Landscaping				
	- jute mat	418,830	2.00	sqm	837,660
	- grass seed, including levelling and maintenance	41.9	8,150	ha	341,346
3	Site Disestablishment				
	- including clean up	1	5	%	133,542
				SUB-TOTAL (SYDNEY)	2,937,920
				CESSNOCK AREA FACTOR (x1.04)	3,055,437
	Additional				
	- design, survey, geotechnical, environmental and construction management	1	10	%	305,544
	- contingencies	1	20	%	611,087
				TOTAL (INCL. CONTINGENCY)	3,972,000

APPENDIX F4: Cost Estimate for Option 4 (Concrete-lined Channel)

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Rev	Description	Orig	Review	Worley-Parsons Approval	Date
0	Issued for Information	WJH W Honour	CRT Reviewer	Approver	18/02/2013

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Note: Wherever possible, cost estimates are based on Rawlinsons Australian Construction Handbook Edition 30, 2012

Item	Description	Quantity	Rate	Unit	Cost
1	<u>Preliminaries</u>				
	- equipment mobilisation and site establishment	1	5	%	515,096
	- site clearing	418,830	1.00	sqm	418,830
	- tree removal	1,900	150	No.	285,000
	- tree disposal	1,900	120	t	228,000
	- coffer dams (to undertake works in 1km sections)	10	30,000	item	300,000
	- low flow piping (1km, to be reused for each section)	1,000	260	m	260,000
2	<u>Concreting</u>				
	- excavate foundation for concrete (0.1m depth)	41,883	7.35	cum	307,840
	- reinforced concrete (25MPa, 70mm thick)	29,318	290	cum	8,502,249
	- disposal of excess material (assume to be used on another project)	96,331	-	t	-
3	<u>Site Disestablishment</u>				
	- including clean up	1	5	%	515,096
			SUB-TOTAL (SYDNEY)		11,332,111
			CESSNOCK AREA FACTOR (x1.04)		11,785,395
	<u>Additional</u>				
	- design, survey, geotechnical, environmental and construction management	1	10	%	1,178,540
	- contingencies	1	20	%	2,357,079
			TOTAL (INCL. CONTINGENCY)		15,321,000

APPENDIX F5: Cost Estimate for Option 5 (Bridge Improvements at Abermain)

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Rev	Description	Orig	Review	WorleyParsons Approval	Date
0	Issued for Information	WJH W Honour	CRT Reviewer	Approver	18/02/2013

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Note: Wherever possible, cost estimates are based on Rawlinsons Australian Construction Handbook Edition 30, 2012

Item	Description	Quantity	Rate	Unit	Cost
1	Preliminaries				
	- equipment mobilisation and site establishment	1	5	%	113,221
	- tree removal	20	150	No.	3,000
	- tree disposal	20	120	t	2,400
	- coffer dam	1	30,000	item	30,000
	- low flow piping	60	160	m	9,600
2	Demolition and Disposal				
	- demolish Cessnock Road bridge	1	20,000	item	20,000
	- demolish footbridges	2	10,000	item	20,000
	- remove piers from Rail bridge	3	10,000	item	30,000
	- disposal of excess material	2,184	130	t	283,920
3	Railway Bridge Works				
	- replace bridge deck with single span	320	1,735	sqm	555,200
	- abutment strengthening	2	30,000	item	60,000
	- rail traffic management	1	50,000	item	50,000
4	Cessnock Road Bridge				
	- install 2 lane 11m wide single span bridge	220	1,735	sqm	381,700
	- upgrade abutments	2	20,000	item	40,000
	- install 2 lane road at abutments	30	620	m	18,600
	- traffic management	1	200,000	item	200,000
5	Footbridges				
	- install footbridges x 2	210	1,000	item	210,000
6	Services Relocation				
	- assume 2 x water mains	50	5,000	m	250,000
	- assume 2 x sewer mains	100	1,000	m	100,000
7	Site Disestablishment				
	- including clean up	1	5	%	113,221
				SUB-TOTAL (SYDNEY)	2,490,862
				CESSNOCK AREA FACTOR (x1.04)	2,590,496
	Additional				
	- design, survey, geotechnical, environmental and construction management	1	10	%	259,050
	- contingencies	1	20	%	518,099
				TOTAL (INCL. CONTINGENCY)	3,368,000

APPENDIX F6: Cost Estimate for Option 6 (Levee System at Weston)

WorleyParsons
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Rev	Description	Orig	Review	Worley-Parsons Approval	Date
0	Issued for Information	WJH	CRT		18/02/2013
		W Honour	Reviewer	Approver	

Disclaimer
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Note: Wherever possible, cost estimates are based on Rawlinsons Australian Construction Handbook Edition 30, 2012

Item	Description	Quantity	Rate	Unit	Cost
1	<u>Preliminaries</u>				
	- equipment mobilisation and site establishment	1	5	%	104,294
	- site clearing	13,821	1.00	sqm	13,821
	- tree removal	20	150	No.	3,000
	- tree disposal	20	120	t	2,400
2	<u>Key Foundation</u>				
	- excavation of foundation channel	1,285	54.90	cum	70,547
	- shaping of batter slopes	2,570	2.75	sqm	7,068
	- compact foundation	2,570	3.15	sqm	8,096
	- crushed rock filling laid and consolidated in 150mm layers	1,285	91.00	cum	116,935
	- geotextile layer	2,570	7.55	sqm	19,404
3	Levee Core Construction				
	- crushed rock filling laid and consolidated in 150mm layers	6,730	91.00	cum	612,430
	- shaping of batter slopes	5,736	2.75	sqm	15,774
4	Levee Bulk Construction				
	- excavate light soil, deposit as fill & compact to 90% (*within 20km*)	17,657	20.55	cum	362,851
	- vapour barrier sand fill (100mm thick)	1,418	35.00	cum	49,640
	- shaping of batter slopes	14,183	2.75	sqm	39,003
5	<u>Surface Treatment and Landscaping</u>				
	- jute mat	14,183	2.00	sqm	28,366
	- grass seed, including maintenance	1.4	8,150	ha	11,264
6	<u>Bridge and Road Works</u>				
	- install replacement 2 lane 11m wide single span bridge at Fourth Street	385	1,615	item	621,775
	- install replacement 2 lane road along Swanson Street between Kline and Fourth Streets	230	450	m	103,500
7	<u>Site Disestablishment</u>				
	- including clean up	1	5	%	104,294
				SUB-TOTAL (SYDNEY)	2,294,460
				CESSNOCK AREA FACTOR (+4%)	2,386,238
	<u>Additional</u>				
	- design, survey, geotechnical, environmental and construction management	1	10	%	238,624
	- additional consultation with residents backing onto creek	1	5	%	119,312
	- contingencies	1	20	%	477,248
				TOTAL (INCL. CONTINGENCY)	3,221,000

