YANCOAL
兖煤澳大利亚有限公司

AshtonCoal
PART OF THE YANCOAL AUSTRALIA GROUP

COMPANY: ASHTON COAL OPERATIONS PTY LIMITED
SITE: Glennies Creek Road
Camberwell NSW 2330
POSTAL: PO Box 699 Singleton NSW 2330
PHONE: +61 2 6576 1111
FAX: +61 2 6576 1122
EMAIL: info@yancoal.com.au
WEBSITE: www.ashtoncoal.com.au
ABN 22 078 556 500

5 September 2012

Dr N Shepherd AM
NSW Planning Assessment Commission
GPO Box 3415
SYDNEY NSW 2001

Email pac@pac.nsw.gov.au **Email megan.webb@planning.nsw.gov.au**

Dear Dr Shepherd

Ashton Coal Project – proposed South East Open Cut Project

I refer to the letter from the NSW Office of Environment and Heritage (OEH) to the Planning Assessment Commission (Commission) dated 17 August 2012 concerning the potential flood impacts of the South East Open Cut (SEOC) Project, and the letter from the Commission to Ashton Coal Operations Pty Limited (ACOL) dated 28 August 2012.

The issues raised by OEH in its letter dated 17 August 2012 are addressed briefly below, in the attached expert reports and in previous submissions made by ACOL to the Commission dated 27 June 2012 and 31 July 2012.

In summary:

Flooding was a key issue identified for assessment by the Director-General (Planning and Infrastructure) in his Environmental Assessment Requirements (DRG's) for the Project.

The Environmental Assessment (EA) for the Project included a detailed technical assessment of flooding, which was prepared by Worley Parsons in consideration of the NSW Floodplain Development Manual and NSW Floodplain Risk Management Guidelines.

The Department of Planning and Infrastructure (DP&I), the NSW Office of Water (NOW) and OEH determined that the EA, including the detailed flood assessment, adequately addressed the DGRs.

Neither flooding impacts, nor the flood assessment were raised as issues of concern by OEH, NOW or DP&I in their assessment of the Project, prior to the Commission determining the Project in December 2011.

Notwithstanding, ACOL with the assistance of its technical experts has validated the hydrologic model used in the original flood assessment, including sensitivity analysis.

The technical experts have confirmed that two-dimensional flood modelling would not change the outcomes of the previously presented flood assessment and is therefore not warranted.

A comprehensive Hunter River flood study or detailed modelling to determine the PMF level would not result in any material changes to the proposed flood management measures or enhance the flood risk management planning for the Project.

The location and alignment of the proposed flood levee is directly related to the location of the proposed mine, which has been agreed to by both DP&I and NOW.

The design level of the levee includes a 1.3m freeboard above the largest known flood on record, which is significantly more conservative than the current recommended flood design level proposed by Singleton Council (across the local government area) and more than adequately meets the guideline requirements of the Floodplain Development Manual.

ACOL will increase its proposed inspection regime for the levee to annually and post any significant flood event, during operations.

The levee will be integrated into the post-mine final landscape and ACOL will need to demonstrate that its rehabilitation of the mine meets requisite completion criteria prior to the NSW government agreeing to the relinquishment of the mining lease for the Project.

Background:

In March 2009, ACOL lodged an application for project approval under Part 3A of the *Environmental Planning & Assessment Act* 1979 (EP&A Act). In May 2009, the Director-General (DP&I) issued his DGR's for the Project.

In November 2009, the Director-General (DP&I) consulted with OEH (at the time the Department of Environment Climate Change and Water) and determined that the EA prepared by ACOL adequately satisfied the DGR's and should be placed on public exhibition. The EA which was placed on public exhibition included a detailed flood assessment.

The EA was publicly exhibited from 27 November 2009 to 18 January 2010 and interested stakeholders, including OEH, were invited to make submissions to DP&I on the EA for the Project.

The OEH commented on several aspects of the Project. However, neither the risk of flooding nor the adequacy of the flood assessment was raised at all by the OEH, NOW or the DP&I in their assessment of the Project.

Contamination of the Hunter River from flooding of the proposed mine pit was raised in three public and two special interest group submissions on the EA for the Project.

In his assessment of the Project, the Director-General (DP&I) noted that the proposed levee provides a 1.3m freeboard above the 100 year Hunter River flood level and that while the levee would cause a small increase in local flood levels it would not result in any significant change to flood behaviour and would not cause an impact to any residences.

In recommending approval of the Project, the DP&I recommended the imposition of a condition of approval requiring ACOL to manage local flooding effects as part of a comprehensive Water Management Plan for the Project.

It is understood by ACOL that the Commission did not request further information on flooding from any government authority prior to determining the Project in December 2011 and that flooding was not considered as a specific issue of concern in the Commission's Determination Report dated 19 December 2011.

Since April 2012, when the Project was remitted to the Commission for re-determination, the Commission has requested a response to new flood related matters on three separate occasions, the first in response to a public submission at the second public meeting on 31 May 2012; the second in response to Commission solicited advice from NOW dated 9 July 2012; and the third in response to Commission solicited advice from the OEH dated 17 August 2012.

Flooding was raised by one member of the public at the second public meeting for the Project on 31 May 2012. The focus of this submission was primarily on the overall risk to the Hunter Valley from a major Hunter River flood event and the need for development proposals to take this into account. The submission further observed that the 1955 Hunter River flood caused localised bank collapse and channel deviation in the lower reaches of Glennies Creek and (anecdotally) the location of the SEOC Project could increase the risk of these impacts occurring during a future flood event.

As a result of this public submission, the Commission sought a response from NOW, however NOW acknowledges in its letter dated 9 July 2012 that flood management is not within its administrative jurisdiction and defers to the OEH as the relevant administrative agency.

The submission by the OEH on 17 August 2012 is made without reference to the additional detailed information provided by ACOL on the Project since the EA was exhibited in late 2009, including ACOL's previous detailed responses to the Commission on flooding issues dated 31 July 2012.

Summary of previous ACOL responses on flooding:

ACOL provided a response to the public submission on flooding in its 27 June 2012 submission to the Commission. This response from ACOL included:

- A summary of the findings of the flood assessment prepared by Worley Parsons in the EA for the Project.
- Provision of detailed design drawings and description for the levee to withstand flood events.
- A peer review of the flood assessment and geomorphic impact assessment (of flooding) studies presented in the EA for the Project prepared by Dr Chris Gippel.

The peer review by Dr Chris Gippel (an expert fluvial geomorphologist) concluded that:

- Standard practice was adopted by Worley Parsons in its flood modelling in the EA.
- There was low potential for Glennies Creek to undergo significant geomorphic channel avulsion or scouring as a result of flood events (with the SEOC Project in place).

Subsequent to this, the Commission provided ACOL with a further submission that it had received from NOW on flooding. The specific issues raised by NOW included:

- The risk of the levee slumping or overtopping with subsequent failure due to it being constructed on unconsolidated alluvium.
- The risk of the pit being inundated by a flood event greater than a 100 year event, including up to a PMF event, during operations and post closure.
- The risk of increased flow velocity and scouring due to the Project causing a restriction of the floodway.
- Geomorphic stability of Glennies Creek including bank slumping due to flood events.

ACOL addressed the issues raised in NOW's correspondence in its 31 July 2012 submission to the Commission. In summary:

- Geotechnical investigations show that the material beneath the ROM pad and levee is structurally sound and capable of taking the compacted loads of the ROM pad and levee.

- Any settlement would be well within the 1.3m freeboard afforded by the embankment design over the design flood level.
- The levee has been designed by engineers taking into account the geotechnical ground conditions and flood flow velocities and scour potential. The inclusion of a 5m wide clay liner and 4m wide, 1m deep, clay key trench provides for protection and stability of the levee and reduces the likelihood of seepage through the foundation and associated risk of piping.
- The design height of the levee was determined in accordance with current NSW government guidelines and policies (i.e., Floodplain Development Manual, Department of Infrastructure Planning and Natural Resources, 2005; and Flood Risk Management Guide, Department of Environment, Climate Change and Water, 2010) and has been designed to prevent inundation from the largest known flood on record (i.e., the 1955 Hunter River flood).
- The design height of the levee is significantly more conservative than the current recommended flood design level proposed by Singleton Council (Singleton Floodplain Risk Management Study, Paterson Consultants Pty Limited, 2011) which recommended the adoption of a 0.5m freeboard above the 100 year ARI flood level on a LGA wide-basis, with an additional adjustment for climate change of 0.18m. This is consistent with the requirements of other NSW Councils.
- The design height of the levee is considered conservative because:
  - It provides 3.3m freeboard above the 100 ARI flood event for the Glennies Creek catchment.
  - The 1955 Hunter River flood event (the largest flood on record) is estimated to be equivalent to a 175 year ARI event at Singleton. Notwithstanding it was assumed to represent a 100 year ARI event for the purposes of the flood assessment for the project.
  - The adopted freeboard of 1.3m above the 1955 Hunter River flood level is well in excess of the 0.5m freeboard that is proposed to be applied LGA-wide by Singleton Council and applied by other NSW Councils when establishing flood planning levels in NSW.
- The final landform of the backfilled pit will be shaped to prevent inundation of the final void from a PMF event.
- A PMF event would overtop the flood protection levees at Singleton and Maitland and cause widespread devastation across the Hunter Valley requiring the evacuation of thousands of people. In comparison the impact from inundation of the SEOC pit under such a scenario would be insignificant. (Note the Maitland levee would overtop for flood events greater than a 1 in 20 year ARI event).
- An analysis of shear stresses associated with a 100 ARI Glennies Creek flood event indicate that:
  - Changes in shear stress due to the SEOC were very small, and more than half of the cross-sections considered were predicted to have reduced shear stress (due to decreased slope and very little change in depth).
  - All shear stresses were lower than 70 N/m^2, so scour of the floodplain surface would not be expected for the 100 year ARI event or smaller floods.
- Under large Hunter River floods, the Glennies Creek floodplain in the area of the SEOC pit is a backwater with very low velocities that do not present a risk of scouring the channel or floodplain and would not be expected to adversely affect the levee.
- As the development would not significantly alter flood depths, and would not influence duration of floods, or rate of fall of water levels during flood recessions, the development of the SEOC will not impact the risk of slumping of the banks of Glennies Creek.

Response to OEH - Additional flooding submission:

In its 17 August 2012 letter, the OEH rightly identified that the DGR's for the Project required ACOL to assess flooding against the NSW Government's Floodplain Development Manual. Further, that the manual requires the impact of flooding on the development, the impact of the development on flood behavior, and the impact of flooding on people and their safety, to be assessed.

As previously indicated, the detailed flood assessment for the Project was determined by DP&I to have adequately addressed the DGR's for the Project, including after consultation with the OEH, and was considered to sufficiently address the requirements of the Floodplain Development Manual.

The following response and attached additional supporting expert reports (see Attachments 1 and 2) are provided to the Commission in response to the OEH letter:

1. Impact on Glennies Creek flood behavior

   SMEC has validated the hydrologic assessment used to predict the flooding impacts of the SEOC Project using flood frequency analysis. This approach is recognised in Australian Rainfall and Runoff (1987) as an alternate method for estimating the magnitude and frequency of peak flood discharges. Australian Rainfall and Runoff is a national guideline document for the estimation of design flood characteristics in Australia.

   A comparison of the two methods (Attachment 1) indicates that the adopted peak flow (calculated from hydrologic modelling) for the 100 year ARI event is broadly consistent with the results of the flood frequency analysis. This verifies the hydrologic modelling results for the 100 year ARI event that are reported in the flood study in the EA.

   SMEC also investigated the sensitivity of the hydraulic model to peak flows and to channel and floodplain roughness (Attachment 1). This analysis indicates that even with very conservative peak flow and roughness assumptions, peak Glennies Creek flood levels adjacent to the proposed levee remain at least 1.2m below the 1955 Hunter River flood level (62.7 m AHD), which has been adopted as the design flood planning level for the project. This design level was conservatively established to provide flood protection up a 150 year Hunter River flood event. (Note the 100 year Hunter River flood level is estimated to be 1m lower than the 1955 flood level in the Project area). Notwithstanding, Hunter River flooding will govern peak flood levels within the Project area, even with the conservative roughness and peak flow assumptions applied to the Glennies Creek hydraulic model. Consequently, increasing the peak flows and hydraulic roughness would not result in any material change to the outcomes of the flood assessment in the EA, as flood levels within the Project area are governed by Hunter River flood events.

   Results from the one-dimensional HEC-RAS model indicate that flow conveyance during a Glennies Creek 100 year ARI flood event will be primarily confined to the river channel and immediate overbank areas. Consequently the flood hydraulics can be reliably represented in a one-dimensional hydraulic model, such as HEC-RAS. A more sophisticated two-dimensional model would be warranted if significant out-of-channel flow conveyance occurred within the Project area. Further, the flood assessment in the EA clearly demonstrated that peak flood levels within the project area are governed by backwater flooding from Hunter River flood events. Hence in SMEC's opinion a steady state one dimensional model is appropriate and the application of a more sophisticated two-dimensional flood model would not change the outcomes of the previously presented flood assessment.

   The hydraulic modelling for a 100 year ARI Glennies Creek flood event was presented in the flood assessment for the project (included as Appendix C to Appendix 6 of the EA). This assessment indicated that the Project would cause:

   - Localised increases in flood levels of up to 50mm. (Note this was previously incorrectly reported as 30mm).
   - Localised increases in channel velocities of up 0.1m/s (less than 5% increase).
   - Localised increases in the average velocity across the floodplain (i.e. including both channel and out of channel flow) of up to 0.3m/s (15% increase).

   These predicted flood impacts are localised and minor and would not result in any material increase in flood risk to adjoining properties or infrastructure as a result of the Project. As peak flood levels within the

Project area are governed by Hunter River flooding, any minor increase in flood levels associated with Glennies Creek flooding is immaterial.

Note the geomorphic impacts of these predicted localised and minor predicted flood impacts are discussed in a report by Fluvial Systems which was provided as Attachment 9 to ACOL's 31 July 2012 submission to the Commission. This report by Fluvial Systems is included with this submission for completeness (see Attachment 3).

2. Hunter River Flooding

SMEC has advised that the flood risk to the Project can be reliably established based on the design level of flood protection, hence a detailed flood study of Hunter River flooding in the vicinity of the Glennies Creek confluence is not warranted. This was discussed in detail in a report by SMEC which was provided as Attachment 8 to ACOL's 31 July 2012 submission to the Commission, and is reproduced for completeness with this submission as Attachment 4.

In summary, a comprehensive Hunter River flood study would not result in any material changes to the proposed flood management measures for the following reasons:

- Any flood model will be calibrated to the known 1955 flood levels and will therefore produce similar results (in terms of peak flood levels) to the known data.
- The adopted freeboard of 1.3m is well in excess of the 0.5m freeboard that is generally applied when establishing flood planning levels in NSW. Hence, the adopted 1.3m freeboard adds contingency to the assumed level of flood protection that the levee provides.
- The flood risk to the pit can be reliably estimated based on the design level of flood protection (i.e. the levee level of 64m AHD would provide protection up to the 150 year ARI event). It is assumed that any flood exceeding the 150 year ARI event would overtop the pit. Hence, the consequences of this occurring would be the same regardless of the degree of overtopping. Accordingly, detailed modelling to determine the PMF level would not enhance the flood risk management planning for the Project.
- Other Hunter River Flood Studies, such as the recently completed Singleton Flood Risk Management Study (Paterson Consultants, 2011), have demonstrated that flood warning times for a major Hunter River flood event would be in the order of 18 to 24 hours. This warning time would enable sufficient time for the safe and orderly evacuation of the pit and other flood affected areas. As documented in the Statement of Commitments for the Project, a flood evacuation plan will be prepared post approval to formalise evacuation triggers and procedures.

3. Levee Alignment, Design and Removal

The location and alignment of the levee is a function of the location of the proposed mine, which ACOL has committed to setback 200m from the high bank of Glennies Creek in consultation with NOW.

The design level of the levee (64 m AHD) was established based on a recorded flood level in the vicinity of the Glennies Creek confluence (62.7 m AHD) during the 1955 flood event plus a 1.3m freeboard. As described above (and in ACOL's submission to the Commission dated 31 July 2012), this design level was conservatively established to provide flood protection up to the 150 year ARI event. It is also significantly more conservative than the current recommended flood design level proposed by Singleton Council and more than adequately meets the guideline requirements of the Floodplain Development Manual (2005).

ACOL assessed the potential for failure of the levee in its 27 June 2012 and 31 July 2012 submissions to the Commission. This included provision of detailed design drawings and detailed consideration of potential failure mechanisms and geomorphic processes, including a report by Parsons Brinckerhoff on the characteristics and integrity of the levee design (see Attachment 10 to ACOL's 31 July 2012 submission to the Commission, which is reproduced here as Attachment 5).

Dr Gippel has extended his review and analysis of the flood and geomorphological assessments previously provided for the Project (see Attachment 6 to ACOL's 27 June 2012 submission to the Commission and Attachment 11 to ACOL's 31 July 2012 submission to the Commission, reproduced here as Attachment 6) by incorporating additional analysis of a 1939 aerial photograph of the Project area. The amended report is included as Attachment 2. Dr Gippel concludes that the mode of channel change in Glennies Creek has been meander migration, and widening and narrowing, rather than avulsion, which is to be expected in an incised channel such as Glennies Creek. Further, based on an interpretation of aerial photography dating back to 1939, there has been no overall tendency for the river to migrate towards the site of the SEOC, and compared to 1958 the channel is now straighter, narrower and much better vegetated.

Most of the channel change between 1939 and 2008 occurred within the first 28 years. Since 1967 the channel has tended to straighten and has been fairly stable, despite riparian vegetation establishing only in recent times. From the New England Highway bridge to the southern extent of the proposed SEOC levee the majority of Glennies Creek has experienced very little movement and no change in general alignment since 1958. The channel has shown no overall tendency to migrate eastwards towards the location of the proposed SEOC levee since 1939.

The creek was virtually devoid of riparian vegetation until recently. In the future, rehabilitation of the riparian vegetation will impart significant resistance to the banks from the scouring effects of future floods. So, Glennies Creek is expected to be more stable into the future, compared to the period 1939 to 1967. Into the future, active encouragement of further development of riparian vegetation will enhance the stability of the channel, such that it will be in a better position to withstand the impacts of an extreme flood like that of 1955.

In recommending approval of the Project the Director-General (DP&I) proposed the imposition of a condition of approval requiring ACOL to manage local flooding effects as part of a comprehensive Water Management Plan. This will include a detailed description of the inspection and maintenance regime for the levee during the life of the Project.

ACOL has committed to a final landform design based on the principles and objectives of the Natural Regrade process. This was described in the EA and Response to Submissions for the Project. The resultant final landform will be consistent with and sympathetic to the surrounding natural landscape. To achieve this goal, the ROM pad to the west of the levee will be removed and the levee regraded and integrated into the reshaped landform.

4. Impact of Climate Change

   As discussed above, the ROM pad will be removed as part of the site rehabilitation works and the levee will be regraded and integrated into the final landform. Where this landform intrudes onto the floodplain it will be constructed with suitable armouring and sufficiently vegetated to accommodate the full range of likely flood events under a climate change scenario.

5. Risk Assessment

   ACOL uses formal risk assessments regularly to assist plan and guide activities carried out on site that have potential to cause human or environmental harm.

   A formal risk assessment was conducted as part of the preparation for the EA of the SEOC Project. This identified flooding and its consequences as a key issue for detailed investigation and mitigation. Both the risk assessment and the outcomes of the detailed investigations were reported in the EA for the Project.

   Post approval, ACOL will be required to prepare and implement a comprehensive Water Management Plan for the Project. The condition proposed by the Director-General requires this plan to be prepared in consultation with OEH, NOW, DRE and Council, and be submitted to the Director-General for approval prior to carrying out any development on site. The preparation of this plan will be informed by a risk assessment of the water related aspects of the Project, including flooding and the monitoring and maintenance of the levee and other control structures.

Further, ACOL has committed to prepare a flood evacuation plan for the Project. This will be based on a risk assessment which will be conducted prior to preparation of the plan.

6. Revised Statement of Commitments

ACOL has previously committed to a formal levee inspection regime following each 20 year ARI flood event. This will be increased to annually and after each significant flood event (as recommended by OEH), and will be described in the Water Management Plan for the Project.

As discussed above, the levee will be regraded and integrated into the final landform, with appropriate completion criteria to be met prior to mine lease relinquishment. Consequently there will be no requirement for ongoing maintenance of the levee post-mine closure.

In summary, many of the issues raised by OEH in its 17 August 2012 letter to the Commission have been previously addressed by ACOL in its various responses to the Commission. The residual issues have been addressed by suitably qualified and experienced experts.

The outcome of this is a rigorous assessment in accordance with the NSW Floodplain Development Manual, which further supports the findings and recommendations in the Director-General's Report and Addendum Report on the Project.

