Foxground and Berry Bypass
Princes Highway Upgrade

Berry Bypass Route Comparison

External Review of the RMS Findings

June 2012

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EXECUTIVE SUMMARY

In February 2012, the NSW Government through the Member for Kiama announced the RMS would review costings related to a possible southern bypass of Berry. A Technical Investigation Group (TIG) was formed to develop a concept design for a southern route with sufficient detail to also produce a comparative strategic cost estimate, so that the feasibility of the southern bypass route could be compared to the currently preferred northern route. In March 2012, the RMS General Manager Project Development requested SMEC Australia to lead an independent External Review Team with its principal objective to observe and record the nature of the process undertaken by the TIG and to ensure it has been thorough and even handed when evaluating the strategic cost estimate for the southern bypass and the technical inputs required to produce it.

The External Review Team conclude that:

- The technical investigations have been undertaken in an unbiased and even handed manner to allow a 'like for like' comparison of concept design for both northern and southern bypass routes of Berry.
- Based on information provided by members of the community, the TIG has prepared a concept design for a southern route that with the inclusion of adjustment items could be compared to the current concept design of the northern route.
- A comparative route design and cost estimate has been prepared in the limited timeframe, and all reasonable measures have been taken by the TIG within the time available to ensure a 'like for like' comparison of both routes.
- The design of a southern route would have a number of technical challenges to overcome to be considered viable, and these have added costs to the southern option.
- In general, the TIG has applied sound engineering principles to both routes and sought to identify solutions that are both practical and feasible to implement. The work undertaken by the TIG has also been completed in accordance with RMS procedures and best practice guidelines.
- A thorough assessment of the constructability has been undertaken and that this information has been taken into account in the preparation of the comparative estimates. All innovations considered by the TIG have including an appropriate risk consideration in the comparative estimates.
- A consistent approach has been applied to both route options and the TIG has followed RMS procedures to address the risks and contingencies for both options. The level of contingency is appropriate for the strategic estimates which have been developed for these comparative estimates.
- The two estimates provided by the TIG are directly comparable, balanced and reasonable for strategic estimates. Adjustment Sums have been included in the estimate for the southern route to allow for a number of developments to the concept design during the comparative cost estimate preparation process; The External Review Team have undertaken a robust review of the estimating process and have completed independent checks of these estimates.
- The end result being the strategic cost estimate for the northern option is approximately $166 million less than the estimate for the southern option based on a reasonable 'like for like' comparison.

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1 INTRODUCTION

1.1 Background to the Review

The Princes Highway Upgrade - Foxground and Berry Bypass (FBB) ('the Project') has been in the planning stage for many years. NSW Roads and Maritime Services (RMS), and its predecessor, the Roads and Traffic Authority (RTA) has conducted a number of environmental and engineering studies together with significant community and stakeholder consultation to inform the development of the concept design. The project will be funded by the NSW Government.

With regard to the township of Berry, the current preferred bypass route runs across the northern edge of the town linking to the Princes Highway at either end. This route has been refined in consultation with the community.

Some members of the community have made a separate submission to the Minister for Roads and Ports requesting that further work be undertaken on an alternative southern bypass route. This runs further south of Berry, crossing over an existing railway corridor at two locations linking to the Princes Highway at either end. Both bypass routes cross a floodplain which is traversed by Broughton Mill Creek and Broughton Creek.

The preferred northern route and suggested southern routes are shown in Figure 1. These are detailed in the TIG Report.