APPENDIX F7: Cost Estimate for Option 7A (Hebburn Reservoir Weir Upgrade)

WorleyParsons
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Rev	Description	Orig	Review	Worley-Parsons Approval	Date
0	Issued for Information	WJH	CRT		18/02/2013
		W Honour	Reviewer	Approver	

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Note: Wherever possible, cost estimates are based on Rawlinsons Australian Construction Handbook Edition 30, 2012

Item	Description	Quantity	Rate	Unit	Cost
1	Preliminaries				
	- equipment mobilisation and site establishment	1	5	%	5,128
2	Gabion Wall Construction				
	- cut concrete foundation trench on upstream side of spillway at gabion footing	60	18	m	1,086
	- excavate concrete foundation trench	29	115	m	3,312
	- concrete binding layer for footing	29	291	cum	8,381
	- supply of gabion mesh baskets	144	50	cum	7,200
	- gabion rock with median diameter = 150mm (30% voids)	232	100	t	23,184
	- extra for labour to install gabions	320	120	hrs	38,400
	- extra for machinery (excavator)	14	1,500	day	21,000
3	Site Disestablishment				
	- including clean up	1	5	%	5,128
				SUB-TOTAL (SYDNEY)	112,819
				CESSNOCK AREA FACTOR (+4%)	117,332
	Additional				
	- design, survey, geotechnical and construction management	1	10	%	11,733
	- environmental management	1	5	%	5,867
	- contingencies	1	20	%	23,466
				TOTAL (INCL. CONTINGENCY)	158,000

APPENDIX F8: Cost Estimate for Option 7B (Hebburn Reservoir Upgrade)

WorleyParsons
resources & energy

Rev	Description	Orig	Review	Worley-Parsons Approval	Date
0	Issued for Information	WJH	CRT		28/03/2013
		W Honour	Reviewer	Approver	

Disclaimer
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Note: Wherever possible, cost estimates are based on Rawlinsons Australian Construction Handbook Edition 30, 2012

Item	Description	Quantity	Rate	Unit	Cost
1	Preliminaries				
	- equipment mobilisation and site establishment	1	5	%	136,231
	- site clearing	15,420	1.00	sqm	15,420
	- tree removal	150	150	No.	22,500
	- tree disposal	150	120	t	18,000
	- dewatering	1	50,000	item	50,000
	- low flow piping	100	160	m	16,000
2	Key Foundation				
	- excavation of foundation channel	3,855	54.90	cum	211,640
	- shaping of batter slopes	3,855	2.75	sqm	10,601
	- compact foundation	3,855	3.15	sqm	12,143
	- crushed rock filling laid and consolidated in 150mm layers	3,855	91.00	cum	350,805
	- geotextile layer	15,420	7.55	sqm	116,421
3	Dam Core Construction				
	- crushed rock filling laid and consolidated in 150mm layers	8,336	91.00	cum	758,561
	- shaping of batter slopes	6,271	2.75	sqm	17,245
4	Dam Bulk Construction				
	- excavate light soil, deposit as fill & compact to 90% (*within 20km*)	18,151	20.55	cum	372,996
	- vapour barrier sand fill (100mm thick)	1,589	35.00	cum	55,610
	- shaping of batter slopes	15,889	2.75	sqm	43,694
5	Surface Treatment and Landscaping				
	- jute mat	15,889	2.00	sqm	31,777
	- grass seed, including maintenance	1.6	8,150	ha	12,949
6	High Flow Spillway				
	- excavation of foundation	1,680	23.70	cum	39,816
	- geotextile layer	1,680	7.55	sqm	12,684
	- supply of rip-rap rock (1m layer)	2,705	80.00	t	216,384
	- supply of underlayer rock (300 mm layer)	811	50.00	t	40,572
	- extra for labour to install spillway rock (assume 6 weeks)	1,440	120	hrs	172,800
	- extra for machinery (excavator x 2)	84	1,500	day	126,000
7	Site Disestablishment				
	- including clean up	1	5	%	136,231
			SUB-TOTAL (SYDNEY)		2,997,080
			CESSNOCK AREA FACTOR (+4%)		3,116,963
	Additional				
	- design, survey, geotechnical and construction management	1	10	%	311,696
	- environmental management, including contamination	1	10	%	311,696
	- contingencies	1	20	%	623,393
			TOTAL (INCL. CONTINGENCY)		4,364,000

APPENDIX F9: Cost Estimate for Option 7C (Hebburn Reservoir Upgrade)

WorleyParsons
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Rev	Description	Orig	Review	WorleyParsons Approval	Date
0	Issued for Information	WJH W Honour	CRT Reviewer	Approver	28/03/2013

Disclaimer
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Note: Wherever possible, cost estimates are based on Rawlinsons Australian Construction Handbook Edition 30, 2012