Yours faithfully

Brian Wesley

Brian Wesley
General Manager
Ashton Coal Operations Pty Ltd

Attachments:

1. Response to OEH letter to the PAC dated 17 August 2012, SMEC 5 August 2012
2. Review of Glennies Creek flood and geomorphology information in relation to South East Open Cut Project: Addendum Revision (1939-2008), Fluvial Systems 28 August 2012
3. NOW letter to PAC dated 9 July 2012 on flood and geomorphic issues, Fluvial Systems 24 July 2012
4. Response to NOW letter to the PAC dated 9 July 2012, SMEC 31 July 2012
5. Report on South East Open Cut Levee Design Characteristics and Integrity, Parsons Brinckerhoff 23 July 2012
6. Review of Glennies Creek flood and Geomorphology information in relation to South East Open Cut Project, Fluvial Systems 22 June 2012

ATTACHMENT 1

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File: 12.09.05_SEOC Project - Response to OEH letter to PAC

5 September 2012

Ashton Coal Operations Pty Limited
PO Box 699
Singleton, NSW, 2230

Attention: Michael Moore, Approvals Manager

Dear Michael,

RE: South East Open Cut Project – Response to OEH letter to the PAC dated 17 August 2012

SMEC were engaged by Ashton Coal Operations Pty Limited (ACOL) to review and respond to issues related to flood risk and flood impacts at the South East Open Cut Project (the project) that were raised by OEH in a letter to the Planning and Assessment Commission (PAC) dated 17 August 2012. The OEH letter commented on a number of aspects of the flood assessment that was prepared by WorleyParsons as part of the Environmental Assessment (EA) for the project[1]. Key staff who prepared the WorleyParsons flood assessment have since moved to SMEC and are the authors of this response letter.

This response letter responds specifically to issues raised in the OEH letter that are associated with:

- The modelling approach applied to the assessment of Glennies Creek flooding within the project area; and

- The modelling approach applied to the assessment of Hunter River flooding within the project area.

Issues associated with the levee design, alignment and maintenance are addressed separately in a covering letter prepared by ACOL.

This response letter should be read in conjunction with the following documents that have been submitted to the PAC over the last 3 months:

- NOW prepared a letter commenting on a number of issues related to flood risk and flood impacts associated with the project[2].

- SMEC prepared a letter responding to NOW's letter that specifically addressed NOW's comments and provided additional information on flood risk for the project[3].

- Fluvial Systems undertook an independent review of the WorleyParsons flood assessment[4].

- Fluvial Systems have also prepared a number of letters that address issues related to fluvial geomorphology that were raised in the NOW letter[5] and the OEH letter[6].

[1] Ashton Coal South East Open Project: Surface Water Assessment (WorleyParsons, 2009)
[2] NOW letter to the PAC (9 July 2012).
[3] South Eastern Open Cut Project – Response to NOW letter to the PAC dated 9 July 2012 (SMEC, 31 July 2012).
[4] Review of Glennies Creek flood and geomorphology information in relation to the South Eastern Open Cut Project (Fluvial Systems 22 June 2012) and addendum (3 July 2012).
[5] NOW letter to PAC dated 9 July 2012 on flood and geomorphic Issues (Fluvial Systems, 24 July 2012)
[6] DOC11-6908, Letter from OE&H to NSW PAC dated 17/8/2012 regarding South East Open Cut (Fluvial Systems, 28 August 2012)

It is our understanding that OEH did not consider the above documents when preparing their letter.

1 Response to Issues Raised in OEH's letter to the PAC

This section specifically addresses the flood related issues that were raised by OEH in a letter to the PAC dated 17 August 2012. For the benefit of readability, issues raised by OEH have been paraphrased in italic font. SMEC responses are provided in normal font.

Issues Related to the Assessment of Glennies Creek Flooding

OEH Issue 1 – "*Calibration of the hydrological and hydraulic models was based on daily rainfalls and daily read stream gauges. The temporal distribution of rainfall was assumed and the peak stream flow was assumed to be simply twice the daily average. The effect of these assumptions should be discussed. Best practice would be to examine these effects through sensitivity analysis."*

SMEC Response (Issue 1)

Verification of Hydrologic Modelling

In order to verify the hydrologic modelling results, SMEC has undertaken further hydrologic assessment of the Glennies Creek Catchment using flood frequency analysis techniques. Flood frequency analysis is recognised in Australian Rainfall and Runoff (AR&R, 1987)[7] as one of the available methods for estimating the magnitude and frequency of peak flood discharges.

The following key assumptions were applied to the flood frequency analysis:

- Recorded stream flows in Glennies Creek at the Middle Falbrook stream gauge were downloaded from the NOW website[8] at hourly increments. 56 years of data was available for the period between January 1956 to August 2012.
- The peak recorded discharge for every calendar year on record was extracted from the stream flow record to form an annual flood series (as per the methodology prescribed in AR&R, 1987).
- The annual series was fitted to a Log-Pearson III (LP3) distribution.

It is noted that the Glennies Creek Dam was commissioned in 1983. As the dam's catchment (220 km^2) is approximately 40% of the total Glennies Creek Catchment (515 km^2), the post dam catchment hydrology would be significantly different (i.e. lower flood peaks from a given event) to the pre dam catchment hydrology. The effect of the dam is likely to be greater for more frequent return period events (such as the 5 year ARI) as the dam storage is more likely to retain a higher portion of the inflow during a given event. Accordingly, as approximately half of the available stream flow data was recorded prior to the dam being constructed, peak flows calculated using flood frequency methods will be moderately conservative, especially for calculating peak flows for higher return interval events.

Plate 1 presents the flood frequency plot for the Middle Falbrook stream gauge. The adopted peak flows from the flood study (calculated from hydrologic modelling) are also indicated in **Plate 1**.

[7] Australian Rainfall and Runoff – A Guide to Flood Estimation (Institution of Engineers Australia, 1987)
[8] http://realtimedata.water.nsw.gov.au/water.stm

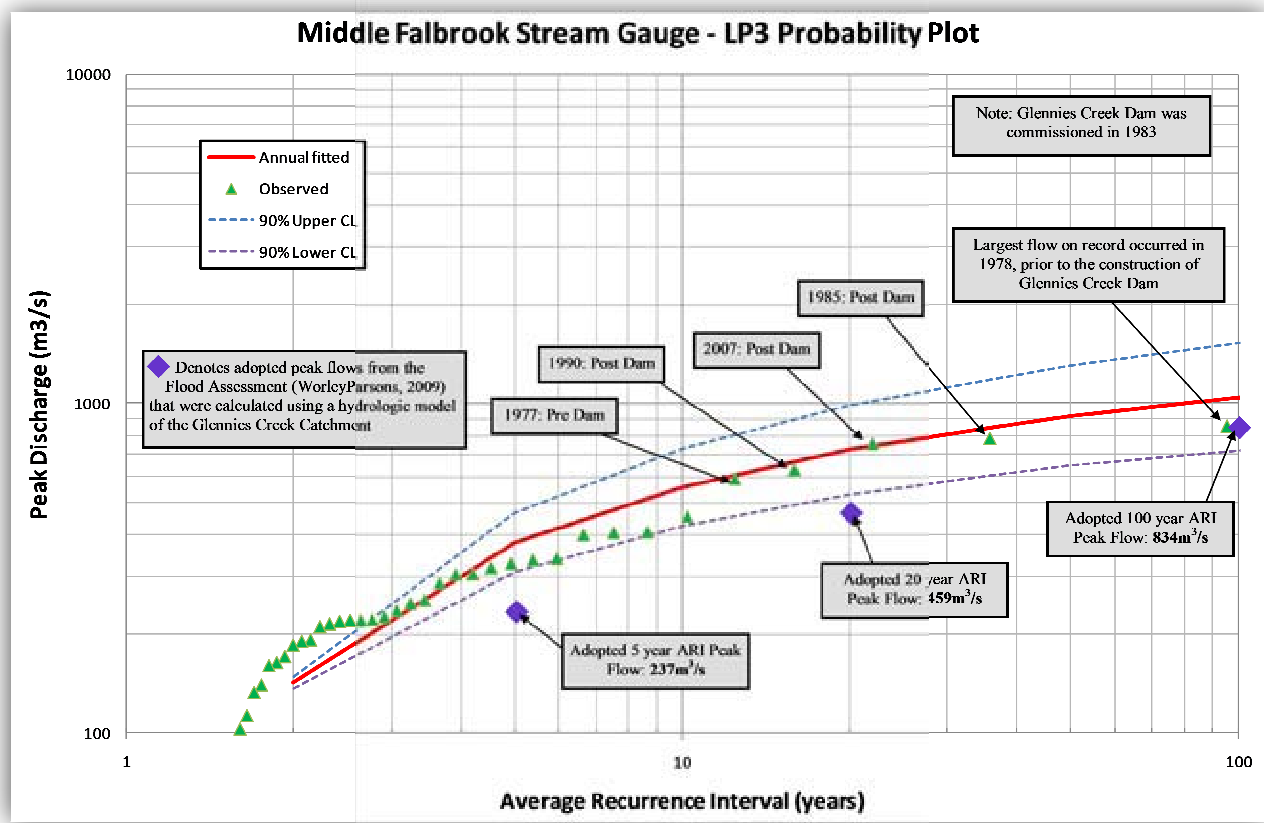


Plate 1 – *Flood Frequency Analysis for Glennies Creek at the Middle Falbrook Stream Gauge*.

With reference to **Plate 1**, peak flows calculated from flood frequency analysis were 25% higher than peak flows calculated using the hydrologic model for the 100 year ARI event and 55 to 60% higher for the 5 and 20 year ARI events. **Table 1** compares the results from the two methods.

Table 1 – *Comparison of peak flows calculated using flood frequency analysis and hydrologic modelling.*

Flood Event	Hydrologic Modelling Adopted Results (WorleyParsons , 2009)	Flood Frequency Analysis	Difference
5 year ARI	237 m^3/s	380 m^3/s	60% higher
20 year ARI	459 m^3/s	726 m^3/s	58% higher
100 year ARI	834 m^3/s	1046 m^3/s	25% higher

When comparing the results from the flood frequency analysis to the hydrologic model results it is important to note that:

- The flood frequency analysis is likely to be moderately conservative as a result of Glennies Creek Dam being constructed in 1983, approximately in the middle of the available stream flow record.
- The reliability of the peak flows calculated using flood frequency analysis techniques is dependent on the reliability of the gauge rating curve, which is used to calculate a stream flow for a given river stage or level. The maximum gauged level at the Middle Falbrook stream gauge is 3.56m (NOW Website)[8], which corresponds to a peak flow of approximately 110 m^3/s. Hence, the estimated peak flows for events such as the 100 year ARI (estimated to be 1,046 m^3/s) are based on extrapolation from the

gauged data. Accordingly, there is potential for inaccuracies in the peak flows calculated using flood frequency analysis methods.

In summary, comparison of peak flows estimated from hydrologic modelling and flood frequency analysis indicate that:

- The adopted peak flows (calculated from hydrologic modelling) for the 5 year and 20 year ARI are likely to be under conservative. This has no significant implications on the outcomes of the study as the 5 and 20 year ARI events are not used as the basis for establishing any flood mitigation controls or assessing flood impacts.
- Given that the peak flows calculated from the flood frequency analysis are likely to be moderately conservative, the adopted peak flow (calculated from hydrologic modelling) for the 100 year ARI event is broadly consistent with the results of the flood frequency analysis. This verifies the hydrologic modelling results for the 100 year ARI event that are reported in the flood study.

Hydraulic Model Sensitivity Analysis to Peak Flows

Notwithstanding the above discussion, sensitivity analysis was undertaken to determine the impact of the higher peak flows calculated using flood frequency analysis methods on the hydraulic model results that were reported in the Flood Assessment (WorleyParsons, 2009). This analysis was undertaken by running additional HEC-RAS simulations using the peak flows derived from flood frequency analysis that are reported in **Table 1**. The results from this analysis are presented in the following formats:

- **Plate 2** plots the predicted peak water surface profiles for a full range of flood events using the peak flows calculated from the hydrologic model (in purple) and flood frequency analysis (in blue).
- **Table 2** compares the key flood characteristics (flood level and velocity) for the 100 year ARI event using the two peak flow scenarios. Results are reported for all cross-sections between river chainage 1785 m (downstream extent of the project area) and 5149 m (New England Highway Bridge). Note the proposed levee extends up to river chainage 4389 m. Refer to **Attachment 1** for cross-section locations.

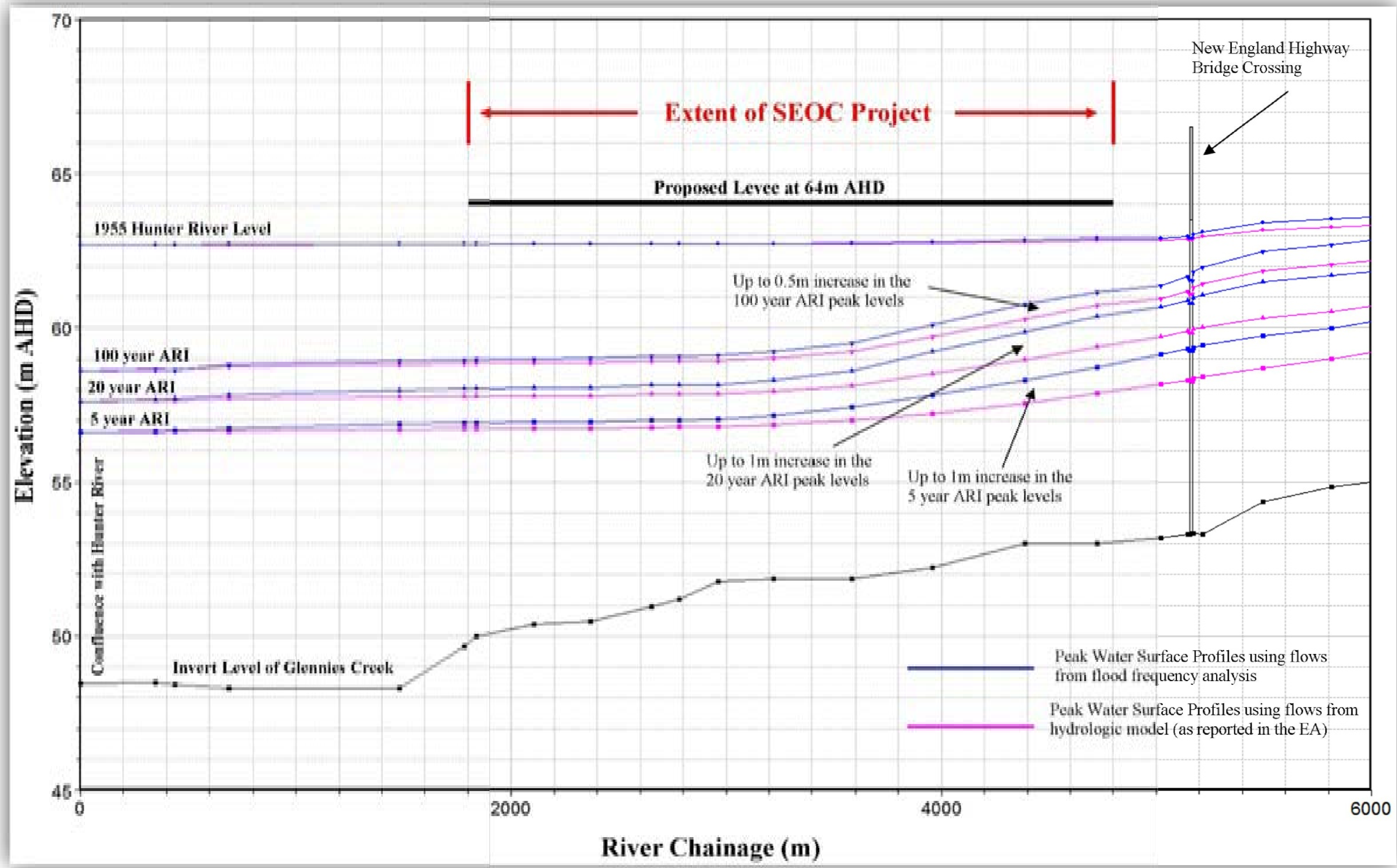


Plate 2 – *Water surface profiles for a full range of flood events using the peak flows calculated from the hydrologic model (in purple) and flood frequency analysis (in blue).*

Table 2 – *Comparison of hydraulic model results for the 100 year ARI Glennies Creek event using peaks flows calculated from the hydrologic model and flood frequency analysis.*

Cross-Section Chainage	Hydrologic Model 100 year ARI Peak Flows (WorleyParsons, 2009)			Flood Frequency Analysis 100 year ARI Peak Flows			Difference		
	Flood Level	Channel Velocity	Average Velocity	Flood Level	Channel Velocity	Average Velocity	Flood Level	Channel Velocity	Average Velocity
	(m AHD)	(m/s)	(m/s)	(m AHD)	(m/s)	(m/s)	(m)	(m/s)	(m/s)
1785	58.8	0.6	0.5	59.0	0.7	0.6	0.2	0.1	0.1
1838	58.9	0.5	0.4	59.0	0.6	0.5	0.1	0.1	0.1
2107	58.9	0.5	0.4	59.0	0.6	0.5	0.1	0.1	0.1
2371	58.9	1.0	0.8	59.0	1.2	1.0	0.1	0.2	0.2
2651	58.9	0.5	0.5	59.1	0.6	0.5	0.2	0.1	0.1
2781	58.9	0.7	0.7	59.1	0.8	0.8	0.2	0.1	0.1
2965	58.9	1.2	1.0	59.1	1.4	1.2	0.2	0.2	0.2
3222	59	1.4	1.2	59.2	1.6	1.4	0.2	0.3	0.2
3584	59.2	2.2	1.9	59.5	2.5	2.0	0.3	0.3	0.2
3958	59.7	1.9	1.8	60.1	2.1	2.0	0.4	0.3	0.2
4389	60.3	1.9	1.6	60.8	1.9	1.6	0.5	0.1	0.0
4724	60.7	1.7	1.4	61.2	1.8	1.5	0.5	0.1	0.1
5022	61	2.6	2.5	61.4	3.0	2.9	0.4	0.4	0.3
5149	61.2	2.6	2.4	61.7	3.0	2.7	0.5	0.4	0.4

The hydraulic model results presented in **Plate 2** and **Table 2** indicate that the higher peak flows (as calculated using flood frequency analysis methods) would result in the following changes to the Glennies Creek flood characteristics within the project area and immediate surrounds:

- Flood level increases of up to 1 m during 5 and 20 year ARI events.
- Flood level increases of up to 0.5 m during 100 year ARI events.
- Velocity increases of up to 0.3 m/s (or 20% increase) in the Glennies Creek channel.

It is important to note that the abovementioned increases are the result of increases to the assumed peak flows and <u>are not</u> flood impacts associated with the project.

As demonstrated in **Plate 2**, the higher Glennies Creek water surface profile is more than 2 m below the 1955 Hunter River flood level (62.7 m AHD), which has been adopted as the flood planning level for the project. Accordingly, increasing the assumed peak flows in Glennies Creek would not result in any material change to the outcomes of the flood study.

Hydraulic Model Sensitivity Analysis to Manning's Roughness Values

Further sensitivity analysis was undertaken to test the sensitivity of the hydraulic model results to assumed channel and floodplain roughness. Roughness is used to represent the friction between water and the channel and floodplain surfaces. Generally, higher roughness values imply higher flood levels but lower velocities (due to the increased flow area). The modelling undertaken for the flood study adopted Manning's 'n' roughness values of 0.050 for channel zones and 0.040 for floodplain areas. These values are consistent, if not slightly higher, than typical values for the respective surfaces. For the purposes of sensitivity analysis, these roughness values were increase by 50% to 0.075 and 0.060 respectively. In order to be conservative, the higher peak flows calculated using the flood frequency analysis methods were also adopted. The results are reported in **Table 3**.

Table 3 – *Hydraulic model results from sensitivity analysis applying 50% higher roughness values and the peak flows calculated from flood frequency analysis.*

Cross-Section Chainage	Adopted 100 year ARI results (WorleyParsons, 2009)			100 year ARI results with Higher Peak flows and Higher Roughness			Difference		
	Flood Level	Channel Velocity	Average Velocity	Flood Level	Channel Velocity	Average Velocity	Flood Level	Channel Velocity	Average Velocity
	(m AHD)	(m/s)	(m/s)	(m AHD)	(m/s)	(m/s)	(m)	(m/s)	(m/s)
1785	58.8	0.6	0.5	59.3	0.7	0.6	0.4	0.1	0.1
1838	58.9	0.5	0.4	59.3	0.5	0.4	0.4	0.1	0.0
2107	58.9	0.5	0.4	59.3	0.6	0.5	0.5	0.1	0.0
2371	58.9	1.0	0.8	59.4	1.1	0.8	0.5	0.1	0.0
2651	58.9	0.5	0.5	59.5	0.6	0.5	0.5	0.0	0.0
2781	58.9	0.7	0.7	59.5	0.7	0.8	0.5	0.1	0.1
2965	58.9	1.2	1.0	59.5	1.2	1.0	0.6	0.0	0.0
3222	59.0	1.4	1.2	59.7	1.4	1.2	0.7	0.0	0.0
3584	59.2	2.2	1.9	60.2	1.9	1.4	1.0	-0.3	-0.4
3958	59.7	1.9	1.8	60.8	1.8	1.5	1.1	-0.1	-0.3
4389	60.3	1.9	1.6	61.5	1.4	1.1	1.2	-0.5	-0.5
4724	60.7	1.7	1.4	61.9	1.5	1.1	1.2	-0.3	-0.3
5022	61.0	2.6	2.5	62.3	2.5	2.1	1.3	-0.1	-0.4
5149	61.2	2.6	2.4	62.6	2.5	2.3	1.4	0.0	-0.1

The hydraulic model results presented in **Table 3** demonstrate that even with very conservative roughness and peak flow assumptions, peak Glennies Creek flood levels adjacent to the proposed levee (between river Chainages 1785 and 4389) remain at least 1.2 m below the 1955 Hunter River flood level (62.7 m AHD), which has been adopted as the design flood planning level for the project.