Item	Description	Quantity	Rate	Unit	Cost
1	Preliminaries				
	- equipment mobilisation and site establishment	1	5	%	186,656
	- site clearing	13,410	1.00	sqm	13,410
	- tree removal	130	150	No.	19,500
	- tree disposal	130	120	t	15,600
	- dewatering	1	50,000	item	50,000
	- low flow piping	100	160	m	16,000
2	Key Foundation				
	- excavation of foundation channel	3,353	54.90	cum	184,052
	- shaping of batter slopes	3,353	2.75	sqm	9,219
	- compact foundation	3,353	3.15	sqm	10,560
	- crushed rock filling laid and consolidated in 150mm layers	3,353	91.00	cum	305,078
	- geotextile layer	13,410	7.55	sqm	101,246
3	Dam Core Construction				
	- crushed rock filling laid and consolidated in 150mm layers	5,788	91.00	cum	526,700
	- shaping of batter slopes	5,160	2.75	sqm	14,190
4	Dam Bulk Construction				
	- excavate light soil, deposit as fill & compact to 90% (*within 20km*)	20,485	20.55	cum	420,963
	- vapour barrier sand fill (100mm thick)	1,370	35.00	cum	47,958
	- shaping of batter slopes	13,702	2.75	sqm	37,681
5	Surface Treatment and Landscaping				
	- jute mat	13,702	2.00	sqm	27,404
	- grass seed, including maintenance	1.4	8,150	ha	11,167
6	High Flow Spillway				
	- excavation of foundation	8,000	23.70	cum	189,600
	- geotextile layer	8,000	7.55	sqm	60,400
	- supply of rip-rap rock (1m layer)	12,880	80.00	t	1,030,400
	- supply of underlayer rock (300 mm layer)	3,864	50.00	t	193,200
	- extra for labour to install spillway rock (assume 6 weeks)	1,440	120	hrs	172,800
	- extra for machinery (excavator x 2)	84	1,500	day	126,000
7	Outlet Works				
	- culvert outlet (approx. 2.7m diameter)	50	3,000	m	150,000
8	Site Disestablishment				
	- including clean up	1	5	%	186,656
				SUB-TOTAL (SYDNEY)	4,106,443
				CESSNOCK AREA FACTOR (+4%)	4,270,701
	Additional				
	- design, survey, geotechnical and construction management	1	10	%	427,070
	- environmental management, including contamination	1	10	%	427,070
	- contingencies	1	20	%	854,140
				TOTAL (INCL. CONTINGENCY)	5,979,000

APPENDIX F10: Cost Estimate for Option 8 (Flood Mitigation Dam)

WorleyParsons
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Rev	Description	Orig	Review	Worley-Parsons Approval	Date
0	Issued for Information	WJH W Honour	CRT Reviewer	Approver	18/02/2013

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Note: Wherever possible, cost estimates are based on Rawlinsons Australian Construction Handbook Edition 30, 2012

Item	Description	Quantity	Rate	Unit	Cost
1	Preliminaries				
	- equipment mobilisation and site establishment	1	5	%	489,776
	- site clearing	40,288	1.00	sqm	40,288
	- tree removal	400	150	No.	60,000
	- tree disposal	400	120	t	48,000
	- coffer dam	1	30,000	item	30,000
	- low flow piping	200	160	m	32,000
2	Key Foundation				
	- excavation of foundation channel	6,847	54.90	cum	375,893
	- shaping of batter slopes	6,847	2.75	sqm	18,829
	- compact foundation	6,847	3.15	sqm	21,568
	- crushed rock filling laid and consolidated in 150mm layers	6,847	91.00	cum	623,066
	- geotextile layer	27,388	7.55	sqm	206,776
3	Dam Core Construction				
	- crushed rock filling laid and consolidated in 150mm layers	29,446	91.00	cum	2,679,609
	- shaping of batter slopes	10,907	2.75	sqm	29,994
4	Dam Bulk Construction				
	- excavate light soil, deposit as fill & compact to 90% (*within 20km*)	58,753	20.55	cum	1,207,377
	- vapour barrier sand fill (100mm thick)	2,301	35.00	cum	80,538
	- shaping of batter slopes	23,011	2.75	sqm	63,280
5	Surface Treatment and Landscaping				
	- jute mat	23,011	2.00	sqm	46,022
	- grass seed, including maintenance	2.3	8,150	ha	18,754
6	High Flow Spillway				
	- excavation of foundation	12,900	23.70	cum	305,730
	- geotextile layer	18,000	7.55	sqm	135,900
	- supply of rip-rap rock (1m layer)	28,980	80.00	t	2,318,400
	- supply of underlayer rock (300 mm layer)	8,694	50.00	t	434,700
	- extra for labour to install spillway rock (assume 6 weeks)	1,440	120	hrs	172,800
	- extra for machinery (excavator x 2)	84	1,500	day	126,000
7	Outlet Works				
	- culvert outlets (approx. 2 x 2.7m diameter pipes)	240	3,000	m	720,000
8	Site Disestablishment				
	- including clean up	1	5	%	489,776
			SUB-TOTAL (SYDNEY)		10,775,073
			CESSNOCK AREA FACTOR (+4%)		11,206,075
	Additional				
	- design, survey, geotechnical and construction management	1	10	%	1,120,608
	- environmental management	1	5	%	560,304
	- additional site access costs	1	5	%	560,304
	- contingencies	1	20	%	2,241,215
			TOTAL (INCL. CONTINGENCY)		15,689,000

APPENDIX F11: Cost Estimate for Option 9 (Voluntary House Raising)

WorleyParsons
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Rev	Description	Orig	Review	WorleyParsons Approval	Date
0	Issued for Information	WJH	CRT		18/02/2013
		W Honour	Reviewer	Approver	

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Note: Wherever possible, cost estimates are based on Rawlinsons Australian Construction Handbook Edition 30, 2012