It is noted that the 1955 flood was a greater than 100 year ARI event. The 100 year ARI Hunter River flood level is likely to be 1m lower than the 1955 level. Notwithstanding, Hunter River flooding will govern peak flood levels within the project area, even with the conservative roughness and peak flow assumptions applied to the Glennies Creek hydraulic model.

Conclusion

In SMEC's view the Glennies Creek flood results that are reported in the Flood Assessment (WorleyParsons, 2009) are appropriate given that:

- The higher peak flows calculated using flood frequency methods are likely to be conservative as a result of the influence of Glennies Creek Dam on the catchment hydrology and the Middle Falbrook stream gauge record; and
- Sensitivity analysis using the hydraulic model has demonstrated that increasing the peak flows and hydraulic roughness would not result in any material change to the outcomes of the Flood Assessment (WorleyParsons, 2009) as flood levels within the project area are governed by Hunter River flood events.

OEH Issue 2 – *"It would appear that all modelling of Glennies Creek was based on a steady state version of the HEC-RAS model. Best practice for this size stream would require an unsteady 2D model, especially in the case of extreme floods"*

SMEC Response (Issue 2) – Results from the one-dimensional HEC-RAS model indicate that flow conveyance during a Glennies Creek 100 year ARI flood event will be primarily confined to the river channel and immediate overbank areas. This is demonstrated in **Plate 3**, which shows that the Glennies Creek flood extent (indicated by the red line) within the project area is primarily confined to the channel and immediate overbank regions. The exception to this is where the inundation extends up the numerous creek gullies that flow into Glennies Creek within the project area (noted as back water flooding in **Plate 3**). Flooding within these gullies occurs due to backwater flooding from the creek channel. Accordingly, minimal flow conveyance would occur in these areas of the floodplain.

As the flow conveyance during a Glennies Creek 100 year ARI flood event will be primarily confined to the river channel and immediate overbank areas, the flood hydraulics can be reliably represented in a one-dimensional hydraulic model, such as HEC-RAS. A more sophisticated two-dimensional model would be warranted if significant out-of-channel flow conveyance occurred within the project area.

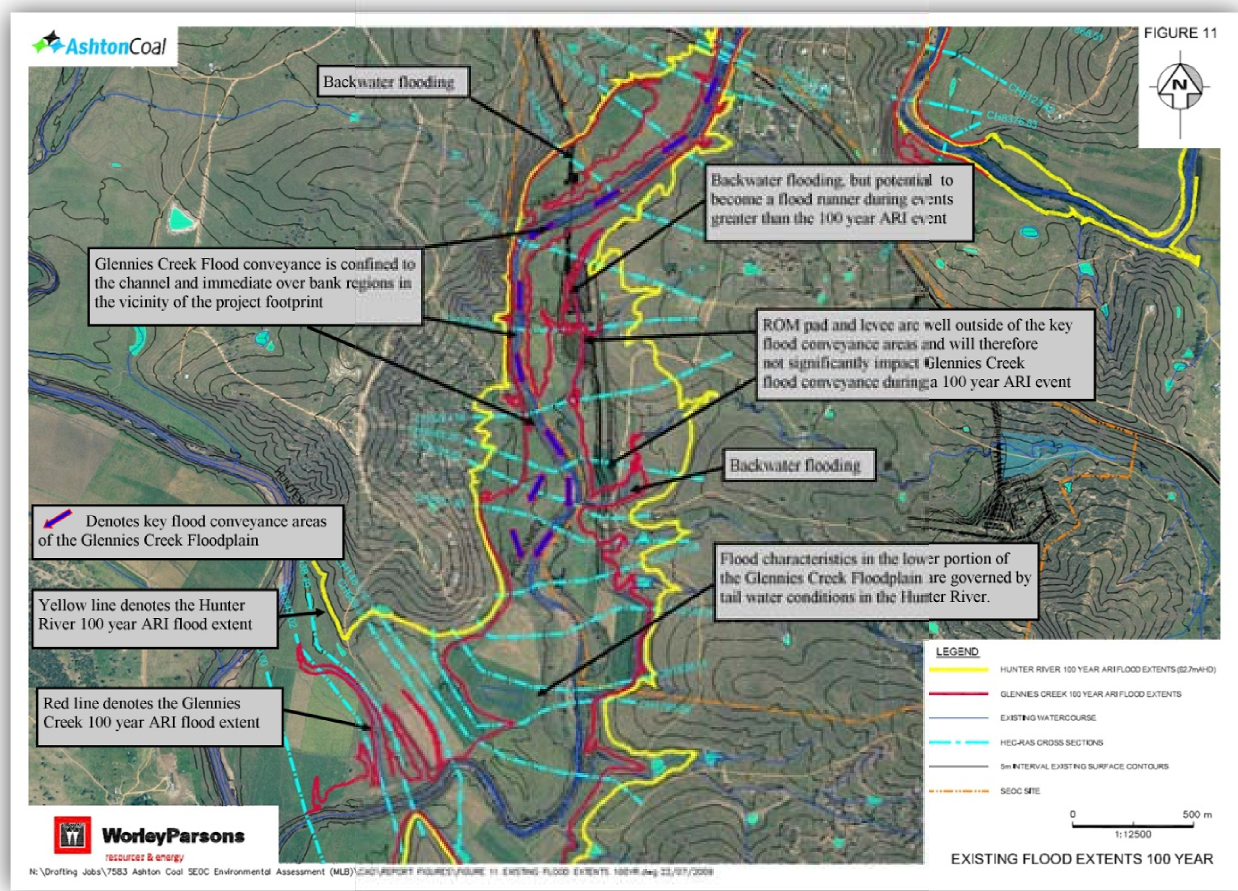


Plate 3 – *Key flood conveyance areas within the Glennies Creek Floodplain. Note: image has been sourced from Figure 11 from the Flood Assessment (WorleyParsons, 2009).*

Conclusion

In SMEC's opinion the application of a steady state one-dimensional model is appropriate for the following reasons:

- Model results indicate that flood conveyance during a Glennies Creek 100 year ARI flood event will be primarily confined to the river channel and immediate overbank areas. Accordingly, the flood hydraulics can be reliably represented in a one-dimensional hydraulic model.
- As noted in **Plate 3**, the project footprint does not encroach into flood conveyance areas of the Glennies Creek floodplain. Hence, significant flood impacts during a Glennies Creek 100 year ARI flood are unlikely to occur.
- The Flood Assessment (WorleyParsons, 2009) clearly demonstrated that peak flood levels within the project area are governed by backwater flooding from Hunter River flood events.

In SMEC's view, the application of a more sophisticated two-dimensional flood model will not change the outcomes of the Flood Assessment (WorleyParsons, 2009).

OEH Issue 3 – *"The report only documents impacts on flood levels. An assessment of the impact on flood velocities and flood hazard should be included in the report"*

SMEC Response (Issue 3) – The predicted impacts to flood levels and velocities are reported in Appendix C of the Flood Assessment (WorleyParsons, 2009). Key results for the Glennies Creek 100 year ARI event have been reproduced in **Table 4** (note: results have been reported to two decimal places to provide clarity on the flood impacts). Refer to Appendix C of the Flood Assessment (WorleyParsons, 2009) for the full set of results.

Table 4 – *Comparison of hydraulic model results for existing and proposed conditions*.

Cross-Section Chainage	Existing Conditions			Proposed Conditions			Difference		
	Flood Level	Channel Velocity	Average Velocity	Flood Level	Channel Velocity	Average Velocity	Flood Level	Channel Velocity	Average Velocity
	(m AHD)	(m/s)	(m/s)	(m AHD)	(m/s)	(m/s)	(m)	(m/s)	(m/s)
1785	58.84	0.58	0.52	58.84	0.58	0.52	0.00	0.00	0.00
1838	58.85	0.47	0.38	58.85	0.48	0.39	0.00	0.01	0.01
2107	58.87	0.50	0.41	58.87	0.52	0.43	0.00	0.02	0.02
2371	58.87	0.98	0.80	58.87	1.03	0.89	0.00	0.05	0.09
2651	58.93	0.53	0.46	58.93	0.52	0.47	0.00	-0.01	0.01
2781	58.93	0.66	0.69	58.94	0.66	0.68	0.01	0.00	-0.01
2965	58.94	1.17	0.99	58.94	1.18	1.03	0.00	0.01	0.04
3222	59.03	1.38	1.21	59.04	1.37	1.21	0.01	-0.01	0.00
3584	59.22	2.15	1.85	59.22	2.24	2.15	0.00	0.09	0.30
3958	59.72	1.86	1.78	59.77	1.85	1.79	0.05	-0.01	0.01
4389	60.29	1.86	1.61	60.32	1.83	1.59	0.03	-0.03	-0.02
4724	60.72	1.73	1.41	60.74	1.72	1.40	0.02	-0.01	-0.01
5022	60.95	2.59	2.53	60.96	2.58	2.52	0.01	-0.01	-0.01
5149	61.19	2.56	2.36	61.20	2.55	2.35	0.01	-0.01	-0.01

The hydraulic model results presented in **Table 4** indicate that the project would result in the following potential impacts during a 100 year ARI Glennies Creek flood event:

- Localised increases in flood levels of up to 50 mm. Note: this increase in flood level was previously incorrectly document as being 30mm in the Flood Assessment (WorleyParsons, 2009). It is noted that as peak flood levels within the project area are governed by Hunter River flooding, any minor increase in flood levels associated with Glennies Creek flooding is immaterial.
- Localised increases in channel velocities of up 0.1 m/s (less than 5% increase).

- Localised increases in the average velocity across the floodplain (i.e. including both channel and out of channel flow) of up to 0.3 m/s (15% increase). The geomorphic impacts of this velocity increases are discussed in a letter to the PAC from Fluvial Systems, dated 24 July, 2012[5].

The abovementioned impacts predominately occur in the northern portion of the project area (between river Chainage 2955m and 4724m). Refer to **Attachment 1** for cross-section locations.

In SMEC's view these predicted flood impacts are both localised and minor and would not result in any material increase in flood risk to adjoining properties or infrastructure.

OEH Issue 4 – "*The significance of the proposed development's impact on flood behaviour (flood levels, velocity and hazards) should be based on a spatial assessment of the modelled impacts. The assessment should consider any impacts on properties / infrastructure.*"

SMEC Response (Issue 4) – Refer to response to Issue 3

Issues Related to the Assessment of Hunter River Flooding

OEH Issue 5 – "*It is recommended that the PAC request the proponent to provide further information that supports the determination of the estimated Hunter River Flood Levels. It is also recommended that the proponent determine the estimated Hunter River PMF for use in the proposed flood evacuation plan for the project. This would involve modelling of the full range of Hunter River floods.*"

SMEC Response (Issue 5)

In SMEC's view, a detailed flood study of Hunter River flooding in the vicinity of the Glennies Creek Confluence is not warranted as the flood risk to the project can be reliably established based on the design level of flood protection. This is discussed in detail in SMEC's letter to the PAC dated 31 July 2012[3] and is summarised as follows.

Level of Flood Protection

The design level of the levee (64 m AHD) was established based on a recorded flood level in the vicinity of the Glennies Creek Confluence (62.7 m AHD) during the 1955 flood event plus a 1.3m freeboard. This design level was conservatively established to provide flood protection up to the 150 year ARI event.

Assessment of Flood Risks

The project will be exposed to the flood risk over a 6 year period (between Years 2 and 7 of the mine life). Should an event of greater magnitude than the 150 year ARI occur during the 6 year risk exposure period, there is a risk that floodwaters will overtop the pit. The consequences of this occurring are discussed as follows:

- **Risk to life**: Given that the flood warning time for a Hunter River event is in the order of 18 to 24 hours (Patterson Consultants, 2011)[9], there would be sufficient time to enable a full evacuation of the pit and other areas of the mine that would be potentially exposed to flood risk should the levee overtop or fail. As part of the statement of commitments for the project, ACOL will develop a flood emergency response plan that will formalise evacuation triggers and procedures. Hence, it can be concluded that the risk to life can be adequately managed by evacuation.
- **Environmental Risk**: If flood waters overtop the levee, it is possible that the pit would become fully inundated and would require dewatering. This would most likely require the release of potentially poor quality water to receiving waters, resulting in a temporary degradation of receiving water quality. The environmental risk could be managed by timing the dewatering with periods of naturally

[9] Singleton Floodplain Risk Management Study: Exhibition Report (Paterson Consultants, 2011)

high flows (which should be in abundance following a major event) to maximise the dilution of released water and minimise the overall environmental risk. This management option is noted by NOW in their letter to the PAC dated 9 July[2]. It is also noted that should a greater than 150 year ARI flood occur in the Hunter Valley, the water management system for most open cut mining operations would become overwhelmed and water releases would be required.

- **Commercial Risk**: If the pit was to become inundated by flooding, it is likely that mining schedules would be significantly disrupted and some mining infrastructure and equipment would be damaged. This risk has been considered by ACOL.

Conclusion

In SMEC's view, a comprehensive Hunter River flood study would not result in any material changes to the proposed flood management measures for the following reasons:

- Any flood model will be calibrated to the known 1955 flood levels and will therefore produce similar results (in terms of peak flood levels) to the known data.
- The adopted freeboard of 1.3 m is well in excess of the 0.5 m freeboard that is generally applied when establishing flood planning levels in NSW. Hence, the adopted 1.3m freeboard adds contingency to the assumed level of flood protection that the levee provides.
- The flood risk to the pit can be reliably estimated based on the design level of flood protection (i.e. the levee level of 64 m AHD would provide protection up to the 150 year ARI event). It is assumed that any flood exceeding the 150 year ARI event would overtop the pit. Hence, the abovementioned consequences of this occurring would be the same regardless of the degree of overtopping. Accordingly, detailed modelling to determine the PMF level would not enhance the flood risk management planning for the project.
- Other Hunter River Flood Studies, such as the recently completed Singleton Flood Risk Management Study (Paterson Consultants, 2011)[9], have demonstrated that flood warning times for a major Hunter River flood event would be in the order of 18 to 24 hours. In SMEC's view, this warning time would enable sufficient time for the safe and orderly evacuation of the pit and other flood affected areas. As documented in the Statement of Commitments, a flood evacuation plan will be prepared post approval to formalise evacuation triggers and procedures.

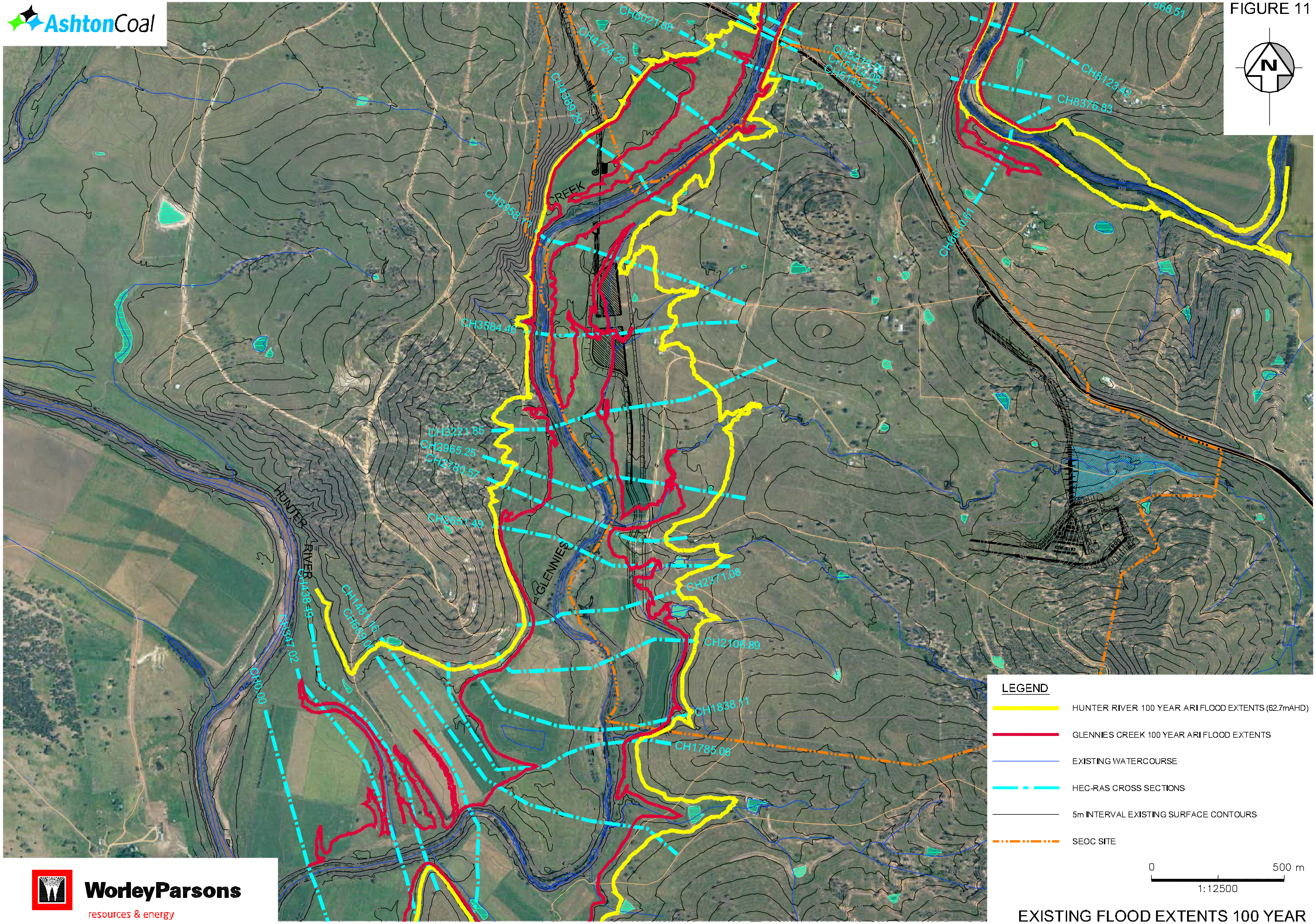
Yours sincerely,

Ben Patterson
NSW Manager, Water Resources

Attachments

Attachment 1- *Figure 11 from the Flood Assessment (WorleyParsons, 2009) that depicts the 100 year ARI flood extent and cross-section locations.*

FIGURE 11



EXISTING FLOOD EXTENTS 100 YEAR

N:\Drafting Jobs\7583 Ashton Coal SEOC Environmental Assessment (MLB)\CAD\REPORT FIGURES\FIGURE 11 EXISTING FLOOD EXTENTS 100YR.dwg 22/07/2009

ATTACHMENT 2

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Review of Glennies Creek flood and geomorphology information in relation to South East Open Cut Project:
Addendum Revision (1939-2008)

Christopher Gippel

Fluvial Systems Pty Ltd

For Ashton Coal Operations Pty Ltd

28 August 2012

FLUVIAL SYSTEMS
GEOMORPHOLOGY • CATCHMENT HYDROLOGY
RIVER REHABILITATION • ENVIRONMENTAL FLOWS

Fluvial Systems Pty Ltd
PO Box 49
Stockton N.S.W. 2295
Australia

Tel: +61 2 49284128
Fax: +61 2 49284128
Mobile: 0404 472114
Email: chris.gippel@bigpond.com
ABN: 71 085 579 095

Summary

This report is a revision of a previous addendum, prompted by the discovery of a 1939 aerial image of Glennies Creek in the area of interest.

The 1939 image allowed the channel change associated with a period of intense flood activity between 1946 and 1955 to be assessed.

Measurable channel change was observed between the 1939 and 1958 photographs, but this change was of the same order as that observed between the 1958 and 1967 photographs. From 1967 onwards, the channel generally straightened and narrowed. The channel migrations were confined to a fairly narrow corridor. Between 1939 and 1958 the channel moved laterally a maximum distance of 80 m. The lateral positions of the edges of the channel in 2008 were no greater than 100 m distant from their positions in 1958. Since 1939, the channel has shown no overall tendency to migrate eastwards towards the location of the proposed SEOC levee.

1 Scope of this report

This report is a revision of the report:

- Gippel, C.J. 2012. Review of Glennies Creek flood and geomorphology information in relation to South East Open Cut Project: Addendum Fluvial Systems Pty Ltd, Stockton. Ashton Coal Operations Pty Ltd, July.

The above report was an addendum to the report:

- Gippel, C.J. 2012. Review of Glennies Creek flood and geomorphology information in relation to South East Open Cut Project. Fluvial Systems Pty Ltd, Stockton. Ashton Coal Operations Pty Ltd, June.

The purpose of the addendum to the original report was to include additional information about the historical pattern of flood flows, and detailed analysis of historical channel change. The Addendum utilised aerial photography dating from 1958, which was the earliest photograph held by Land and Property Information, NSW Government. The Planning Assessment Committee noted that an earlier photograph, if available, might reveal the scale of channel change that was associated with the 1955 flood which was the largest on record. A search of Australian Army survey aerial photography located an image dated 1939. Discovery of the image necessitated review of the Addendum. The Addendum is reproduced here, with additions and revisions that relate to the 1939 photograph.

2 Review of Flood Hydrology

Worley Parsons (2009a) undertook modelling of flood levels in the vicinity of South East Open Cut (SEOC) for a number of scenarios including Hunter River flood, and Glennies Creek flood independent of Hunter River flood. They correctly argued that under regional flood conditions, Glennies Creek would likely peak before the Hunter River (at the Glennies Creek junction). However, they assumed that when Glennies Creek was in flood, the Hunter River would not be at a low baseflow level, but at a sufficiently high level that would cause a backwater effect into Glennies Creek for 3 to 3.5 kilometres upstream of the junction with the Hunter River (for 5 year to 100 year ARI events). Gippel (2012b) found that in this lower reach of Glennies Creek the bank top edges graded down towards the Hunter River, which was evidence that channel forming flows must have occurred in the absence of a backwater effect from the Hunter River.

The historical mean daily flow records were obtained for the gauges on the Hunter River @ Singleton (210001) and Glennies Creek@ Middle Falbrook (210044). The data were obtained from NSW Office of Water HYDAY V120 Output 27/06/2012 (http://waterinfo.nsw.gov.au). Hunter River data were available for complete years from 1913 to 2009, and Glennies Creek data from 1957 to 2011. Both gauges had occasional missing data. No attempt was made to infill the missing data, as the relatively small number of missing days would not have had a major impact on the analysis.

Flood frequency analysis was undertaken using the mean daily data. Normally this is done using instantaneous peak flow data, but such data were not readily available. The main objective of this analysis was to examine the pattern of floods through time, and their relative (not absolute) magnitude. As the instantaneous peak and mean daily flow are usually very closely correlated, the use of mean daily flow data for this application is justified.

The approach to flood frequency analysis was to plot the annual maximum series. The highest daily flow of each year was selected and then plotting positions were calculated using the standard Cunnane formula. The data were fitted to the standard General Extreme Value Type II (GEVII) distribution (Figure 1), and this relationship was used to predict the Average Recurrence Interval of the maximum flood of each year of record (Figure 2).

The flood of 1955 was a widespread event that affected the whole south-eastern part of Australia. In the Hunter River it was the largest flood on record by a large margin. The analysis suggested that at Singleton the 1955 flood was a 1 in 158 year event, while the next largest event on record (2007) was a 1 in 47 year ARI event (Figure 2); this event was only about 10 year ARI at Maitland.

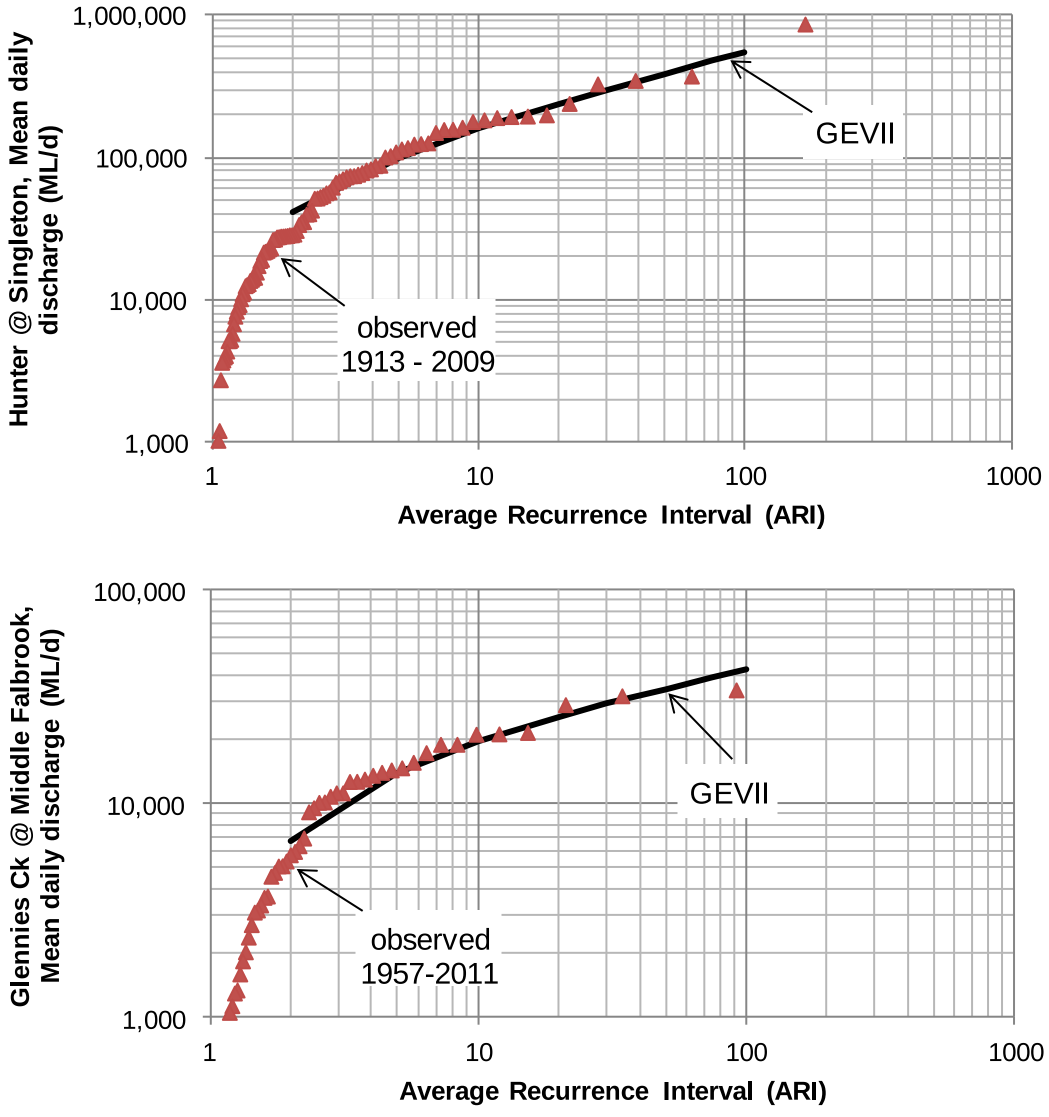

Figure 1. Annual series flood frequency curves for gauges on the Hunter River and Glennies Creek.

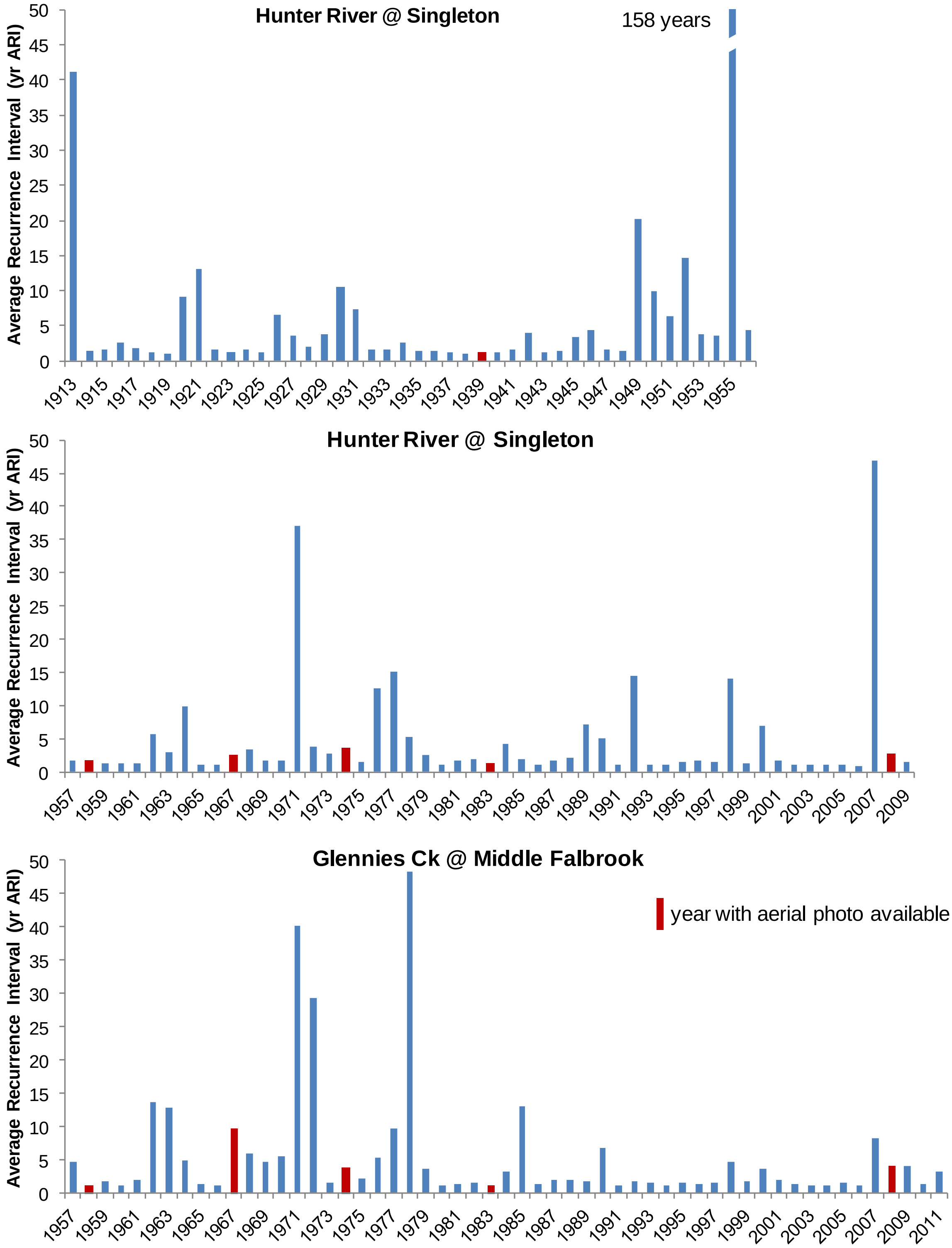

Figure 2. Historical pattern of the ARI of the maximum annual maximum flood for gauges on the Hunter River and Glennies Creek. Red coloured bars indicate years when aerial photographs of Glennies Creek in the vicinity of the SEOC were analysed.

The period 1949 to 1956 was a flood-dominated period that resulted in widespread geomorphological changes to rivers in the Hunter Valley (Erskine, 1992). At the time, Glennies Creek was virtually devoid of riparian vegetation (due to intentional clearing), which is evidenced in photographs taken from the ground (Gippel, 1012b) and from the air (see the 1939 and 1958 aerial photographs later in this report). A comparison of the pattern of floods in the Hunter River and Glennies Creek suggests only a broad level of correspondence (Figure 2). While there is a statistically significant correlation between the ARIs of the annual maximum floods, it is clear that a high flood can occur in Glennies Creek, but not in the Hunter River, and vice-versa (Figure 3). Thus, it cannot be assumed that the major floods of each year are regional events. This result supports the suggestion by Gippel (2012b) that the morphology of lower Glennies Creek is shaped by floods acting independently of floods in the Hunter River.

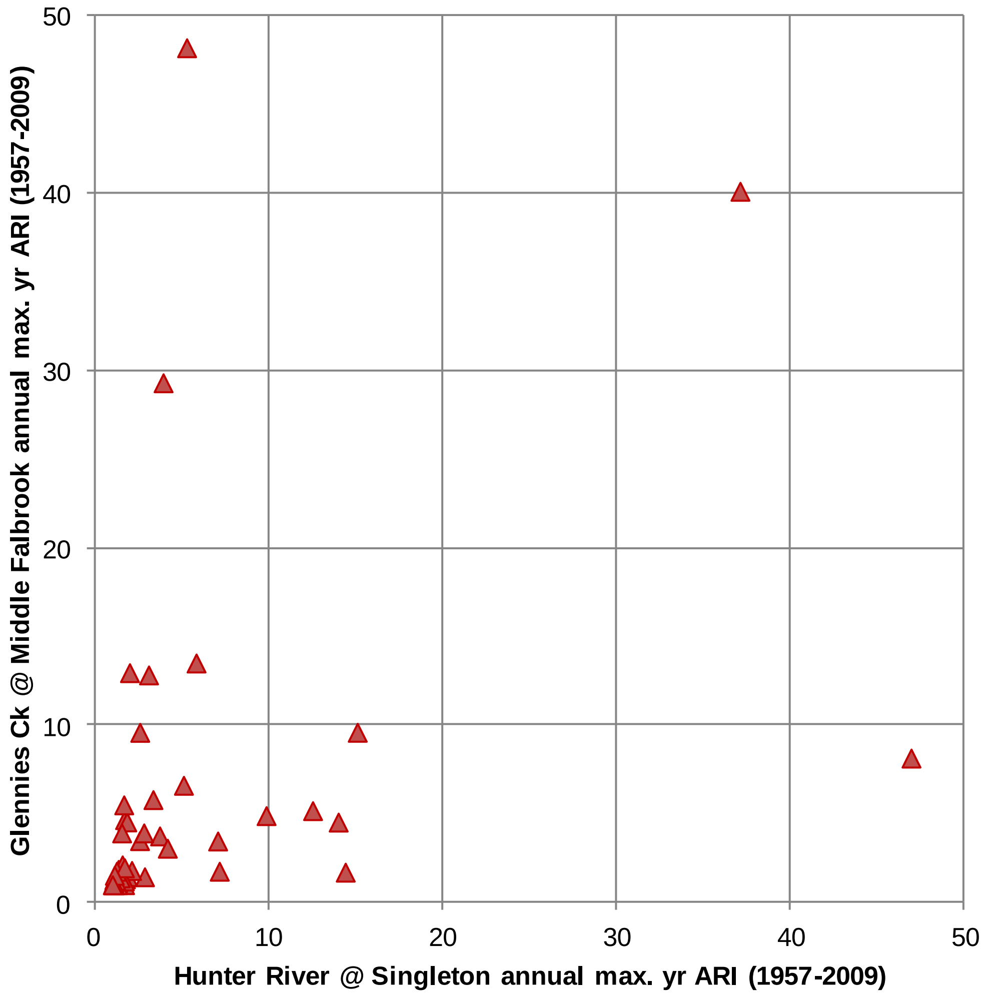

Figure 3. Relationship between the ARI of the maximum annual maximum flood for gauges on the Hunter River and Glennies Creek over the period of common record from 1957 to 2009.

3 Review of Fluvial Geomorphology

Worley Parsons (2009b) investigated the geomorphic processes in lower Glennies Creek by comparison of historical aerial photographs. They plotted the centreline of the creek from photographs taken in 1958, 1974, 1996, 2005 and 2007. Their analysis concluded that between 1958 and 1996 the channel of Glennies Creek generally straightened, and there was no significant tendency to migrate towards the proposed pit of the SEOC. From 1996 to 2007 the channel position remained essentially stable.

The aerial photograph analysis of Worley Parsons (2009b) was refined by plotting the edges of the bed of the creek, rather than the centreline. The bed was fairly easy to distinguish on most of the photographs due to the lack of dense riparian vegetation, and a sandy/gravelly bed that was not colonised by plants. The most recent photograph analysed was taken in 2008, and at this time the creek had a narrow strip of riparian vegetation. However, in this case the bed could be distinguished with the assistance of digital elevation data (from an aerial survey). As well as the creek bed, distinctive linear features that might indicate bank edges or depressions on the floodplain were marked. The purpose of this was to record any changes to major bank lines. The photographs selected for analysis were 1939, 1958, 1967, 1974, 1983 and 2008 (Figure 4, Figure 5, Figure 6, Figure 7, Figure 8 and Figure 9). Prior to analysis, the photographs were carefully re-rectified to remove distortion and offsets in the vicinity of the main area of interest. Worley Parsons (2009b) established that the channel changed little from 1996 onwards, so the focus of the re-analysis was on the period prior to this.

The photographs (Figure 4, Figure 5, Figure 6, Figure 7, Figure 8 and Figure 9) revealed that the main channel changes occurred between 1939 and 1967. In 1939 the creek was generally devoid of riparian vegetation and had considerable variation in width. In the area of interest, the channel was wider in the downstream reach. Between 1939 and 1958 the meander in the downstream reach became more sinuous, some parts of the channel widened, and other parts narrowed (Figure 4, Figure 5). In 1958 the channel was overly-wide on the meander in the southern part of the study area (Figure 5). The changes between 1939 and 1958 can be attributed to the series of floods that occurred between 1949 and 1955 (Figure 2). Four significant erosional changes occurred between 1958 and 1967 (Figure 5 and Figure 6). In Glennies Creek, significant floods occurred in 1962, 1963 and 1964 (Figure 2), which seem to have compounded the impact of the major 1955 event (Figure 2). While the meander in the southern part of the study area generally straightened, two areas to the side of the channel were scoured, and two bends were scoured (Figure 6). Also, sometime between 1958 and 1967 river training works were installed at three locations (Figure 6). By 1974, the upstream set of training works appears to have been scoured away, while the other two appear to have been effective in maintaining the course of the river (Figure 7). The land in the previously eroded areas became revegetated. There were no major changes of course between 1967 and 1974, despite the occurrence of major floods in 1971 and 1972 (Figure 2). Loss of the upstream set of training works did not result in any further eastward migration of the river at that location, with the river remaining stable in 1983 and 2008 (Figure 8 and Figure 9). Between 1974 and 1983 there was a major flood in 1978 (Figure 2). This did not result in any changes in course, but the channel widened in the most southern part of the study area (Figure 8). The 2008 conditions were characterised by general channel narrowing, and growth of a narrow strip of riparian trees and shrubs (Figure 9). Despite a moderate flood in 2007 (Figure 2), there were no course changes.

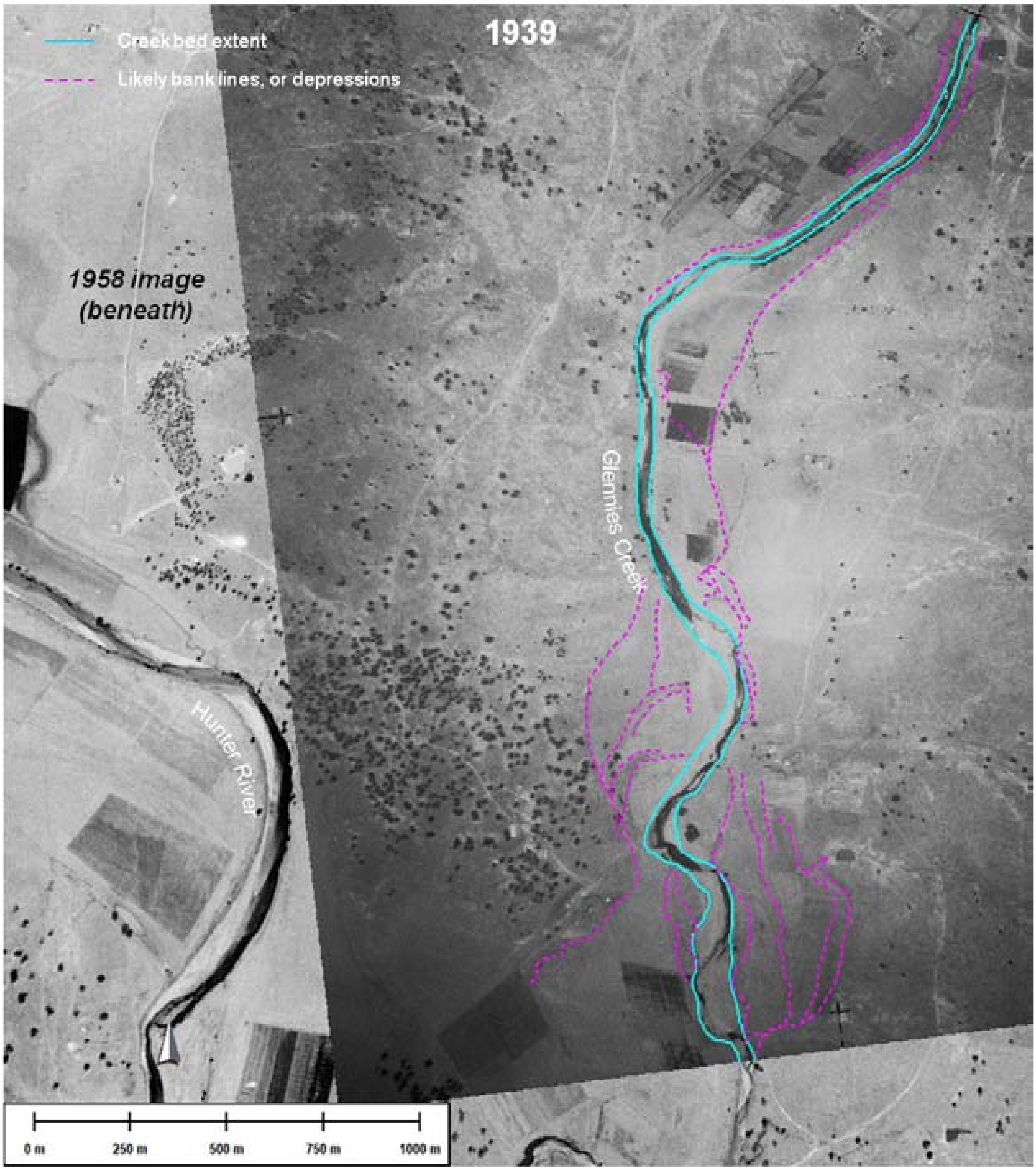

Figure 4. 1939 aerial photograph, showing the bed of Glennies Creek, and features suggestive of bank edges and depressions on the floodplain. Coverage of the 1939 image was less than that of the later photographs, so it was overlaid on the 1958 image.