Item	Description	Quantity	Rate	Unit	Cost
1	House Raising Works				
	- raise houses by 1.2m (average height)	20	50,000	item	1,000,000
	- costs for residents alternative accommodation (rent for 6 weeks)	120	700	week	84,000
	- costs for residents removals	40	1,500	item	60,000
			SUB-TOTAL (SYDNEY)		1,144,000
			CESSNOCK AREA FACTOR (+4%)		1,189,760
	Additional				
	- additional consultation with residents	1	10	%	118,976
	- contingencies	1	20	%	237,952
			TOTAL (INCL. CONTINGENCY)		1,547,000

APPENDIX F12: Cost Estimate for Option 10 (Voluntary House Purchase)

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Rev	Description	Orig	Review	WorleyParsons Approval	Date
0	Issued for Information	WJH W Honour	CRT Reviewer	Approver	18/02/2013

Disclaimer
This cost estimate is based on WorleyParsons' experience and judgement as a firm of practising professional engineers familiar with the construction industry. This cost estimate can NOT be guaranteed as we have no control over Contractor's prices, market forces and competitive bids from tenderers. This cost estimate excludes authority approval fees.

Note: Wherever possible, cost estimates are based on Rawlinsons Australian Construction Handbook Edition 30, 2012

Item	Description	Quantity	Rate	Unit	Cost
1	House Purchase				
	- cost of purchases (based on average sale price)	26	370,000	item	9,620,000
	- legal fees	26	3,000	item	78,000
	- stamp duty	1	4.0	%	384,800
2	Demolition				
	- demolition of houses, including waste disposal charges	26	25,000	item	650,000
3	Surface Treatment and Landscaping				
	- jute mat	10,400	2.00	sqm	20,800
	- grass seed, including loam layer	10,400	8.10	sqm	84,240
				SUB-TOTAL (SYDNEY)	10,837,840
				CESSNOCK AREA FACTOR (+4%)	11,271,354
	Additional				
	- additional consultation/negotiation with residents	1	5	%	563,568
	- contingencies	1	20	%	2,254,271
				TOTAL (INCL. CONTINGENCY)	14,089,000

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APPENDIX F13: Cost Estimate for Option S1 (Targeted Vegetation Clearing)

Rev	Description	Orig	Review	Worley-Parsons Approval	Date
0	Issued for Information	WJH W Honour	CRT Reviewer	Approver	22/07/2013

Disclaimer
This cost estimate is based on WorleyParsons' experience and judgement as a firm of practising professional engineers familiar with the construction industry. This cost estimate can NOT be guaranteed as we have no control over Contractor's prices, market forces and competitive bids from tenderers. This cost estimate excludes authority approval fees.

Note: Wherever possible, cost estimates are based on Rawlinsons Australian Construction Handbook Edition 30, 2012

Item	Description	Quantity	Rate	Unit	Cost
1	Preliminaries				
	- equipment mobilisation and site establishment	1	5	%	42,575
	- site clearing	100,000	1.00	sqm	100,000
	- tree removal	500	150	No.	75,000
	- tree disposal	500	120	t	60,000
	- coffer dams (to undertake works in three sections)	3	30,000	item	90,000
	- low flow piping (1km, to be reused for each section)	1,000	190	m	190,000
2	Surface Treatment and Landscaping				
	- jute mat	100,000	2.50	sqm	250,000
	- native grass seed, including levelling and maintenance	10.0	8,650	ha	86,500
3	Site Disestablishment				
	- including clean up	1	5	%	42,575
			SUB-TOTAL (SYDNEY)		936,650
			CESSNOCK AREA FACTOR (x1.04)		974,116
	Additional				
	- design, survey, geotechnical, environmental and construction management	1	10	%	97,412
	- contingencies	1	20	%	194,823
			TOTAL (INCL. CONTINGENCY)		1,266,000
	Vegetation Offsetting (If Required)				
	- cost of land/ easement acquisition	6	60,000	ha	360,000
	- site preparation and seeding	6	10,000	ha	60,000
					420,000

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APPENDIX F14: Cost Estimate for Option S2 (Targeted Voluntary House Raising and Purchase)

Rev	Description	Orig	Review	Worley-Parsons Approval	Date
0	Issued for Information	WJH W Honour	CRT Reviewer	Approver	28/03/2013

Disclaimer

This cost estimate is based on WorleyParsons' experience and judgement as a firm of practising professional engineers familiar with the construction industry. This cost estimate can NOT be guaranteed as we have no control over Contractor's prices, market forces and competitive bids from tenderers. This cost estimate excludes authority approval fees.

Note: Wherever possible, cost estimates are based on Rawlinsons Australian Construction Handbook Edition 30, 2012

Item	Description	Quantity	Rate	Unit	Cost
1	House Raising Works				
	- raise houses by 1.2m (average height)	10	50,000	item	500,000
	- costs for residents alternative accommodation (rent for 6 weeks)	60	700	week	42,000
	- costs for residents removals	20	1,500	item	30,000
2	House Purchase				
	- cost of purchases (based on average sale price)	5	370,000	item	1,850,000
	- legal fees	5	3,000	item	15,000
	- stamp duty	1	4.0	%	74,000
3	Demolition				
	- demolition of houses, including waste disposal charges	5	25,000	item	125,000
4	Surface Treatment and Landscaping				
	- jute mat	2,000	2.00	sqm	4,000
	- grass seed, including loam layer	2,000	8.10	sqm	16,200
			SUB-TOTAL (SYDNEY)		2,656,200
			CESSNOCK AREA FACTOR (+4%)		2,762,448
	Additional				
	- additional consultation with residents	1	10	%	276,245
	- contingencies	1	20	%	552,490
			TOTAL (INCL. CONTINGENCY)		3,591,000

Appendix G – Triple Bottom Line Assessments for Flood Mitigation Options

Table G1 Triple-Bottom-Line Assessment for Option 1 (Excavate Channel Bed by 1 metre)