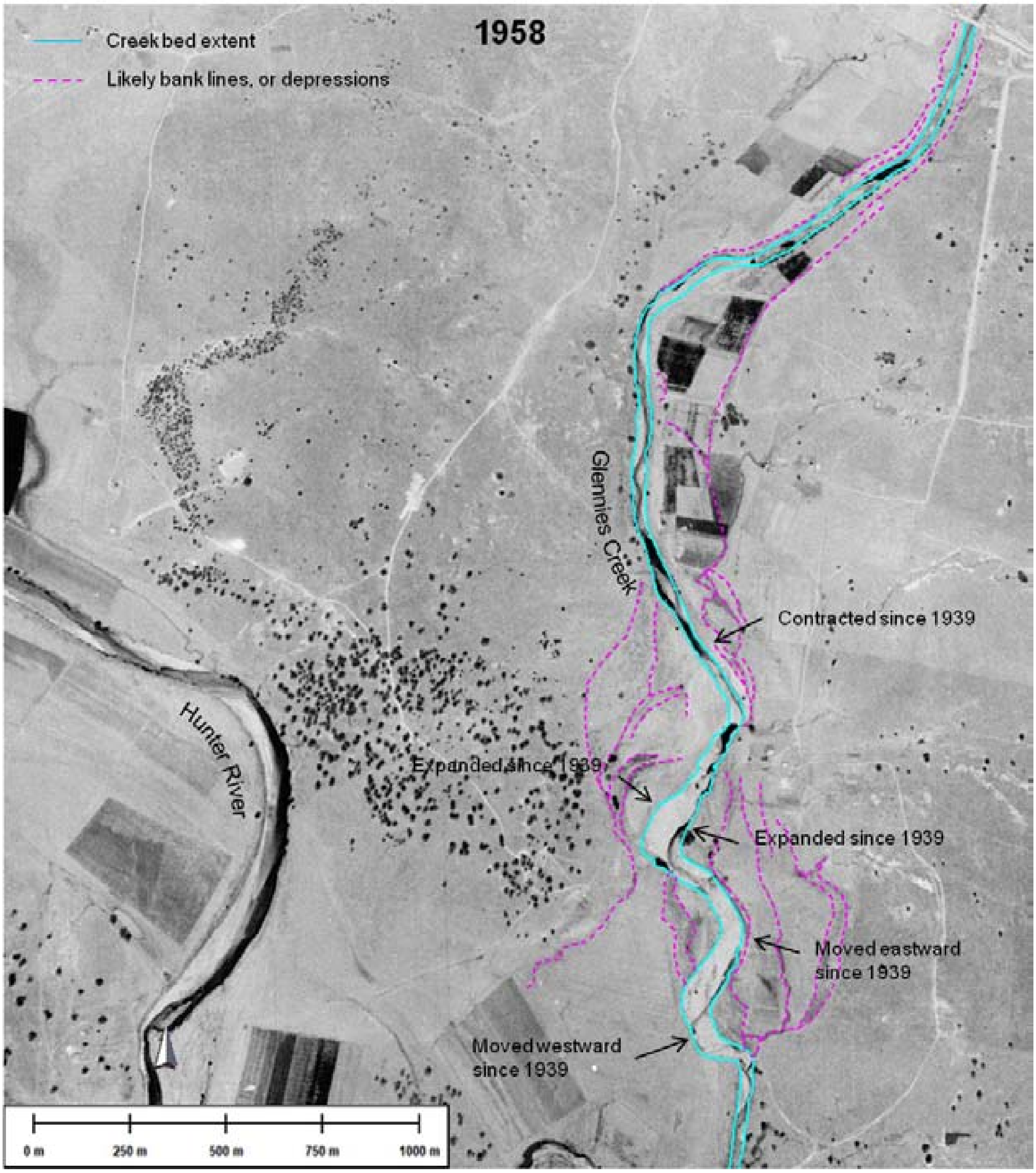

Figure 5. 1958 aerial photograph, showing the bed of Glennies Creek, and features suggestive of bank edges and depressions on the floodplain. Sometime between 1939 and 1958 the New England Highway Bridge was rebuilt just downstream of the former bridge.

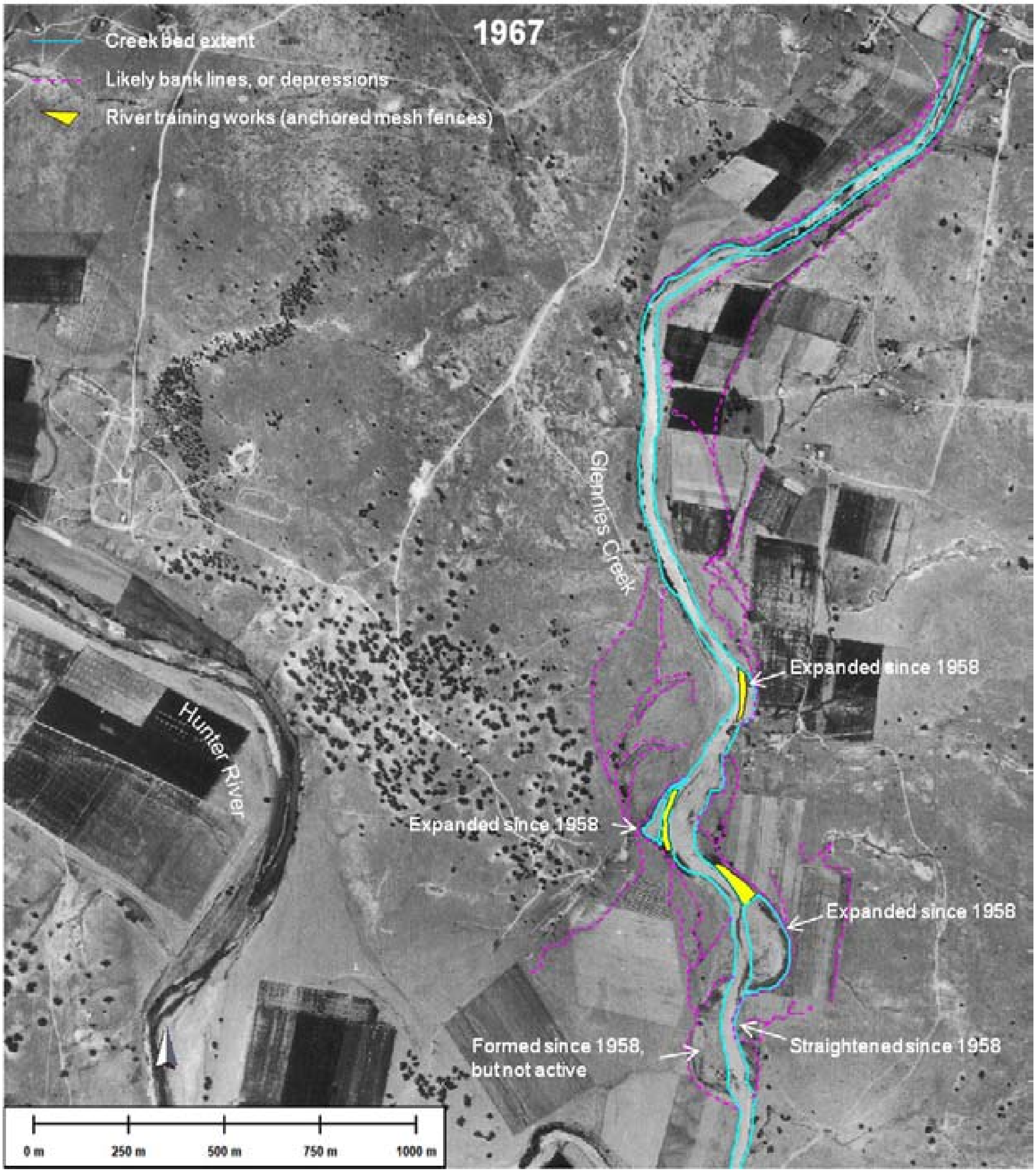

Figure 6. 1967 aerial photograph, showing the bed of Glennies Creek, and features suggestive of bank edges and depressions on the floodplain.

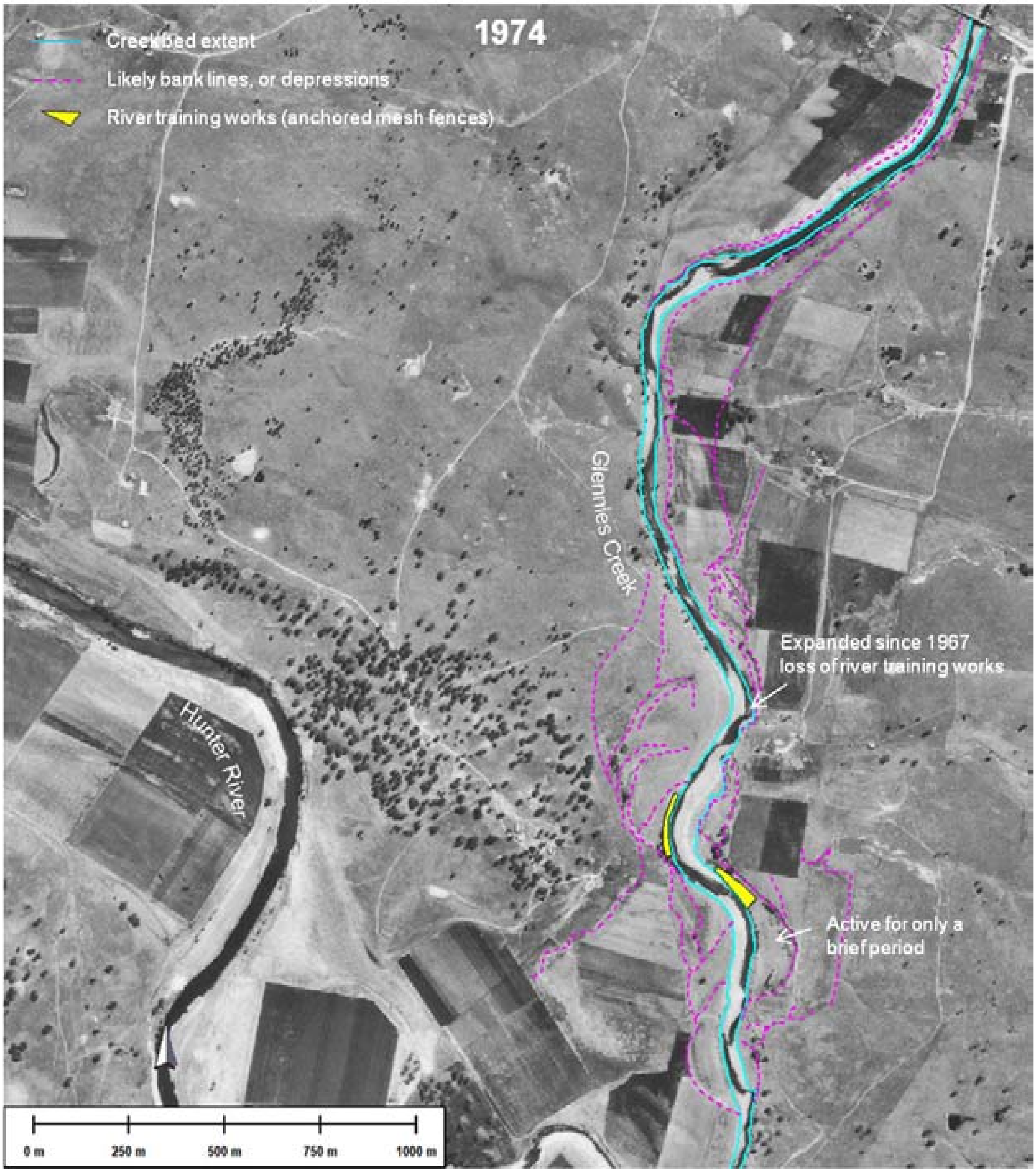

Figure 7. 1974 aerial photograph, showing the bed of Glennies Creek, and features suggestive of bank edges and depressions on the floodplain.

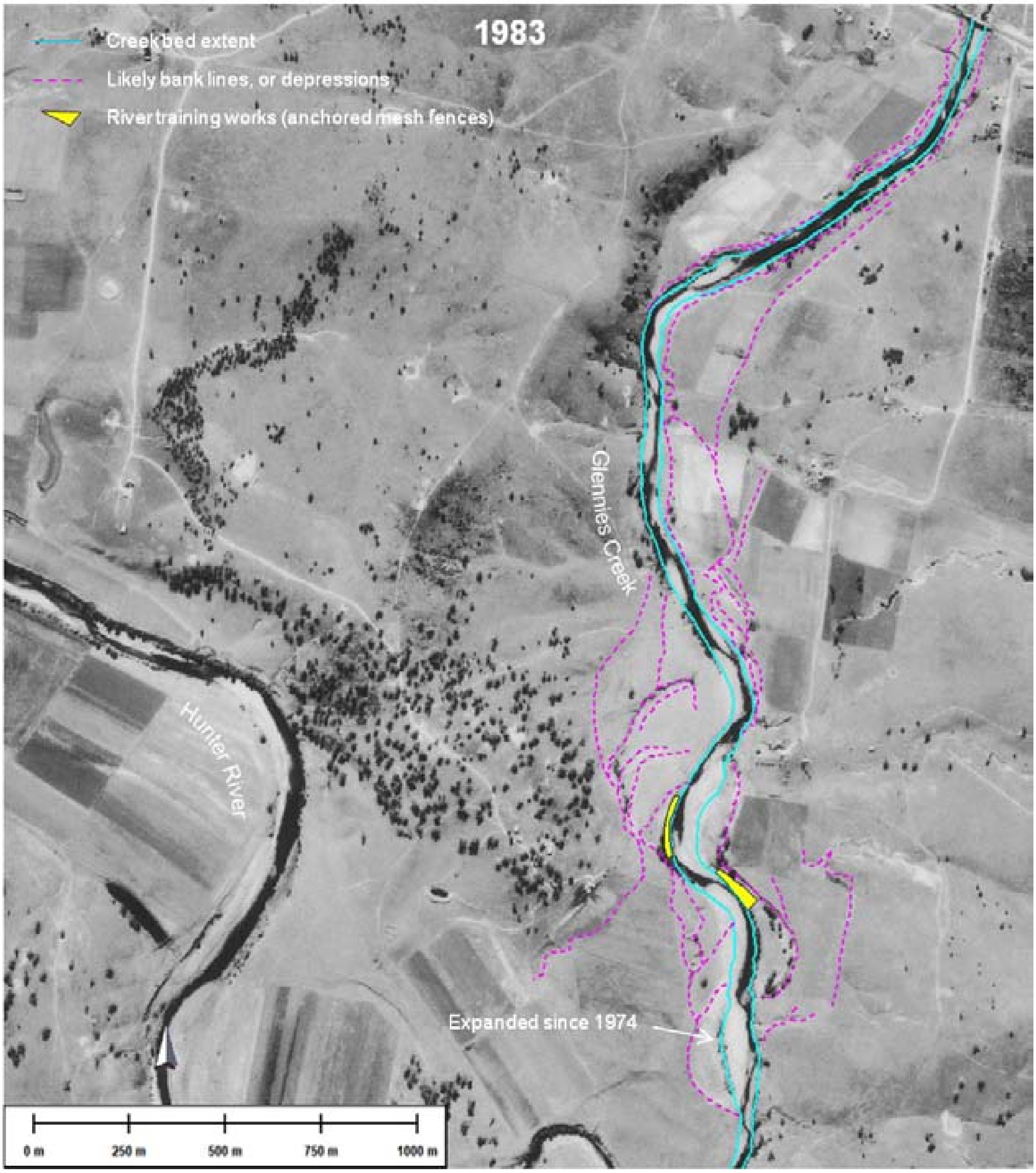

Figure 8. 1983 aerial photograph, showing the bed of Glennies Creek, and features suggestive of bank edges and depressions on the floodplain.

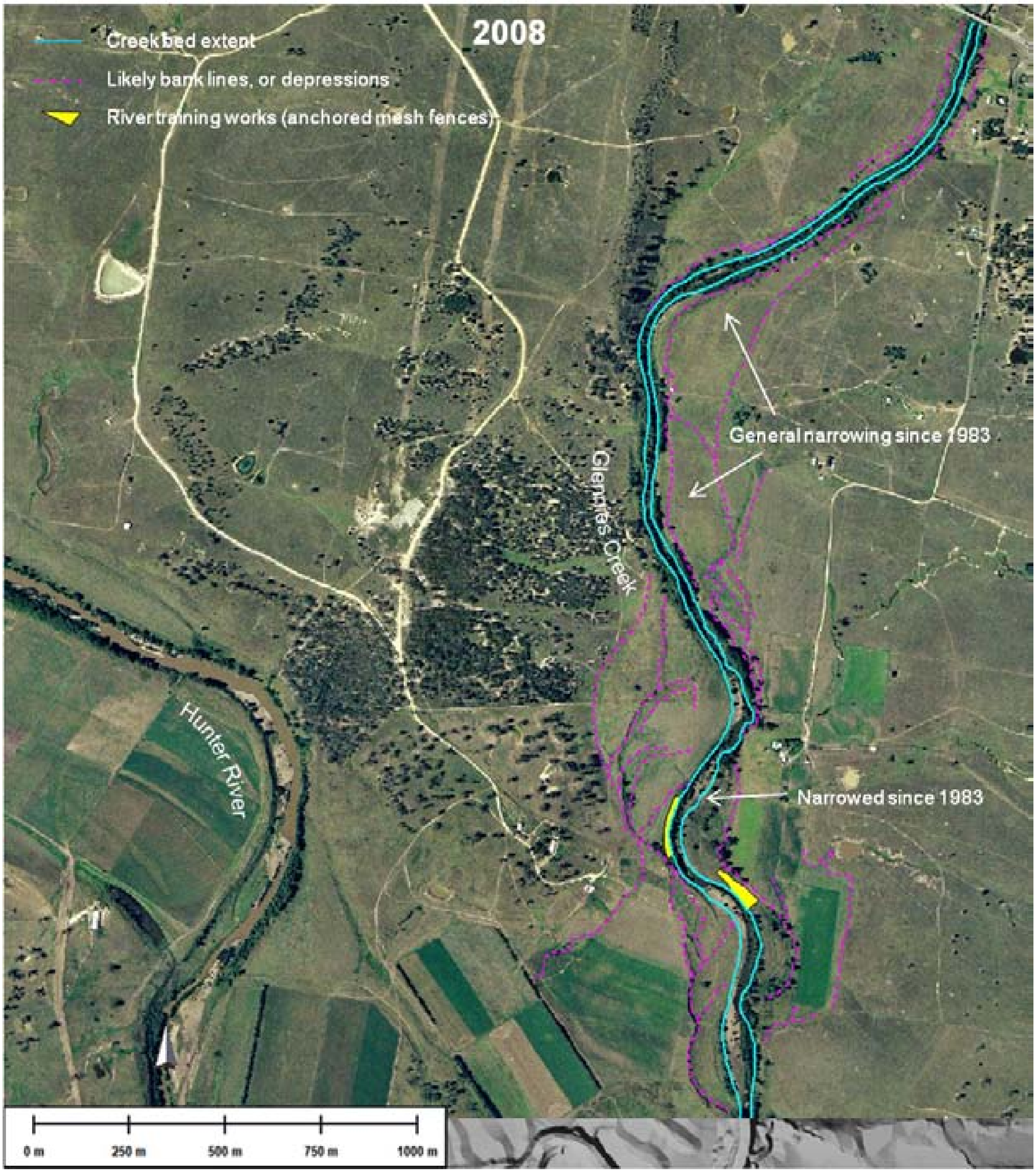

Figure 9. 2008 aerial photograph, showing the bed of Glennies Creek, and features suggestive of bank edges and depressions on the floodplain.

The aerial photograph analysis undertaken here confirmed the result of Worley Parsons (2009b), and added more detail. Most of the channel change between 1939 and 2008 occurred within the first 28 years (Figure 10). Since 1967 the channel has tended to straighten and has been fairly stable, despite riparian vegetation establishing only in recent times (Figure 10 and Figure 11). River training works constructed in three locations sometime between 1958 and 1967 might have played a role in stabilising the creek position, or, as suggested by Erskine (1992) for the Upper Hunter River, "The channels would have recovered naturally, to some extent, from this damage". One of the sets of training works appears to have been washed away by 1974, but the river did not further shift its position in that location.

From the New England Highway bridge to the southern extent of the proposed SEOC levee (~3,200 m), the majority of Glennies Creek (~2,500 m) has experienced very little movement and no change in general alignment since 1958 (local left and right migrations up to a maximum of 50 m were observed between photographs) (Figure 12). The southern 700 m length of the creek adjacent to the proposed levee experienced lateral shifts in position of up to 100 m (between 1939 and 1967). Between 1939 and 1958 the channel moved laterally a maximum distance of 80 m. The maximum difference in lateral position of the channel between 1958 (after the impact of the 1955 flood) and 2008 was 100 m. Between 1958 and 1967 there was an area of bank scour that was 130 m from the former bank edge, but this channel position was not maintained (Figure 6 and Figure 7). In general, the channel movements were confined within a narrow band, and showed no overall tendency to migrate eastwards towards the location of the proposed SEOC levee (Figure 12).

The topography of the floodplain indicates that the creek has occupied alternative positions in the past (pre-1939) (Figure 12), but the timing, and the distance the creek moved in response to any one flood event or series of floods, cannot be determined from the topographic information alone.

The historical changes in channel position observed from aerial photographs are not necessarily a reliable guide to future changes. The creek was virtually devoid of riparian vegetation until recently. In the future, rehabilitation of the riparian vegetation will impart significant resistance to the banks from the scouring effects of future floods. So, Glennies Creek is expected to be more stable into the future, compared to the period 1939 to 1967, when the channel was observed to migrate in response to a sustained period of high flow events.

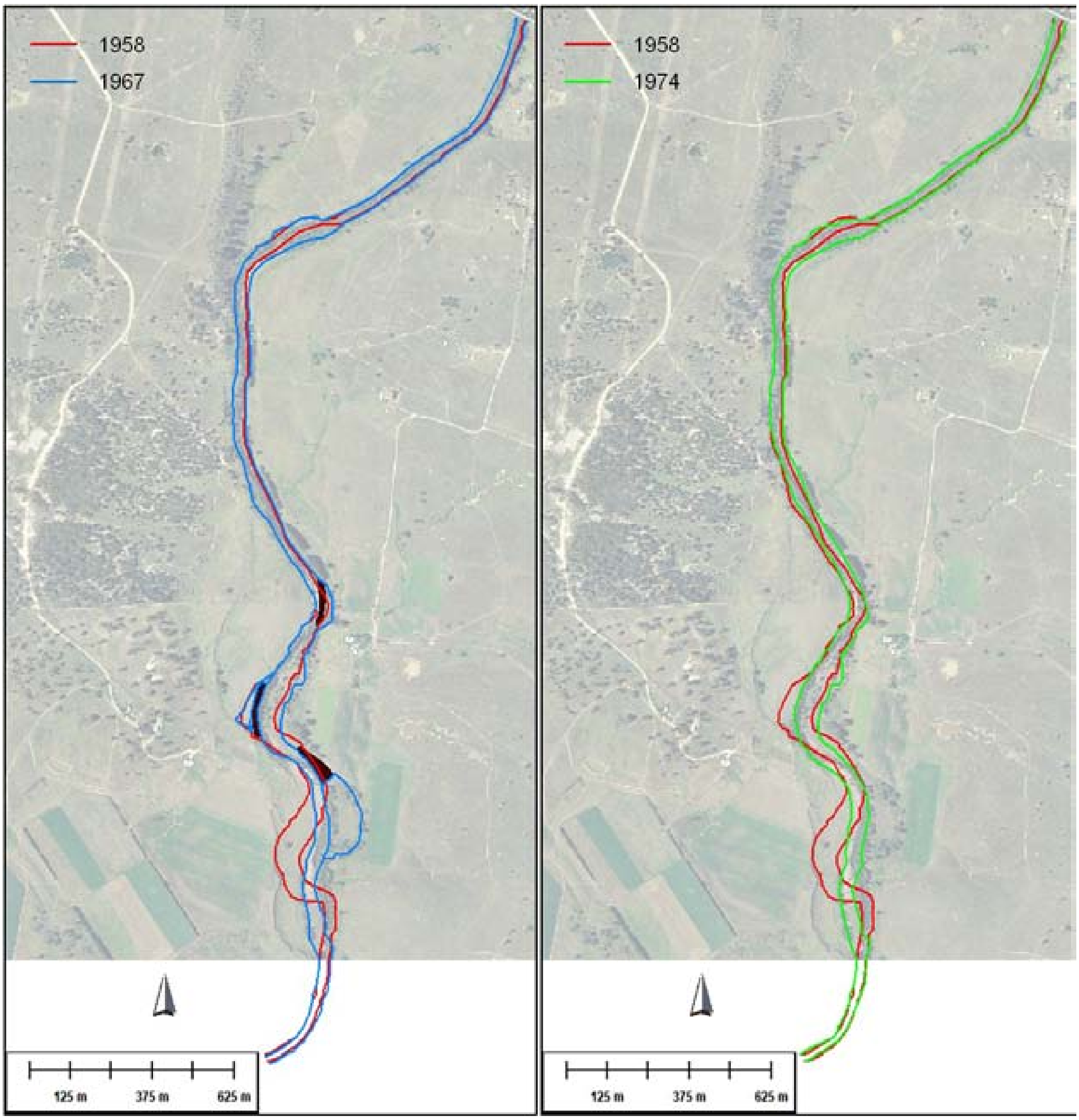

Figure 10. Comparison of 1967 and 1974 channel bed position with that of 1958. The 1967 lines show the position of the river training works installed sometime between 1958 and 1967. Lines are overlayed onto the 2008 aerial image.

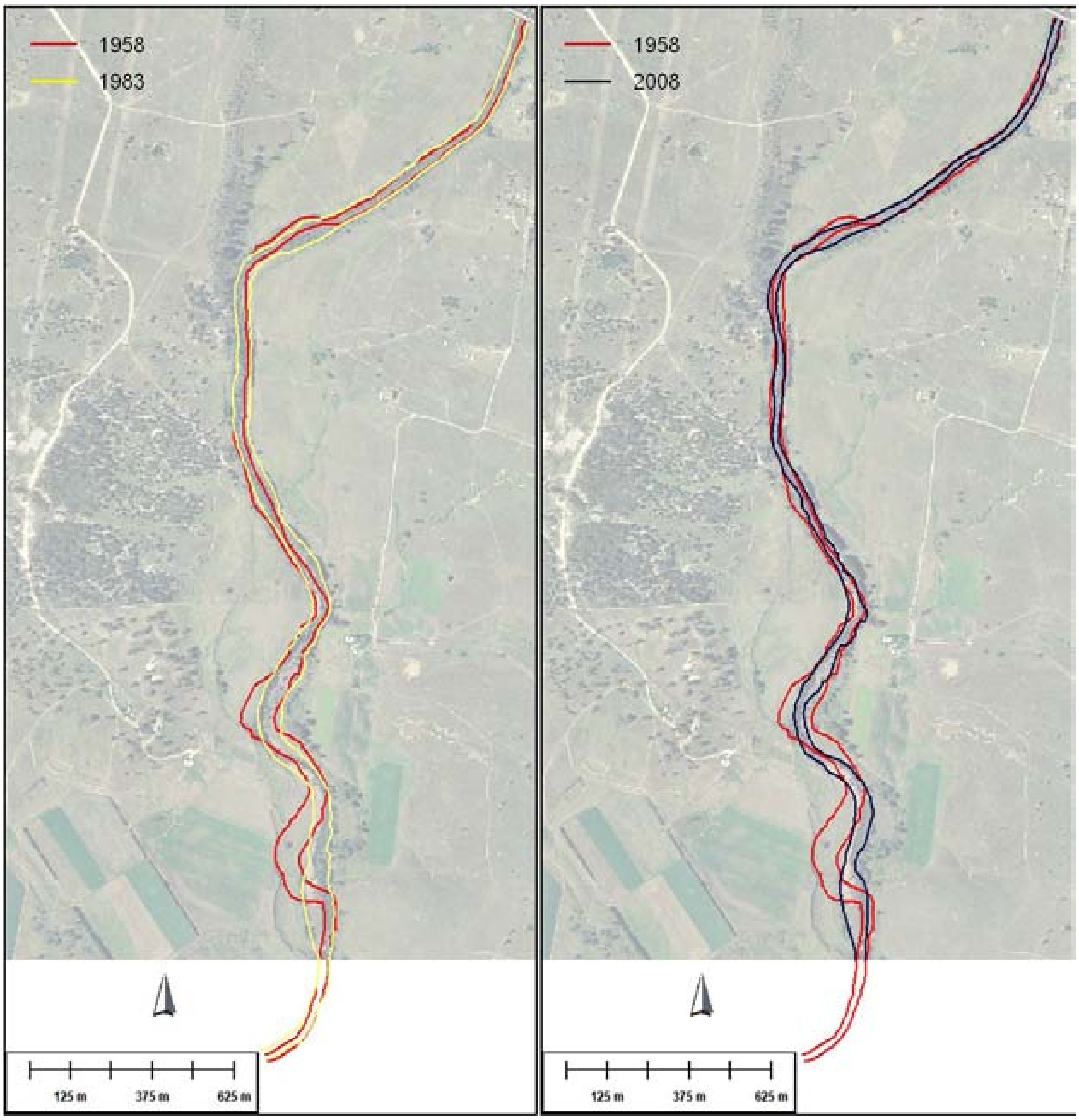

Figure 11. Comparison of 1983 and 2008 channel bed position with that of 1958. Lines are overlayed onto the 2008 aerial image.

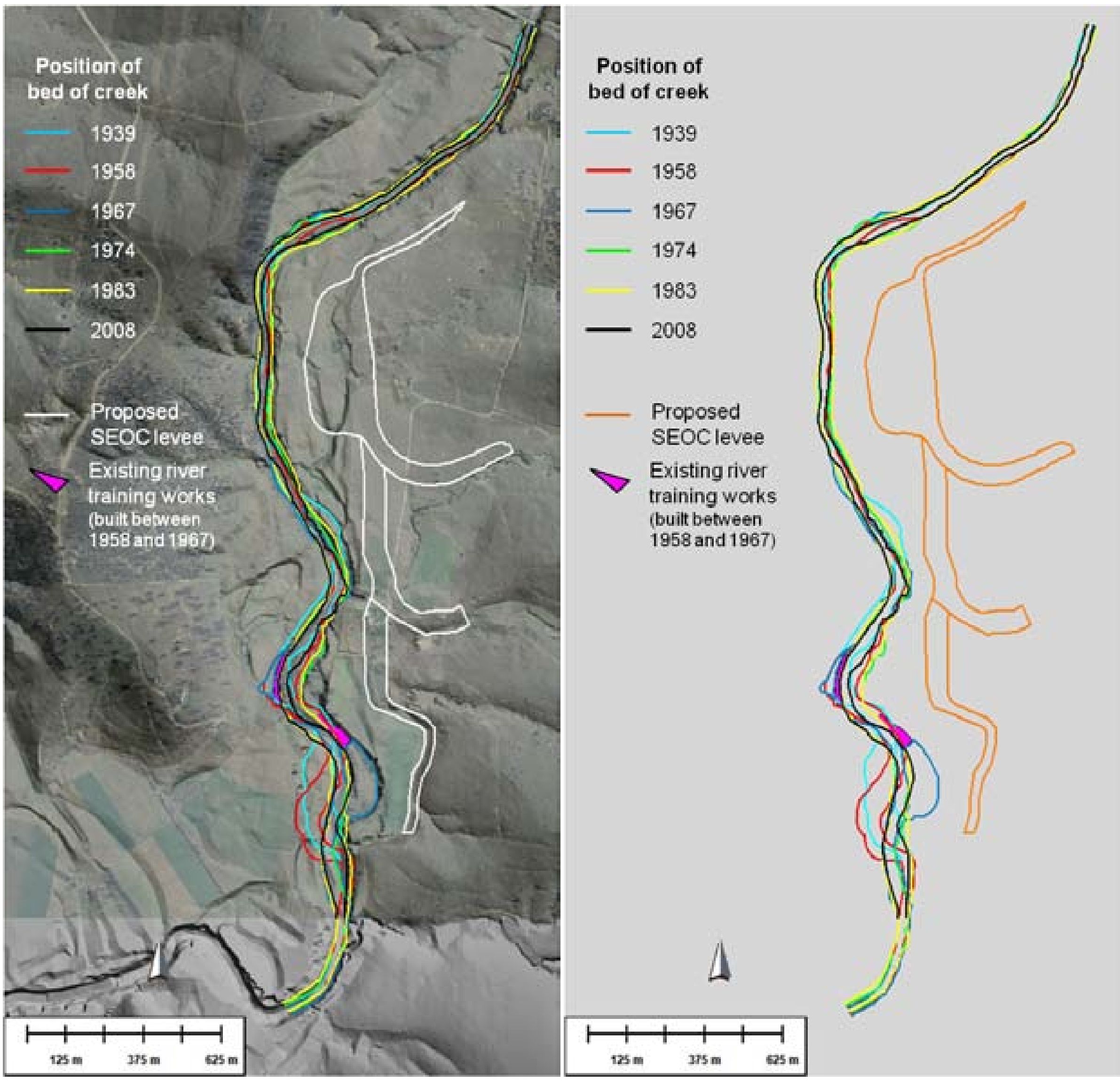

Figure 12. Comparison of bed position of lower Glennies Creek in 1939, 1958, 1967, 1974, 1983 and 2008. The two images are the same, except that the left-hand image shows the topography (hillshaded digital elevation model) and land cover.

4 References

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ATTACHMENT 3

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FLUVIAL SYSTEMS
GEOMORPHOLOGY • CATCHMENT HYDROLOGY
RIVER REHABILITATION • ENVIRONMENTAL FLOWS

Fluvial Systems Pty Ltd
PO Box 49
Stockton N.S.W. 2295
Australia

Tel: +61 2 49284128
Fax: +61 2 49284128
Mobile: 0404 472114
Email: chris.gippel@bigpond.com
ABN: 71 085 579 095

24 July 2012

Attention: Michael Moore, Approvals Manager

Ashton Coal Operations Pty Limited
PO Box 699
Singleton NSW 2330

RE: NOW letter to PAC dated 9 July 2012 on flood and geomorphic issues

Dear Michael

This letter addresses the three issues related to fluvial geomorphology that were raised by NOW in a letter to PAC dated 9 July.

1. Page 1, paragraph 5, dot point 4 (impact of flooding of the pit)

In the reports I have submitted in relation to this matter (Gippel, 2012a; Gippel 2012b) I did not consider the geomorphic impacts of a flood that might overtop the levee and allow water into the pit because events of this magnitude (and very low probability of occurrence) exceeded the 100 year ARI flood planning level adopted for design of the levee. The levee was designed with 3.3 m freeboard above the level of the modelled Glennies Creek 100 year ARI event and 1.3 m freeboard above the peak level of the 1955 flood in the vicinity of Glennies Creek junction (conservatively adopted as the 100 year ARI event for the flood study). Also, I am of the understanding that the levee was designed by Parsons Brinkerhoff with geotechnical properties to withstand scour and slumping under flood conditions up to the 100 year ARI event.

2. Page 2, paragraph 4 (altered hydraulics and risk of scour)

The letter from NOW claims that "*Restricting the floodway adjacent to the mine will inevitably increase the height of individual events, raise the velocity of flows, and increase the likelihood of scouring*".

In fact, these consequences are not inevitable. Firstly, the majority of storm event flows (those more frequent than every 5 years on average) would not reach the toe of the levee, in which case the levee cannot possibly influence the hydraulics of the events. Secondly, for Glennies Creek floods that do reach the levee, Figure 13 in Worley Parsons (2009a) shows that the displaced flood storage volumes are 63 ML for the 100 year ARI event, 15 ML for the 20 year ARI event and 4 ML for the 5 year ARI event. These small volumes reflect the fact that the levee would occupy a very small proportion of the active Glennies Creek floodplain, so a large hydraulic impact would not be expected. The displaced flood storage of large Hunter River floods is larger than for Glennies Creek floods of the same recurrence interval. However, under large Hunter River floods, the area of Glennies Creek floodplain adjacent to the proposed SEOC levee is a backwater with very low velocities that do not present a risk of scouring the channel or floodplain.

The Glennies Creek hydraulic model developed by Worley Parsons (2009a) included 33 cross-sections, with water level, depth, mean velocity and energy slope (which approximates water surface slope) predicted for the Glennies Creek 5 year, 20 year and 100 year ARI events, for existing conditions and with the proposed SEOC development (i.e. the levee) in place. The results were provided in Appendix C of Worley Parsons (2009a). The level, depth, and mean velocity data were provided with a precision of 0.01 units and slope to 0.000001 units (while this level of precision may exceed the accuracy of the modelling, it allows reporting of very small theoretical differences between scenarios).

At the reported levels of precision, there were no differences in any of the modelled hydraulic parameters between the existing and proposed scenarios for the 5 year and 20 year ARI events.

For the 100 year ARI event, some post-SEOC differences were predicted in elevation, depth, mean velocity and/or slope in the reach between 1838 and 5174 m chainage, which was characterised by 14 cross-sections (see attached figure).

In general, for the 100 year ARI event, the predicted differences in the modelled hydraulic parameters were very small:

- The maximum predicted change in elevation was a 5 mm increase, with 11 of the 14 cross-sections having a predicted increase of 1 mm or less.
- At 9 of the cross-sections the model indicated either no change in slope, or a reduced slope of up to 5 mm per 100 metres; at 4 of the cross-sections the slope increased by less than 2 mm per 100 metres; and at the other cross-section (chainage 3584 m) the predicted increase in slope was 12 mm per 100 metres.
- At half of the cross-sections there would be either no change in velocity or a maximum reduction of 0.02 m/s or 1.4% reduction. At six of the cross-sections the mean velocity was predicted to increase by between 0.01 and 0.09 m/s; at one cross-section (chainage 3584 m) the mean velocity was predicted to increase from 1.85 m/s to 2.15 m/s (16% increase). This velocity change was associated with an increase in slope (see attached figure) and was the result of the run of mine (ROM) pad blocking a flood runner that is located to the east of the main channel. As indicated in Worley Parsons (2009a, Figure 11), this flood runner may not convey flow during a 100 year event as it may not connect to the channel upstream (in which case it would be dead water). So, this modelling assumption is conservative for the 100 year event.

3. Page 2, paragraph 6 (historical channel change, shear stress, erosion risk, Mannings n and risk of bank slumping)

The letter from NOW states that "…*evidence exists of previous scouring during events within the natural floodway*". Evidence of scour would be expected in every river and creek, because erosion is a natural geomorphic process (Florsheim et al., 2008). The fact that Glennies Creek eroded during and after the 1955 flood event is not surprising. Such change was not confined to Glennies Creek (e.g. Erskine, 1992).

An analysis of the historical changes in the channel of Glennies Creek in the vicinity of the proposed SEOC was presented in Worley Parsons (2009b), and in more detail in Gippel (2012b). The channel changes that occurred in the in 1950s and 1960s would not necessarily occur today if the same sequence of floods occurred. The main reason is that in the 1950s and 1960s, Glennies Creek was virtually devoid of riparian vegetation, having been cleared earlier and maintained in that state in association with agricultural activities. Historical photographs evidencing bare banks were presented in Gippel (2012a) and Gippel (2012b). In recent decades a narrow strip of riparian trees and shrubs has established close to the channel, and this would have enhanced the erosion resistance of the banks. The floodplain has continued to be used for grazing or cropping, so remains essentially devoid of trees and shrubs. A secondary reason why Glennies Creek channel is currently more stable than in the 1950s is because erosion control works were established on three bends sometime between 1958 and 1967. On one of these bends the works were apparently destroyed sometime between 1967 and 1974, but the works remain intact on the other two bends (Gippel, 2012b).

The issue is not whether the morphology of the channel and floodplain of Glennies Creek would continue to change over time (it will, as expected), but whether the proposed SEOC would increase the risk of scour beyond expected limits. The letter from NOW states that "…*geomorphic assessment would be better informed by presentation of shear stress values, Mannings n values used in the modelling, presence and condition of bank erosion control works on outside bends and engineering assessment of potential bank slumping due to saturation*". I agree that shear stress is more informative than velocity, and an assessment of the likely impact of the SEOC on shear stress on the floodplain was presented in Gippel (2012a). The conclusion was that the floodplain, under conditions of good grass cover, was not at risk of scour under the existing and proposed scenarios. To support that preliminary analysis, the maximum floodplain shear stress was estimated for the 100 year ARI event for existing and proposed conditions on the basis of hydraulic data provided in Worley Parsons (2009a), and an estimate of bank top elevation made from digital elevation data supplied by Ashton Coal Operations Pty Ltd (this enabled estimation of the maximum depth of water over the bank top, i.e. at the edge of the riparian zone). A critical shear stress in the range 100 – 200 N/m^2 is a reasonable guide to the upper limit of shear stress tolerable by grass covered surfaces (Fischenich, 2001). The analysis revealed (see attached figure) that: (i) changes in shear stress due to the SEOC were very small (all being less than 1 N/m^2 change), and more than half of the cross-sections were predicted to have reduced shear stress under SEOC (due to decreased slope and very little change in depth), and (ii) all shear stresses were lower than 70 N/m^2, so scour of the floodplain surface would not be expected for the 100 year ARI event or smaller floods.

The above result is consistent with the lack of flood-related morphological changes in the Glennies Creek *floodplain surface* observed over the historical period since 1958 (when the first aerial photograph was taken) (Gippel ,2012b). Anecdotal evidence suggests that the *main channel* eroded in association with the 1955 flood event, and aerial photographs evidence further change between 1958 and 1967. These changes were mainly localised expansion of meander bends. Since 1967 the channel has tended to straighten and has been fairly stable, despite riparian vegetation establishing only in recent times (Gippel, 2012b).

The Mannings n values were chosen by the hydraulic modellers (Worley Parsons, 2009a), and are not considered here. Bank erosion control works were mapped, and their significance discussed, by Gippel (2012b). Engineering assessment of potential bank slumping due to saturation would not be warranted unless the SEOC was predicted to alter conditions that would enhance the risk of slumping. As the development would not significantly alter flood depths, and would not influence duration of floods, or rate of fall of water levels during flood recessions, it can be concluded that the SEOC would not impact the risk of slumping of the banks of Glennies Creek.

Yours sincerely

Dr Chris Gippel

References

Erskine, W.D. 1992. Channel response to large-scale river training works: Upper Hunter River, Australia. *Regulated Rivers: Research & Management* **7**: 261-278.

Fischenich, C.J. 2001. Stability thresholds for stream restoration materials. EMRRP Technical Notes Collection (ERDC TNEMRRP-SR-29), U.S. Army Engineer Research and Development Center, Vicksburg, MS.