CRITERIA	RAW SCORE	COMMENTS
Flood Impacts		
Impact on hydraulic behaviour	4	Significant reduction in flood levels
Reduction in flood damages	4	Successful at protecting houses
Economic		
Benefit-Cost	1	Relatively low benefit-cost
Lifecycle cost of option	0	Significant – unlikely to raise sufficient funding
Social		
Impact on local community	2	Significant disruption along the creek line during construction
Likely community acceptance	2.5	Community and local media often request channel excavation, but could be largely offset by impact of construction works
Environmental		
Disruption to natural character of the area	1	Would require removal of a large amount of riparian vegetation from Swamp Creek (native and exotic). Extended construction time.
Ecological impacts	1	Existing watercourse will be excavated extensively
Total	15.5	

Table G2 Triple-Bottom-Line Assessment for Option 2 (Excavate Channel Bed by 2 metres)

CRITERIA	RAW SCORE	COMMENTS
Flood Impacts		
Impact on hydraulic behaviour	5	Most successful option in reducing flood levels (in most areas)
Reduction in flood damages	5	The most successful option in reducing damages
Economic		
Benefit-Cost	1	Relatively low benefit-cost
Lifecycle cost of option	0	Significant – unlikely to raise sufficient funding
Social		
Impact on local community	2	Significant disruption along the creek line during construction
Likely community acceptance	2.5	Community and local media often request channel excavation, but could be largely offset by impact of construction works
Environmental		
Disruption to natural character of the area	1	Would require removal of a large amount of riparian vegetation from Swamp Creek (native and exotic). Extended construction time.
Ecological impacts	1	Existing watercourse will be excavated extensively
Total	17.5	

Table G3 Triple-Bottom-Line Assessment for Option 3 (Vegetation Clearing)

CRITERIA	RAW SCORE	COMMENTS
Flood Impacts		
Impact on hydraulic behaviour	4	Significant reduction in flood levels
Reduction in flood damages	3	Successful at protecting several houses
Economic		
Benefit-Cost	3	Relatively high benefit-cost approaching 1.0
Lifecycle cost of option	2	Unlikely to raise sufficient funding
Social		
Impact on local community	2.5	Some disruption along the creek during clearing works
Likely community acceptance	4	Option requested for consideration by community members
Environmental		
Disruption to natural character of the area	2	Would require removal of a large amount of riparian vegetation from Swamp Creek (native and exotic)
Ecological impacts	2	Minimal works other than to clear vegetation
Total	22.5	

Table G4 Triple-Bottom-Line Assessment for Option 4 (Concrete lining of channel)

CRITERIA	RAW SCORE	COMMENTS
Flood Impacts		
Impact on hydraulic behaviour	4	One of the most effective options in reducing the flood levels
Reduction in flood damages	4	Successful at protecting some houses, however other options are more successful
Economic		
Benefit-Cost	0	Relatively low benefit-cost
Lifecycle cost of option	0	Significant – unlikely to raise sufficient funding
Social		
Impact on local community	1	Disruption along the creek during construction works, potentially traffic issues during import of concrete
Likely community acceptance	1	Concrete-lined channel not expected to be supported
Environmental		
Disruption to natural character of the area	1	Would require removal of a large amount of riparian vegetation from Swamp Creek (native and exotic). Concrete is not aesthetically pleasing.
Ecological impacts	0	Ongoing impact due to loss of habitat
Total	11	

Table G5 Triple-Bottom-Line Assessment for Option 5 (Bridge Upgrades in Abermain)

CRITERIA	RAW SCORE	COMMENTS
Flood Impacts		
Impact on hydraulic behaviour	3	Only minor reductions in peak water level were achieved
Reduction in flood damages	1	Only reduces damages for a limited number of properties from inundation
Economic		
Benefit-Cost	0	Relatively low benefit-cost
Lifecycle cost of option	2	Unlikely to raise sufficient funding
Social		
Impact on local community	2	Would require the temporary traffic diversion at Cessnock Road, the main road in the area.
Likely community acceptance	2	Road blockage has a broad impact on the community, while the benefits are relatively local.
Environmental		
Disruption to natural character of the area	4	Localised impact only. The site can be rehabilitated afterwards.
Ecological impacts	4	Localised impact only. The site can be rehabilitated afterwards.
Total	18	

Table G6 Triple-Bottom-Line Assessment for Option 6 (Levee System at Weston)

CRITERIA	RAW SCORE	COMMENTS
Flood Impacts		
Impact on hydraulic behaviour	1	Increases in flood level and velocity are expected upstream of and between the levees. Adverse impact on some upstream properties.
Reduction in flood damages	3	Protects a limited number of properties behind the levees.
Economic		
Benefit-Cost	3	Relatively high benefit-cost approaching 1.0
Lifecycle cost of option	2	Unlikely to raise sufficient funding
Social		
Impact on local community	2	Construction would require the interruption of local roads. Loss of green space and impact on visual amenity.
Likely community acceptance	2.5	May or may not be acceptable to local residents.
Environmental		
Disruption to natural character of the area	2	Loss of green space and impact on visual amenity.
Ecological impacts	3	Impacts limited to works site. The site can be rehabilitated following works.
Total	18.5	

Table G7 Triple-Bottom-Line Assessment for Option 7A (Hebburn Dam Weir Upgrade)

CRITERIA	RAW SCORE	COMMENTS
Flood Impacts		
Impact on hydraulic behaviour	0	Increase in flood levels downstream of the dam
Reduction in flood damages	0	No reduction in the number of properties that receive damages
Economic		
Benefit-Cost	0	Negative benefit-cost due to increase in flooding
Lifecycle cost of option	5	Significantly less cost than other options
Social		
Impact on local community	2	Minor upgrades to the Hebburn Dam weir can be achieved with relatively little disturbance to the community. However, this is offset by the minor increase in flood levels.
Likely community acceptance	1	Community unlikely to accept an option that provides no benefit and even a small negative impact
Environmental		
Disruption to natural character of the area	5	Construction works are minor and contained within the site
Ecological impacts	4	Minimal localised impacts
Total	17	

Table G7B Triple-Bottom-Line Assessment for Option 7B (Hebburn Dam Upgrade)

CRITERIA	RAW SCORE	COMMENTS
Flood Impacts		
Impact on hydraulic behaviour	2	Minor increase in flood levels and velocity downstream of the dam
Reduction in flood damages	0	Minimal reduction in the number of properties that receive damages
Economic		
Benefit-Cost	0	Very low benefit-cost
Lifecycle cost of option	2	Unlikely to raise sufficient funding
Social		
Impact on local community	2	Upgrades to the Hebburn Dam likely to require significant construction site, impacts on local traffic.
Likely community acceptance	1	Community unlikely to accept an option with significant cost that provides minimal to no benefit
Environmental		
Disruption to natural character of the area	2	Construction works are expected to have impact on local visual amenity from Chinamans Hollow
Ecological impacts	1	Potential for contamination issues to arise due to history of the dam and past mining activities
Total	10	

Table G7C Triple-Bottom-Line Assessment for Option 7C (Hebburn Dam Upgrade)

CRITERIA	RAW SCORE	COMMENTS
Flood Impacts		
Impact on hydraulic behaviour	3	Minor decreases in flood levels downstream of the dam
Reduction in flood damages	1	Minor reduction in the flood damages
Economic		
Benefit-Cost	0	Very low benefit-cost
Lifecycle cost of option	1	Unlikely to raise sufficient funding
Social		
Impact on local community	2	Upgrades to the Hebburn Dam likely to require significant construction site, impacts on local traffic.
Likely community acceptance	1	Community unlikely to accept an option with significant cost that provides minimal benefit
Environmental		
Disruption to natural character of the area	2	Construction works are expected to have impact on local visual amenity from Chinamans Hollow
Ecological impacts	1	Potential for contamination issues to arise due to history of the dam and past mining activities
Total	11	

Table G8 Triple-Bottom-Line Assessment for Option 8 (Flood Mitigation Dam)

CRITERIA	RAW SCORE	COMMENTS
Flood Impacts		
Impact on hydraulic behaviour	2	Decreases in flood levels downstream of the dam, but temporary inundation behind the dam is expected to impact on some private property, including some dwellings in the Probable Maximum Flood
Reduction in flood damages	2	Reduction in the number of properties damaged, however other options are mode effective
Economic		
Benefit-Cost Ratio	0	Low cost benefit ratio due to the high cost of option
Lifecycle cost of option	0	Significant – unlikely to raise sufficient funding
Social		
Impact on local community	2	Some impacts on private property upstream of the dam
Likely community acceptance	2	Unlikely to be supported by nearby residents
Environmental		
Disruption to natural character of the area	2	The dam would occupy a large site in a nature reserve, but otherwise would be largely out of the public domain
Ecological impacts	1	The dam construction would require a large site within an existing nature reserve of native bushland
Total	11	

Table G9 Triple-Bottom-Line Assessment for Option 9 (Voluntary House Raising)

CRITERIA	RAW SCORE	COMMENTS
Flood Impacts		
Impact on hydraulic behaviour	1	No impact of flood levels. There is potential for some houses to become more readily isolated (as islands) in high hazard areas if floor levels are raised and effective flood warning time is reduced.
Reduction in flood damages	4	Effective at reducing the number of properties that receive over floor damages; however, properties will still receive some damage below floor level.
Economic		
Benefit-Cost Ratio	5	High benefit-cost ratio for this option due to significant reduction in damages cost.
Lifecycle cost of option	3	Funding may be possible.
Social		
Impact on local community	2.5	Limited impacts on surrounding properties, but temporary disruption and inconvenience for residents living at houses to be raised.
Likely community acceptance	2	Minimal support expected from affected residents. Others not in support of expenditure that does not benefit wider community.
Environmental		
Disruption to natural character of the area	2	Minimal impact expected, but neighbouring residents might have affected visual amenity.
Ecological impacts	2.5	Neutral impact expected.
Total	22	

Table G10 Triple-Bottom-Line Assessment for Option 10 (Voluntary House Purchase)

CRITERIA	RAW SCORE	COMMENTS
Flood Impacts		
Impact on hydraulic behaviour	2.5	No impact on flood levels.
Reduction in number of dwellings impacted	5	Effective at reducing the number of properties that receive damages.
Economic		
Benefit-Cost Ratio	2	Low cost benefit ration due to the high cost of purchasing houses in the floodplain.
Lifecycle cost of option	0	Significant – Unlikely to obtain funding.
Social		
Impact on local community	2	A number of residents will need to be relocated.
Likely community acceptance	2	Minimal support expected from affected residents. Others not in support of expenditure that does not benefit wider community.
Environmental		
Disruption to natural character of the area	3	Some houses will be demolished and the site converted to a use compatible with flooding such as parklands.
Ecological impacts	3	Some houses will be demolished and the site converted to a use compatible with flooding such as parklands.
Total	19.5	

Appendix H – Benefit-Cost Analysis for Options S1 and S2

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Option S1 - Targeted Vegetation Clearing along Swamp Creek

Values in $ '000 (Real Terms)		Year 1	2	3	4	5	6	7	8	9	10	11	12	13	14	24	25	26	27	28	29	30
	Total	*2013/14*	*2014/15*	*2015/16*	*2016/17*	*2017/18*	*2018/19*	*2019/20*	*2020/21*	*2021/22*	*2022/23*	*2023/24*	*2024/25*	*2025/26*	*2026/27*	*2036/37*	*2037/38*	*2038/39*	*2039/40*	*2040/41*	*2041/42*	*2042/43*
Benefits (Damage Reduction)		-	-	**100**	**188**	**188**	**188**	**188**	**188**	**188**	**188**	**188**	**188**	**188**	**188**	**188**	**188**	**188**	**188**	**188**	**188**	**188**
Cost of works	**1,266**	200	500	566	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Maintenance		-	-		30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Total Costs		**200**	**500**	**566**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**
Net Balance		**- 200**	**- 500**	**- 466**	**158**	**158**	**158**	**158**	**158**	**158**	**158**	**158**	**158**	**158**	**158**	**158**	**158**	**158**	**158**	**158**	**158**	**158**