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Worley Parsons 2009b. Ashton Coal South East Open Cut Project, Geomorphic Assessment of Glennies Creek. Worley Parsons Pty Ltd, Newcastle East. Ashton Coal Operations Pty Ltd, Camberwell, July.

Plots of HEC-RAS model results for Glennies Creek 100 year ARI event from Worley Parsons (2009a), showing comparison of existing and with SEOC proposed development. The model covered 33 cross sections from chainage zero (Hunter River junction) to 8681 metres. Only the section between 1838 and 5174 m chainage (the 14 cross-sections shown on these plots) had differences in elevation, depth and/or velocity between existing and proposed scenarios. Floodplain maximum bed shear stress was not provided in Worley Parsons (2009) but was calculated using their slope and water level data, combined with digital elevation data supplied by Ashton Coal Operations Pty Limited.

ATTACHMENT 4

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File: 12.07.31_SEOC Project - Response to NOW letter to PAC

31 July 2012

Ashton Coal Operations Pty Limited
PO Box 699
Singleton, NSW, 2230

Attention: Michael Moore, Approvals Manager

Dear Michael,

RE: South East Open Cut Project – Response to NOW letter to the PAC dated 9 July 2012

SMEC were engaged by Ashton Coal Operations Pty Limited (ACOL) to review and respond to issues related to flood risk and flood impacts at the South East Open Cut Project (the project) that were raised by NSW Office of Water (NOW) in a letter to the Planning and Assessment Commission (PAC) dated 9 July 2012.

Fluvial Systems have also prepared a letter that address issues related to fluvial geomorphology[1] that were also raised in the NOW letter.

An assessment of the flood characteristics at the project was undertaken by WorleyParsons as part of the Environmental Assessment (EA) for the project[2]. Key staff who prepared the WorleyParsons flood assessment have since moved to SMEC and are the authors of this response letter.

1 Overview of the WorleyParsons Flood Assessment

The SEOC Project Area (the project area) is located within the known flood extents of both Glennies Creek and the Hunter River. Accordingly, the flood risk to the project was recognised and assessed at an early stage of the project design and environmental assessment process. As part of the EA, a detailed flood assessment was prepared by WorleyParsons. This assessment is documented in Section 4 of the Surface Water Assessment (EA Appendix 6)[2]. The WorleyParsons flood assessment is referred to as the Flood Assessment in the remainder of this response letter.

The following sections provide an overview of the Flood Assessment methodology and key recommendations.

Assessment of Glennies Creek Flooding

The Flood Assessment applied the following methodology to assess the Glennies Creek flood characteristics within the project area:

- A Hydrologic model (using the XP-RAFTS software package) was developed for the Glennies Creek Catchment. The model was calibrated using daily rainfall and stream flow data recorded during two moderate flood events that occurred in 1962 and 1970. Once calibrated, the model was modified to include Glennies Creek Dam, which was constructed in 1983. The model was used to estimate the runoff hydrographs from the Glennies Creek Catchment for the 5, 20, 100 year Average Recurrence Interval (ARI) and Probable Maximum Flood (PMF) events.
- Peak discharge hydrographs for a Glennies Creek Dam break scenario were provided by NSW State Water.

[1] Letter titled RE:NOW letter to PAC dated 9 July 2012 on flood and geomorphic Issues (Fluvial Systems, 24 July 2012)
[2] Ashton Coal South East Open Project: Surface Water Assessment (WorleyParsons, 2009)

- A hydraulic model (using the HEC-RAS software package) was developed for the lower portion of the Glennies Creek Floodplain. Downstream boundary conditions were applied based on estimated Hunter River flood levels (explained below under Hunter River flooding). The hydraulic model was used to estimate flood characteristics, such as flood levels and velocities, for the 5, 20, 100 year ARI and PMF events as well as the Glennies Creek dam break scenario.
- The HEC-RAS model was modified to assess flood impacts associated with the project. This was undertaken using the method of applying blockages to areas of the floodplain that will be filled or modified as a result of the project.

Assessment of Hunter River Flooding

The Hunter River is located approximately 2km downstream from the project. During a Hunter River flood event, flood waters are expected to back-up the lower portion of the Glennies Creek Floodplain. Due to the larger contributing catchment area, typically a Hunter River flood peak would occur approximately 24 hours after a flood peak in Glennies Creek. Hence, these events are likely to be relatively independent. This was evidenced by the recorded flood stage within the project area during the June 2007 event (refer to Plate 4-1 in the Flood Assessment)

The Flood Assessment applied the following methodology to assess the Hunter River flood levels within the project area:

- The Department of Water and Energy provided a number of Hunter River flood levels that were surveyed in the vicinity of the Glennies Creek confluence following the 1955 event (refer to Plate 4-2 in the Flood Assessment for flood mark location and survey levels). The 1955 event is the largest flood on record in the Hunter Valley and was estimated to be a 175 year ARI event in the recently completed Singleton Floodplain Risk Management Study[3]. A flood level that was recorded adjacent to the Glennies Creek confluence (62.7 m AHD) was conservatively adopted as the 100 year ARI Hunter River flood level at the project.
- Flood levels for higher recurrence interval events, such as the 5 and 20 year ARI event were not considered overly important as flood mitigation measures were to be established based on higher magnitude flood events such as the 100 year ARI event. Accordingly, flood levels for these events were established using interpolation methods.
- As the assessment methodology was based on a review of historic flood levels, no assessment of extreme events such as the PMF was undertaken. This is considered appropriate as any flood that results in the levee overtopping would have the same consequence (i.e. inundation of the pit). Hence the flood risk to the pit can be reliably estimated based on the design level of flood protection provided by the levee.

Key Conclusions

WorleyParsons made the following key conclusions from the Flood Assessment:

- Peak flood levels at the project would be governed by Hunter River flood events. Accordingly, the 1955 Hunter River flood level of 62.7 m AHD was adopted as the 100 year ARI flood level for the project. As explained above, this is considered conservative as the 1955 is considered to be a higher magnitude flood than the 100 year ARI event.
- Peak flow velocities in Glennies Creek are governed by a Glennies Creek event. This is because back-water flooding from the Hunter River would be characterised by either slow moving or stagnant water.
- A Glennies Creek Dam break scenario would result in the highest perceivable flood levels within the project area, with estimated levels within the project area ranging between 73.2 to 79.5 m AHD. These high flood levels are associated with the large volume of water that would be released in the unlikely event of a dam failure.

[3] Singleton Floodplain Risk Management Study: Exhibition Report (Paterson Consultants, 2011)

- An assessment of the project's potential flood impacts concluded that the potential impacts on local flooding in Glennies Creek and regional flooding in the Hunter River are considered to be insignificant. This is discussed in more detail in Section 3 of this response letter.

Proposed Flood Mitigation Measures

The Flood Assessment clearly identified that without flood mitigation measures, the proposed pit would be inundated by minor flood events such as the 5 year ARI event. Accordingly, a levee was proposed to substantially reduce the flood risk to the pit. A minimum levee height of 64m AHD was adopted based on the abovementioned flood planning level of 62.7 m AHD plus a 1.3m freeboard. The Flood Assessment describes this levee as providing 100 year ARI flood protection for the pit. This is considered to be conservative for the following reasons:

- As noted above, the 1955 event is estimated to be a 175 year ARI event at Singleton[3]. The Singleton Gauge is the closest gauge to the project area that has a sufficiently long term record to enable the estimation of the ARI of major flood events (such as the 1955 event) using flood frequency analysis methods.
- The adopted freeboard of 1.3m is well in excess of the 0.5m freeboard that is generally applied when establishing flood planning levels in NSW. Hence, the adopted 1.3m freeboard adds contingency to the assumed level of flood protection that the levee provides.

Based on the above discussion, SMEC considers that the proposed levee would provide greater than 150 year ARI flood protection for the pit. This level of flood protection applies conservatism through:

- For the purposes of estimating flood risk at the project, the assumed ARI at the Glennies Creek confluence for the 1955 event has been reduced from 175 years (as estimated at Singleton) to 150 years.
- Application of a larger than normal freeboard.

2 Assessment of Flood Risk at the SEOC Project

The NSW Government's Floodplain Development Manual[4] recommends that a risk based approach is applied to assessing flood planning levels. This section assesses the flood risk during the operational and post mine closure periods of the project in this context.

Flood Risk during the Mine Operation

During Year 1 of the mine plan, the pit will commence in higher ground with mining generally occurring above the 68m AHD level (Refer to Figure 17 in Flood Assessment[2]), over 5m above the 1955 flood level (62.7 m AHD). Hence, the flood risk to the pit during the initial year of mining is negligible. For the remainder of the mine life (6 years), the flood protection levee will be required to mitigate the flood risk to the pit. Should an event of greater magnitude than the 150 year ARI occur during the 6 year risk exposure period, there is a risk that floodwaters will overtop the pit. The consequences of this occurring are discussed as follows:

- **Risk to life**: Given that the flood warning time for a Hunter River event is greater than 24 hours, there would be sufficient time to enable a full evacuation of the pit and other areas of the mine that would be potentially exposed to flood risk should the levee overtop or fail. As part of the statement of commitments for the project, ACOL will develop a flood emergency response plan that will formalise evacuation triggers and procedures. Hence, it can be concluded that the risk to life can be adequately managed by evacuation.
- **Environmental Risk**: If flood waters overtop the levee, it is possible that the pit would become fully inundated and would require dewatering. This would most likely require the release of potentially poor quality water to receiving waters, resulting in a temporary degradation of receiving water quality. The environmental risk could be managed by timing the dewatering with periods of naturally high flows (which should be in abundance following a major event) to maximise the dilution of released water and minimise the overall environmental risk. This management option is noted by

[4] Floodplain Development Manual (Department of Infrastructure, Planning and Natural Resources, 2005)

NOW in their letter. It is also noted that should a greater than 150 year ARI flood occur in the Hunter Valley, the water management system for most open cut mining operations would become overwhelmed and water releases would be required.

- **Commercial Risk**: If the pit was to become inundated by flooding, it is likely that mining schedules would be significantly disrupted and some mining infrastructure and equipment would be damaged. This risk has been considered by ACOL.

In SMEC's view, the 150 year ARI level of flood protection provided by the proposed levee design is appropriate for the following reasons:

- The proposed levee would provide flood protection for all Hunter River flood events on record. Hence, an event of greater magnitude than the 1955 event would be required for the levee to overtop. In the unlikely event that this should occur:
  - Risk to life can be adequately managed by evacuation.
  - Environmental risk associated with dewatering flood water that enters the pit would be temporary and could be mitigated by dilution through releasing water during periods of high flow in the receiving waters.

Flood Risk Post Mine Closure

ACOL have revised the final landform to accommodate a berm that will be built to 80m AHD (refer to Attachment 1 for section drawings). This berm will be constructed between the final void and Glennies Creek and will effectively prevent the ingress of flood waters into the final void under any conceivable event, including a Glennies Creek Dam Break event. Hence, it can be concluded that there is no risk that floodwaters will enter the final void following mine closure. This effectively manages the long term flood risk profile of the final landform design.

3 Response to NOWs Comments

This Section specifically addresses the flood related issues that were raised by NOW in a letter to the PAC dated 9 July 2012. For the benefit of readability, NOW issues have been paraphrased in italic font. SMEC responses are provided in normal font.

Issue 1 (Page 1, paragraph 3 and 4) – "*The levee provides protection up to the 100 year ARI event. There is limited discussion or outcomes of an event of a greater magnitude, or if the levee were to fail either during the operational or post mine operations. The impact of levee overtopping or failure could include:*

- *Complete inundation of the pit.*
- *Disposal of contaminated water from the pit following inundation.*
- *The potential for flood water to flow through the pit, carry unconsolidated material downstream into Glennies Creek and the Hunter River.*
- *Possible channel avulsion should flows pass though the pit."*

SMEC Response – Section 2 of this response letter discusses the flood risks at the project. In addition to the discussion in Section 2, SMEC makes the following points:

- In the event that the levee overtops, it is unlikely that flood water would flow though the pit. Rather flood water would enter the pit until either the pit is fully inundated or flood levels recede to a level below which water will cease entering the pit. It is unlikely that any substantial volume of water would flow from the pit into receiving waters.
- The channel avulsion risks are discussed separately in a response prepared by Fluvial Systems[1].

Issue 2(Page 2, paragraph 2) – "*Excluding the dam failure scenario, consideration should be given to reducing the risk of levee overtopping during the operational phases by raising the levee to cater for the PMF event. Raising the levee by 1 m to 65m AHD would achieve 1 m freeboard over the PMF*"

SMEC Response – This analysis is technically incorrect as it is based on the reported PMF levels at the project for a Glennies Creek flood event, and does not consider PMF levels from a Hunter River flood event. As discussed in Section 1 of this response letter, flood levels at the project are governed by backwater flooding from the Hunter River. This will certainly be the case for the PMF. Hence, for a levee to achieve a PMF level of flood protection, it would need to be constructed to the Hunter River PMF level. The Hunter River PMF level was not estimated as part of the Flood Assessment as any flood that results in the levee overtopping would have the same consequence (i.e. inundation of the pit). Hence, the flood risk to the pit can be reliably estimated based on the design level of flood protection. As discussed in Section 2 of this response letter, the proposed flood levee would provide a greater than 150 year ARI level of flood protection, which in SEMC's view, provides an appropriate level of flood risk mitigation.

Issue 3 (Page 2, paragraph 4) – "*The flood protection works and associated mine infrastructure will inevitably exacerbate the impacts of flooding events within the riverine system. Restricting the floodway adjacent to the mine will inevitably increase the height of individual events, raise the velocity of flows and increase the likely hood of scouring*"

Section 8 of the Flood Assessment quantified the predicted impacts to local and regional flooding resulting from the project. To summarise, the following flood impacts are predicted:

- Impacts to flow conveyance in Glennies Creek were assessed using the HEC-RAS model described in Section 1 of this response letter. The modelling predicted that minor impacts to flow conveyance would occur as a result of the ROM pad encroaching into the predicted 100 year ARI Glennies Creek flood extent (refer to Figure 11 in flood assessment). Modelling indicates that this will result in a localised water level increase of up to 30mm and a localised velocity increase of up to 16% during a 100 year ARI Glennies Creek flood event. These impacts are not considered significant from a flooding perspective. It is noted that these potential impacts would be temporary as the ROM pad will be removed as part of the mine closure and rehabilitation plan.
- The project will result in the loss of approximately 1,157 ML of existing flood storage in the Glennies Creek floodplain during a 100 year ARI Hunter River flood event. The Flood Assessment concluded that the impact of this displaced flood storage on the flood characteristics of the Hunter River is likely to be insignificant due to the displaced storage volume being only a small fraction of the total storage volume in the Hunter River Floodplain.
- The project is not expected to have any impact on Hunter River flow conveyance.

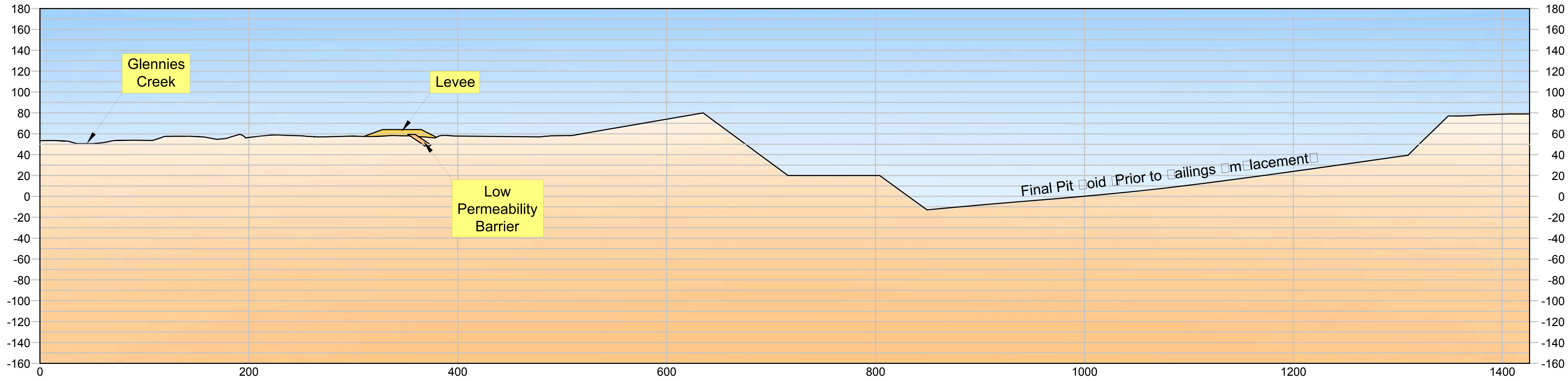
Fluvial Systems have assessed the above flood impacts in relation to associated impacts on fluvial geomorphology[1]. Refer to their response letter for further details.

Yours sincerely,

Ben Patterson
NSW Manager, Water Resources

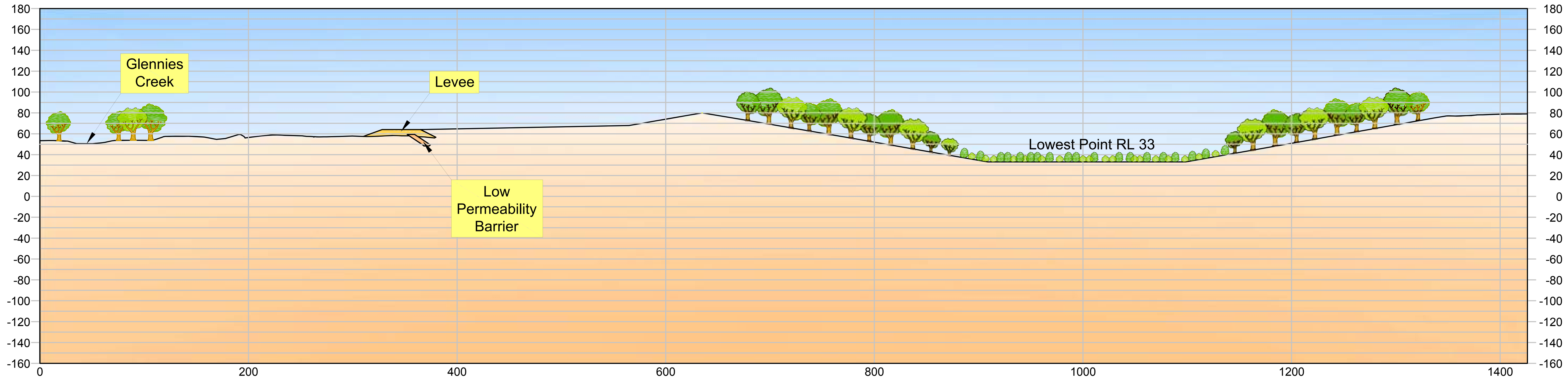
Attachments

Attachment 1 –*Section Drawings of the Final Void*



Section B-B[1]

Scale 1:400



Section C-C¹

Scale 1:400

AshtonCoal

SEOC Final Landform Section

Figure 10

Cad File Ref:08575B.dwg

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ATTACHMENT 5

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PARSONS BRINCKERHOFF

Parsons Brinckerhoff Australia Pty Limited

ABN 80 078 004 798

Level 3 51-55 Bolton Street
Newcastle NSW 2300
PO Box 1162
Newcastle NSW 2300
Australia
Tel: +61 2 4929 8300
Fax: +61 2 4929 8382
Email: newcastle@pb.com.au

www.pbworld.com

Certified to ISO 9001, ISO 14001, AS/NZS 4801
A+ GRI Rating: Sustainability Report 2010

23 July 2012

Mr Brian Wesley
General Manager
Ashton Coal Operations
PO Box 699
SINGLETON NSW 2330

Our ref: 2172775A/LT_0388

Dear Sir

Ashton Coal Levee Integrity

Parsons Brinckerhoff has been requested by Mr John Quinn of John Quinn Projects on behalf of Ashton Coal Operations to respond to comments received from the NSW Office of Water (NOW) relating to the proposed levee at Ashton Coal. The levee is part of the proposed South East Open Cut (SEOC).

We understand that the concerns from NOW relate to levee stability under a flood event in particular:

'*The likelihood of either the levee slumping or overtopping with subsequent failure are both increased due to the construction of the levee on unconsolidated alluvial material. This needs to be addressed in any levee design*.'

This letter outlines the levee design characteristics and the foundation conditions, and comments on the adequacy of the design concept.

1. Levee design characteristics

Figure 1 is an extract from Parsons Brinckerhoff drawing no. 2123195A – CIV – 0508 – B and illustrates in section some of the key levee characteristics, namely:

- The levee is formed by the ROM pad Zone 2 earthworks protected on the outer (Glennies Creek) side by a Zone 1 select clayfill zone.
- The Zone 1 select clayfill is 5 m wide and has a 2.5H:1V upstream face batter.
- The clayfill zone features a 1 m deep foundation cutoff.
- The downstream batter on the pit side is 2H:1V.

The clay liner is required to minimise the ingress of water following any flood event. A 5.0 m width was chosen for constructability to allow for the safe movement of plant and equipment to construct the liner. At a 2.5H:1V slope, it also equates to an approximately 2 m thick clay layer when measured perpendicular to the slope.

The foundation cut off is a typical provision for levee type structures. It reduces the likelihood of seepage through the foundation and associated risk of piping. The 1 m depth key will usually penetrate to the base of cracking in clay soils.

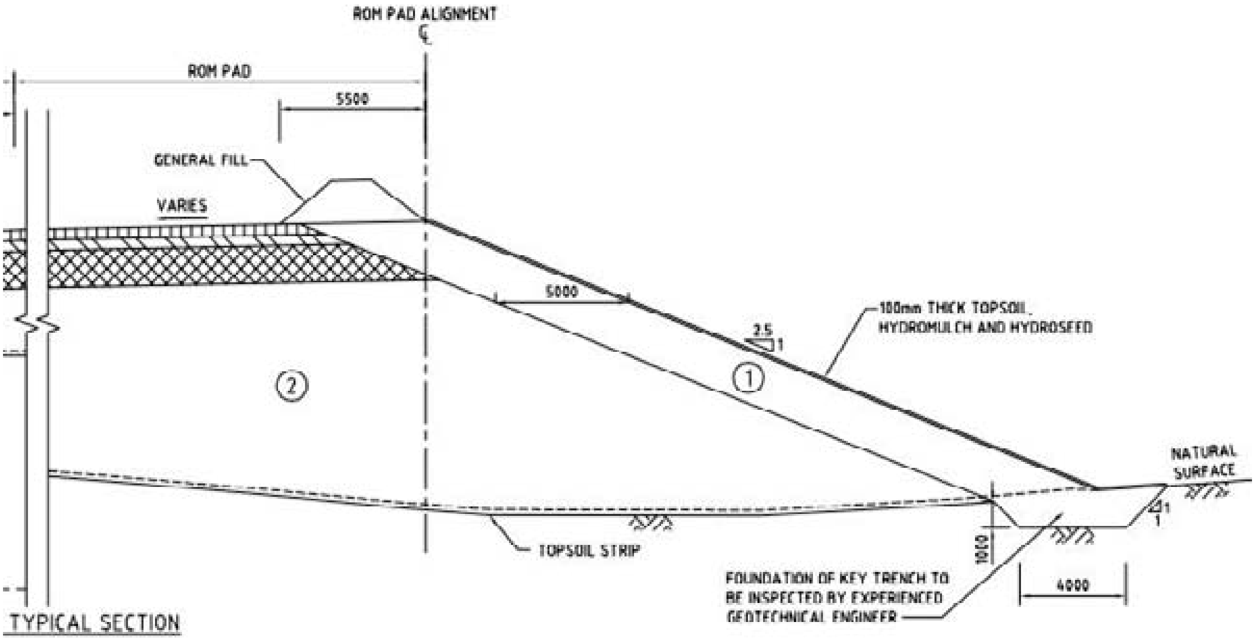

Figure 1 Ashton Levee typical section (source: PB drawing 2123195A – CIV – 0508 – B)

2. Foundation conditions

With reference to the Parsons Brinckerhoff geotechnical report for the Proposed Mine Infrastructure Area, Levee, Run-Of-Mine Pad and Dump Station, Ashton Coal South East Open Cut Project (reference: 2123195A/PR_0154 dated April 2010), the subsurface conditions encountered at the location of the levee, run-of-mine pad and dump station area were described as follows:

'The test pits and boreholes generally encountered topsoil at depths to between 0.1 m and 0.2 m. This was underlain by alluvial clayey silt, very stiff to hard sandy clay, and medium dense silty sands.

Bedrock was countered at depths of 8.1 m and 11 m in BH08 and BH09 respectively and comprised extremely weathered, extremely low strength conglomerate, underlain by distinctly weathered, medium to low strength siltstone and sandstone. Borehole BH09 encountered a layer of medium dense to dense sandy gravel from a depth 7.0 m to 11 m which may correlate to the conglomerate encountered in BH08, but in a more weathered state.

Groundwater was encountered in BH08 at a depth of 6.2 m. BH08 at a depth of 6.2 m.'

3. Design concept adequacy

The concerns specifically raised by NOW in the comments received are levee slumping and overtopping with subsequent failure due to construction of the levee on unconsolidated alluvial material.

The geotechnical report referenced above indicates that the soil profile underlying the levee generally comprises medium dense to dense sands and gravels and very stiff to hard silts and clays. These soils are unlikely to settle excessively and would provide good foundation strength even when saturated.

Therefore, loss of crest height due to settlement is likely to be small and within the normally accepted tolerances. In addition the stability of the levee batters should be able to be managed with appropriate batter slope design taking into account the strength of the underlying alluvial sediments and compacted levee earthfill and the range of loading and pore pressure conditions normally considered for hydraulic embankment design.

We trust that this letter adequately addresses the concerns raised by NOW. Should you wish to discuss this further, please contact Cesar Martinez or the undersigned on (02) 4929 8300.

Yours faithfully

Robert Kingsland
Principal Geotechical Engineer
Parsons Brinckerhoff

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ATTACHMENT 6

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Review of Glennies Creek flood and geomorphology information in relation to South East Open Cut Project

Christopher Gippel

Fluvial Systems Pty Ltd

For Ashton Coal Operations Pty Ltd

22 June 2012

FLUVIAL SYSTEMS

GEOMORPHOLOGY • CATCHMENT HYDROLOGY
RIVER REHABILITATION • ENVIRONMENTAL FLOWS

Fluvial Systems Pty Ltd
PO Box 49
Stockton N.S.W. 2295
Australia

Tel: +61 2 49284128
Fax: +61 2 49284128
Mobile: 0404 472114
Email: chris.gippel@bigpond.com
ABN: 71 085 579 095

1 Scope of this report

This report is in response to a request by Ashton Coal Operations Pty Ltd (ACOL) to provide:

- A review of the South East Open Cut Environmental Assessment (SEOC EA) in relation to flood hydrology (Chapter 4 in Worley Parsons, 2009a) and fluvial geomorphology (Worley Parsons, 2009b) assessments;
- Expert comment and or advice in response to the concerns raised by Alistair Bowman in his presentation to the Planning Assessment Commission (PAC) in early June 2012 (these concerns were provided in the form of ACOL notes on Mr Bowman's presentation and an email from M Webb (PAC) to D Harriss (NSW Office of Water) dated 13 June 2012); and
- Comment on any other aspect of the project that is relevant to Mr Bowman's concerns (e.g. adequacy of flood levy, effect of change to floodplain volume and flood velocities due to the project, stability of Glennies Creek, etc.).

2 Review of Flood Hydrology

Worley Parsons (2009a) followed standard practice in modelling the flood hydrology of Glennies Ck and the Hunter River, and appropriate parameter values appear to have been selected. The 1 in 5, 20, 100 year and PMF (Probable Maximum Flood) events were considered for Glennies Creek and the Hunter River.

Probable Maximum Precipitation (PMP) is "...the greatest depth of precipitation for a given duration meteorologically possible for a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends." (World Meteorological Organisation, 1986). The PMP magnitude, plus its spatial and temporal distributions, is used to calculate the PMF. The PMF concept is non-probabilistic and is considered to represent the most severe combination of meteorological and hydrological conditions that are reasonably possible in a region. This approach does not provide an explicit estimate of the probability of occurrence associated with the PMF flow. The frequency of the PMP and PMF will vary from location to location, reflecting the physical context of the catchment. While it is not possible to state the return period of the PMF in Glennies Creek or the Hunter River, it would likely be in the order of 10,000 years or more.

Observed flood levels from 2007 supported the assumption that under a regional flooding situation, Glennies Creek would peak before the Hunter River. Thus, Glennies Creek floods were modelled on the basis of relatively low tailwater levels in the Hunter River. Under a regional flooding situation, the severity of flooding in the lower Glennies Creek floodplain (in the vicinity of the SEOC) is associated more with floodwater from the Hunter River than from Glennies Creek. In the unlikely event that Glennies Creek peaked at the same time as the Hunter River, it was predicted that the extent and elevation of flooding would still be overwhelmingly controlled by Hunter River flows.

The flood planning level adopted by Worley Parsons (2009a) was 64 metres AHD, which was set as 1.3 m above the predicted Hunter River 100 year ARI flood level of 62.7 m. Worley Parsons (2009a) did not indicate what flood recurrence interval 64 m was associated with, but the data suggest that a flood level of 64 m is associated with a rare event (Figure 1). The likely reason why this was not estimated is the lack of a nearby flow gauge with historical flow data on which to base a detailed flood frequency analysis. In the report, the 100 year ARI event was based on an estimated profile of the 100 year ARI event for the Hunter River. The peak 100 year ARI event water level for the ACOL site (62.7 m) (Figure 1) was determined by interpolating between flood levels that were measured upstream (at Muswellbrook) and downstream (at Singleton) from the junction of Glennies Creek. It is generally assumed that the 1955 flood approximated the 100 year ARI event. In fact, near Glennies Creek this flood reached an elevation of 63 m, or 0.3 m higher than the 100 year ARI event profile (Plate 4-3 in Worley Parsons, 2009a).

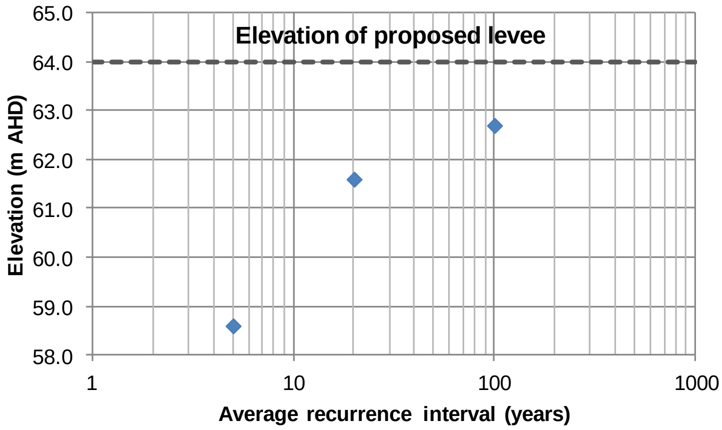

Figure 1. Modelled flood frequency of the Hunter River near Glennies Creek. Data are from Worley Parsons (2009a, p. 39).

Worley Parsons (2009a) also estimated the PMF for Glennies Creek under conditions of Glennies Creek Dam intact, and Glennies Creek Dam breached. Under the scenarios of the dam intact, the highest elevation of the river was estimated to be 63.84 m at the upstream cross-section (i.e. limit of model) and 60.28 m at the downstream cross-section. The upstream cross-section is not relevant to the SEOC, because the New England Highway lies between the upper cross-sections and the SEOC and is at a sufficiently high elevation to prevent flood water flowing directly south to the mine. So, the SEOC-relevant elevation for the PMF in Glennies Creek would be lower than 63.84 m but higher than 60.28 m. A PMF with dam breach would be a much more serious event, predicted to reach an elevation of 79.47 m at the upstream cross-section and 73.19 m a the downstream cross-section.

The PMF analysis in Worley Parsons (2009a) was for Glennies Creek only. The other flood assessment work in Worley Parsons (2009a) determined that the severity of flooding in the vicinity of SEOC was determined by the Hunter River more so than Glennies Creek. However, it was not necessary for Worley Parsons (2009a) to undertake modelling to confidently state that a Hunter River PMF event would inundate the SEOC. Most developments on rivers are designed to protect against damage or inundation by a flood that occurs more frequently than the PMF. Protection of the SEOC against the PMF would not be feasible so the project was designed to protect against the 100 year ARI flood, allowing for a factor of safety. The PMF analysis was undertaken by Worley Parsons (2009) to establish the absolute upper limit of flood depth, and to establish that in the highly unlikely event of a PMF the mine would be inundated and appropriate action would need to be taken.

In consideration of the flood assessment, Worley Parsons (2009a) recommended construction of a levee to 64 m, which would protect against inundation by the Hunter River 100 year ARI event with 1.3 m freeboard (equivalent to a flood at the same level as the 1955 event with 1 m freeboard).

3 Review of Fluvial Geomorphology

Worley Parsons (2009b) investigated the geomorphic processes by comparison of historical aerial photographs and evaluation of predicted velocities on Glennies Creek floodplain under flood conditions.

The aerial photographs from 1958 to 2007 indicated that between 1958 and 1996 the channel of Glennies Creek generally straightened, and there was no significant tendency to migrate towards the proposed pit of the SEOC. From 1996 to 2007 the channel position remained essentially stable.

One of the main concerns addressed by Worley Parsons (2009b) was the risk of channel avulsion towards the SEOC (the stream suddenly cutting a new straighter course through the floodplain under a flood event). This process occurs through scour of the surface of lower-lying areas of the floodplain, initiating at the downstream end and rapidly working upstream. Avulsion is normally associated with highly sinuous rivers with perched and naturally leveed channels, where the water escaping to the floodplain represents the great majority of the flow, and is relatively deep and fast flowing (Brizga and Finlayson, 1990). An incised channel, such as Glennies Creek, would not normally be prone to avulsion, as the majority of flood flow remains within the main channel, and overbank flows do not reach particularly high velocities or great depths.

A hydraulic model was used by Worley Parsons (2009b) to predict velocities on the floodplain under conditions of 100 year and 500 year ARI events in Glennies Creek. This modelling assumed no major flood in the Hunter River. Under Hunter River flood conditions the Glennies Creek floodplain would be inundated and velocities would be quite low. Under a major regional flood situation, Glennies Creek would flood first, and subsequently the lower Glennies Creek floodplain would be inundated by Hunter River flood waters. So, the analysis of Worley Parsons (2009b) refers to worst-case velocity conditions on Glennies Creek floodplain.

Worley Parsons (2009b) estimated floodplain velocities at 8 sites. Under 100 year ARI conditions, velocities ranged from 0.2 to 1.2 m/s, but only one site exceeded 0.7 m/s. Under 500 year ARI conditions, velocities ranged from 0.3 to 1.5 m/s, but only one site exceeded 0.9 m/s. Worley Parsons (2009b) concluded that these velocities would not present a risk of floodplain scour on the basis of the assumption that grass surfaces would withstand velocities up to 1.7 m/s. This is known as the “maximum permissible velocity” approach to assessment of erosion risk. Tables of maximum permissible velocity appear in many channel design, engineering and hydraulics publications (e.g. Chang, 1988). These values assume a bare channel surface (i.e. no grass or other lining or vegetation). Vegetation failure usually occurs at much higher levels of flow intensity than for soil (Fischenich, 2001). Bare soil material would be at risk of fluvial erosion under conditions of velocity exceeding approx. 0.8 m/s for short duration events, and conditions of velocities exceeding approximately 0.4 m/s for long duration events (longer than half a day). A grass covered surface would be at risk of erosion for velocities exceeding 2 m/s for short duration events and conditions of velocities exceeding approximately 1.5 m/s for long duration events (longer than half a day) (Fischenich, 2001). These values of maximum permissible velocity are in general agreement with the value of 1.7 m/s used by Worley Parsons (2009b). So, this approach suggests low risk of scour of the floodplain, provided it has good grass cover.

The weakness of the maximum permissible velocity approach is that the likelihood of scour is more dependent on bed shear stress than velocity. Most of the tabulated values of maximum tolerable velocities assume a certain depth of flow typical of drainage channels (in the order of 1 – 2 m), when in fact the risk of scour increases with depth of flow. Bed shear stress is flow depth and slope dependent, so is a preferred way of assessing scour risk. Maximum permissible shear stress is the maximum bed shear stress that will not cause serious erosion. Tables of maximum permissible shear stress appear in many channel design, engineering and hydraulics publications (e.g. Chow, 1981; Chang, 1988), and they are all based on values given by the U.S. Bureau of Reclamation (Lane, 1952; Carter, 1953). Alluvial silty soils have a maximum permissible shear stress of 12.5 N/m^2. When soil is covered by vegetation its resistance to scour is considerably enhanced. A critical shear stress in the range 100 – 200 N/m^2 is a reasonable guide to the shear stress required to scour grass covered surfaces (Fischenich, 2001).

Worley Parsons (2009b) did not indicate the depths of water on the floodplain, but Figure 14 in Worley Parsons (2009a) suggests that in the vicinity of the SEOC, under 100 year ARI conditions the flow over the floodplain would be about 2.5 m in proximity of the channel, and shallower than this over the majority of the floodplain. The slope of the water surface of the 100 year ARI event varies across the extent of the SEOC, but at its steepest is approximately 0.00125 (from Figure 14 in Worley Parsons, 2009a). These parameter values suggest that the maximum shear stress on the floodplain under 100 year ARI conditions would be approximately 30 N/m^2. This is well below the threshold for risk of scour of a grassed surface, so in this case it is in agreement with the assessment based on maximum permissible velocity.

Worley Parsons (2009b) recommended that the flood protection levee be designed to resist scour from floods. This is an appropriate recommendation. However, as well as scour erosion, the levee would also be subject to risk of slumping failure, upon the recession of a prolonged high flood event. This needs to be taken into account in designing the geotechnical properties of the flood levee.

4 Addressing the Concerns of Alistair Bowman

The map of 1955 flood extent provided by Mr Bowman is virtually identical to the map of the predicted extent of the 100 year ARI flood provided by Worley Parsons (2009a) in their Figure 11. So, there is nothing new or surprising about this map in the context of the flood assessment undertaken by Worley Parsons (2009a). The proposed levee will be 1 m higher than the elevation of this flood.

The map depicts “washouts and slips (shown in red)” which it was claimed were associated with the 1955 flood, plus “another washout (shown in pink – date unknown)” (according to email from M Webb to D Harriss). These so-called washouts are identifiable as areas of lower-lying land on aerial photographs and the digital elevation model. The earliest available aerial photograph was flown in 1958, so it might be possible to determine if these formed in 1955 (if the washouts appear unvegetated). However, the main channel did not follow the alignment of the washouts in 1958 or any other photographed year. It is possible that the outer extent of these features represents the line of the banks of a former course of the river (prior to 1958).

The flood of 1955 was a major event in the Hunter Valley, and it was the last of a sequence of other notable floods that occurred over a period beginning in 1949. This period of high flood activity caused major, but variable geomorphological impacts to rivers and streams in the Hunter Valley (Erskine 1992). The size of these events, plus their high frequency, meant that there was insufficient time for vegetative recovery between events. In fact, prior to the onset of this period of flood activity Glennies Creek was devoid of natural riparian vegetation, having been cleared in association with agricultural activities (Figure 2 and Figure 3).

Figure 2. Glennies Creek New England Highway crossing. Photographs dated 1936. Left is looking west from Camberwell and right is looking east. Photographs from State Library NSW (cannot be copied or reproduced).

Figure 3. Glennies Creek New England Highway crossing. Photographed dated 1947. Photograph from State Library NSW (cannot be copied or reproduced).

River training works were undertaken in NSW in response to the channel changes following floods in the period 1949-1955 (including in Glennies Creek). According to Erskine (1992), referring to the Hunter River between Aberdeen and Bureen, upstream of Glennies Creek, "The channels would have recovered naturally, to some extent, from this damage". Erskine (1992) was of the opinion that in the Hunter River the works controlled channel migration and bank erosion to such an extent that the river no longer derived sediment through re-working of bank and floodplain deposits. This led to undesirable bed degradation (lowering of the bed through scour). The same processes would likely have applied at Glennies Creek. The form of stabilisation works undertaken after 1955 is no longer popular, with the current fashion being to allow geomorphological processes to proceed at their natural rates. One natural geomorphological process that has a positive association with ecological health is bank erosion (Florsheim et al., 2008). According the Erskine (1992), "the cause of the channel changes on the upper Hunter River was essentially natural".

Glennies Creek, like all other streams in the Hunter, would be expected to undergo geomorphological change under conditions of a 100 year ARI event. In Glennies Creek, these changes would not likely involve channel avulsion. Meander migration would be expected, but this is a natural process that is characteristic of healthy rivers.

While all streams are likely to undergo some geomorphological change under conditions of major floods, their inherent stability against catastrophic change is enhanced by good vegetative cover, while their fragility is exposed by removal of riparian vegetation, stock access and clearance of floodplain vegetation for cropping and pasture.

5 References

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Worley Parsons 2009a. Ashton Coal South East Open Cut Project, Surface Water Assessment. Worley Parsons Pty Ltd, Newcastle East. Ashton Coal Operations Pty Ltd, Camberwell, August.

Worley Parsons 2009b. Ashton Coal South East Open Cut Project, Geomorphic Assessment of Glennies Creek. Worley Parsons Pty Ltd, Newcastle East. Ashton Coal Operations Pty Ltd, Camberwell, July.

Appendix 4 – Other Correspondence received by the Commission

Correspondence raising issues for consideration by the Commission received from special interest groups and members of the public:

1. 23 May 2012 – correspondence from the Hunter Valley Water Users Association
2. 31 May 2012 – Copies of presentations made at the public meeting, from:
    a. Singleton Council
    b. Alistair Bowman
    c. Darrel Watling
    d. Singleton Healthy Environment Group
    e. Nature Conservation Council
3. 31 May 2012 – correspondence from a member of the public who requested confidentiality
4. 4 June 2012 – additional information from Ms Wendy Bowman
5. 5 June 2012 – additional information from Mr Alistair Bowman
6. 7 June 2012 – additional information from Ms Wendy Bowman
7. 7 June 2012 – additional information from Mr Alistair Bowman
8. 12 June 2012 – additional information from a member of the public who requested confidentiality
9. 16 August 2012 – additional information from a member of the public who requested confidentiality

Key correspondence from the Proponent is listed in Appendix 3, other correspondence from the Proponent is listed here:

1. 18 April 2012
2. 27 April 2012
3. 1 May 2012
4. 8 May 2012
5. 18 May 2012
6. 25 May 2012
7. 28 May 2012
8. 18 June 2012
9. 6 July 2012