Present value of Benefits	1,921
Present value of Costs	1,379
Net Present Value	542
Internal rate return (%)	11.8%
Benefit Cost Ratio	**1.39**
Real Discount Rate (%)	7%

Note:

Dollar values as at December 2012 (indicative of start of 2013)

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Option S2 - Targeted Voluntary House Raising and Purchase

Values in $ '000 (Real Terms)		Year 1	2	3	4	5	6	7	8	9	10	11	12	13	14	24	25	26	27	28	29	30
	Total	*2013/14*	*2014/15*	*2015/16*	*2016/17*	*2017/18*	*2018/19*	*2019/20*	*2020/21*	*2021/22*	*2022/23*	*2023/24*	*2024/25*	*2025/26*	*2026/27*	*2036/37*	*2037/38*	*2038/39*	*2039/40*	*2040/41*	*2041/42*	*2042/43*
Benefits (Damage Reduction)		-	-	**50**	**100**	**120**	**136**	**136**	**136**	**136**	**136**	**136**	**136**	**136**	**136**	**136**	**136**	**136**	**136**	**136**	**136**	**136**
Cost of works	**3,591**	500	700	800	800	791	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Maintenance #		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Costs		**500**	**700**	**800**	**800**	**791**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Net Balance		**- 500**	**- 700**	**- 750**	**- 700**	**- 671**	**136**	**136**	**136**	**136**	**136**	**136**	**136**	**136**	**136**	**136**	**136**	**136**	**136**	**136**	**136**	**136**

Present value of Benefits	1,333
Present value of Costs	2,906
Net Present Value	- 1,573
Internal rate return (%)	0.2%
Benefit Cost Ratio	**0.46**
Real Discount Rate (%)	7%

Note:

Dollar values as at December 2012 (indicative of start of 2013)

Assumed that no maintenance is required

Appendix I – Floor Level Survey Database

Details removed from public document for privacy reasons.

Appendix J – Public Exhibition Submissions

TO THE GENERAL MANAGER

CESSNOCK CITY COUNCIL

ABERMAIN, WESTON, KURRI, FLOOD SUBMISSION

26 09 2013

Since the earliest days of the 20th century the local mines have been using Swamp Creek as a drain for acid mine waste, a seepage into the mines from sulphurous soils and coal. Aberdare South (Siberia) at Abernethy, Abermain No 2 at Kearsley, Abermain No 3 at Neath, Abermain No 1 at Abermain, Hebburn No 2 at Abermain and Hebburn No 1 at Weston have all pumped their toxic drainage waste into Swamp Creek. Seepage from, at grass, coal spoil piles have and are still leaching heavy metals and acid waste into the creek.

The oxides of Iron and Aluminium, as well as lead, Nickel and Manganese are all present in the silt bed of Swamp Creek at Weston posing danger to residents and making the area prone to regular and more dangerous flash floods.

To my knowledge there have been some 12 flood or catchment studies since the first intrusive flood in 1990. All except one Director's report in 2008 by the same consultant. There have been in my opinion false, misleading and untrue statements and incompetence in those studies combined with lack of action. The senior staff and the councillors themselves have been negligent and obstructive.

Now the indications are that council will attempt to gain funds to remove selected vegetation from the creek channel. This is obviously inadequate since to our observations there is nearly 2 metres of silt much of it mine waste silt that over the some 100 years of mining in this area has been deposited in the creek. We have sampled the creek bed at Weston down to 1.8 metres and laboratory analysis shows the high level of heavy metals synonymous with acid mine drainage. These readings are available and have been previously supplied to Council officers.

To any observation the costings promoted in the latest flood study are exorbitant and misleading. $25 million to excavate the comparatively short stretches of silted creek is without doubt excessive. The failure to use the detention basins in HEZ and Hebburn Dam and so cut the peak flow through Weston by 25% during the peak flood period is to my mind criminal negligence.

A 1 metre underflow culvert to lower the normal dam level by one metre and a one metre slotted Gabion Wall above the present spillway height would allow the dam to store around 500,000 cubic metres more of sudden rush flood waters. A two metre slotted Gabion Wall 3 metres upstream of the road culvert's detention basin at the main road crossings in HEZ would gain another three quarters of a million cubic metres of peak flood flows.

An estimated 25% of the peak flood flows through Weston would be greatly minimised during the Time of Flood Concentration there.

A flat Gabion Wall across the 330 kv power line valley beside Hebburn Road, Abermain, some 200 metres long varying from zero to 2 metres height at centre with a one metre slot and associated overflow spillway and channel control costing less than $200,000 would momentarily store enough peak flood flows to minimise the Time of Concentration peak flows at Williams St Abermain by around 20%. This would also tend to minimise the flow through Weston and Kurri.

The failure of the consultant to assess the Time of Concentration of Peak Flood height at the towns seems incompetent at best. The peak flow at Weston from HEZ and Hebburn Dam is reported as 75 minutes after an excessive shower, the same timing as the Peak Flow from Deep Creek, an equal flow and together with associated flows from smaller creeks and the exceedingly narrow channel and choking vegetation obstruction at Fifth and Sixth Sts plus the raised creek bed and the obstructive bridges must and does produce flooding at Weston.

I asked the consultant at a public meeting in 2010 had he walked the creek and he replied " No but my guys have." This is to my mind is incompetence in the extreme. His guys seem not to have their eyes open.

Council allowed a temporary road crossing to be built at Abermain South on [redacted] property and another on the Hebburn No 2 creek both dangerously inadequate and the collapse of the [redacted] illegal dam/causeway is claimed to have exacerbated the flooding at Abermain and consequently at Weston in the 2007 flood event. This additive event has not appeared in the various Flood Studies but maps of the area are included in the 2011 Flood Study. This must be seen as fraudulent and misleading.

Cessnock Councillor

The amazingly constricted structures at the bridge crossings at Abermain's Cessnock Road are a condemnation of Council and consultant competence. The observation that they were causing " Backing Up " of flood waters was noted in the flood of 1990 and reported in the minutes of the Public Meeting of December 1996 but was not included in the flood studies until [redacted] raised the matter around 2009. The obstructing structures, pipes, support battens and pillars, have to be seen to be believed. It is I claim a perfect indication that no one has walked under there. In fact a local claims there is a 300mm cast iron pipe on pillars at mid height under there that serves no purpose. It is a major flood obstruction. Why has it not been removed? The amount of obstructing debris during flooding in the creek at that area is great. This crossing area shows Council and consultant negligence.

Senior officers the Mayor and General Manager have been conducted around the worst flood enhancing areas but have not even acknowledged the problems later, contrary to their promises.

OEH Officer

I find the senior staff untruthful and obstructive. They have misled the Minister who claimed that the No 1 Flood Study was done in 2005? The General Manager claims the No 1 Flood Study was done in 2000. The indications are that the Minister was trying to put her own misleading twist on the sad saga. The [redacted] said," If as you say the creek is silted with mine waste heavy metals what do we do with it if we remove it?" Giving an indication I claim that the main reason for leaving people and homes in danger is to protect the polluting mining industry. Experience overseas shows treating the same silt with phosphates negates the toxicity and the spoil could be contoured into levees and bank smoothing. Cheaply.

It has been alleged that some councillors are paid by the Mines Dept up to $4,000 per month to attend a three hour meeting. Perhaps this is a conflict of interest? Why have no councillors, senior staff nor executives apologised to the people whose lives and property are at risk from the regular

East Coast Low flood rains in February and June. Early warning forecasts indicate this February could be very wet and flood risks are high.

There is no mention of clearing through Kurri and Loxford and this is most necessary. The useless exercise of including upper works around Hebburn Dam to protect against a Probable Maximum Flood seems to be a purile attempt to obstruct the use of Hebburn Dam as a detention basin. Probably because that use was raised in the 1996 Public Meeting and has been raised by consultant decriers since. If so this is petty emotionalism and false costings designed to mislead.

All in all this Flood Study and costings, at least $60,000 for this latest unit according to the grant, are monies that could have been spent on remediation. People who were given Council approval to build beside the unsilted creek in the past should not have to live in fear of property damage and even danger to life because of Council and consultant incompetence and lack of care.

RECOMMENDATIONS:

Clean the silt and mining spoil from out of the creek bed as recommended in the No 1 Flood Study of 1992, by the community meeting in 1996 and by subsequent Flood Studies until 2011.

Create suitable detention basins on the Hebburn No 1 and Hebburn No 2 creeks as recommended in the 1992 Flood Study and at the Community Meeting of 1996 and subsequent Flood Studies until 2011.

Modify the jungle of obstructions at the Cessnock Road crossings at Abermain.

Clean out the narrow obstructing and vegetation choked gorge at 5th St Weston.

Increase the flood flow passageway at Loxford to minimise flooding in Kurri Kurri.

Put these works to tender rather than a flawed consultant's submission that these necessary works are " Unlikely to obtain funding."

Stop the ludicrous "there have only been two flood studies," mantra. It is both illogical and false. The Council staff and the consultant have been criminally negligent and have attempted to explain their gross dereliction of duty by rewriting fact. The seemingly incompetent Catchment Management Committee have not acted to protect the flood prone residents. The Issue No I Flood Study was in 1992. A series of flood studies begun in 1992 without remediation in 21 years is an insult to ratepayers.

Cessnock Council has an abysmal record on stealing, corruption, bickering, wasted court costs, incompetence and payouts to staff they want to sack, it is reported. It is time to repair this pollution damaged creek and minimise flood danger to resident's homes and lives.

Signed by [redacted]

1. Analysis of Acid Mine Drainage run off from Neath Colliery into Swamp Creek.
2. Laboratory analysis of silt in the creek bed at Neath, Abermain, Peace park Weston and from silt in creek bed at Fourth St Weston.
3. Records of Flood Studies of 1992, 1997, Catchment Sudies of 1999 and 2000, Flood studies of 2005, 2006. The Flood Report by Dir Lew Oldfield to Council in 2008.
4. The False Flood Study of 2009 or 2010, The Flood Study of 2010 and Resident Questionairre.
5. The Issue 5 Flood Study of Apr 2011 followed by negation in Flood "Study" May 2011.
6. The incorrect and misleading and exaggerated Flood Study and costings of 2013.

E-mail Message

From:	[redacted]@yahoo.com.au]
To:	council [SMTP:council@cessnock.nsw.gov.au]
Cc:	
Sent:	27/9/2013 at 1:11 PM
Received:	27/9/2013 at 1:11 PM
Subject:	Draft 'Swamp/Fishery Creek Floodplain Risk Management Study and Plan"

Attention Peter Jennings

Hi Peter,

I met you at the Kurri Kurri community centre

Just some comments

In the draft it does,nt say about the silt build up and where it actual comes from so if the creek is actual dredged what actions will be taken to stop silt build up in the future?
Is the creek actual contaminated?When you look at sites like BHP in Newcastle and Pasminco at Boolaroo both companies had to pay for remedial work for the sites!So is there a possibility to claim from someone these monies?(assuming site is contaminated)

There is nothing in the draft in regards to the possibility of a company or companies buying the dirt?If a company/ies bought the dirt then this could possible offset some of the costings of works?

Is there a site earmarked for the dumping of the dirt and the affects of all that soil in the area that it is dumped?EIS?

Climate change has been ignored in the document? yet you have councils like Lake Macquire planning for it?

Cheers

[redacted]