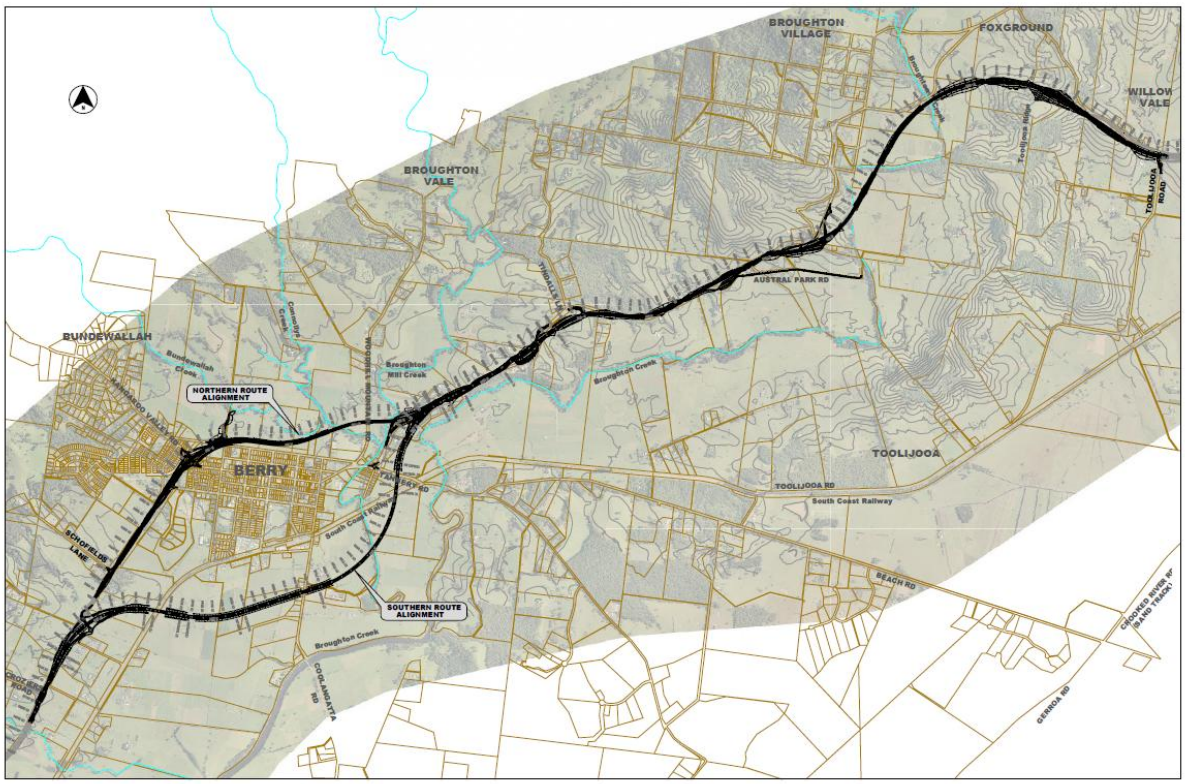

Figure 1 Proposed Foxground and Berry Bypass Route showing both the proposed Northern and Southern Route Alignments

Figure 2 shows the different alignments considered for the proposed southern bypass route. These are described in the TIG Report.

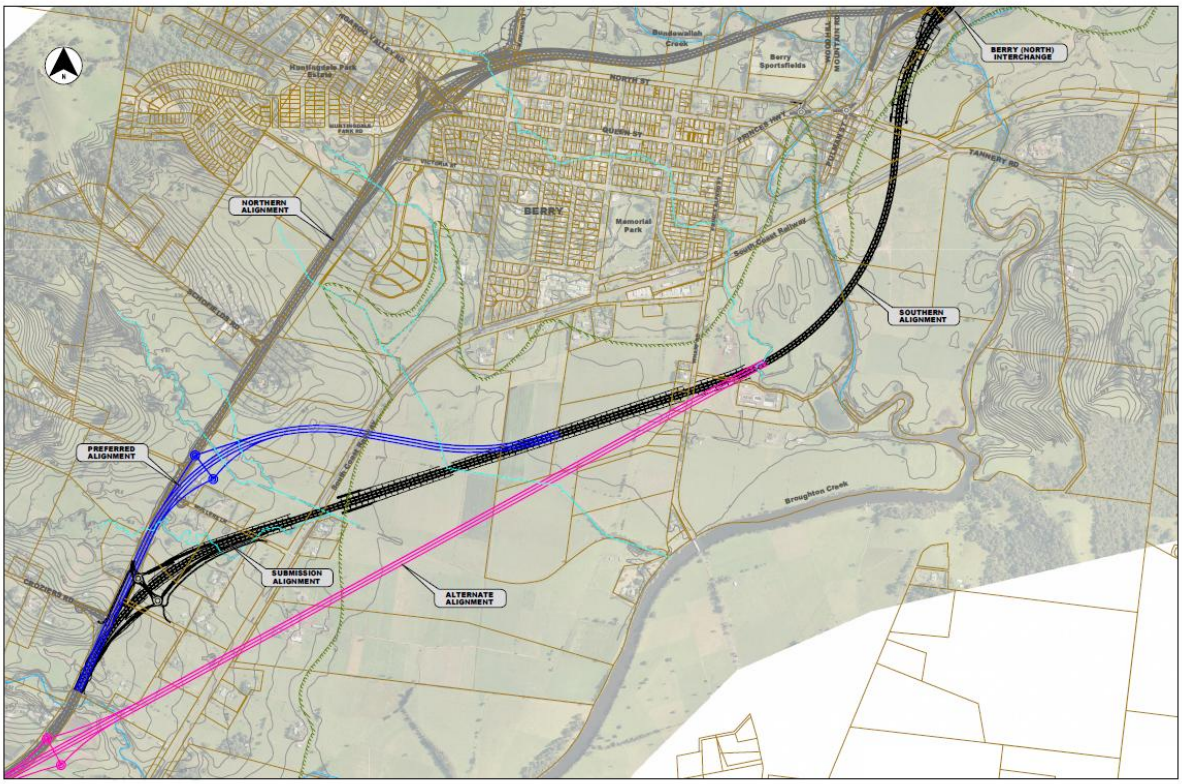

Figure 2 Proposed Berry Bypass Route showing the Proposed and the Preferred Southern Alignments

1.2 Technical Investigation Group

RMS established a Technical Investigation Group (TIG) to examine the Berry Bypass southern route and to undertake sufficient work to develop a strategic cost estimate that would allow a comparison with the northern bypass route.

As stated in Section 3.2 of the comparative costs estimate report prepared by the TIG, the TIG is responsible for the following tasks:

- Develop an indicative route bypassing Berry to the south with sufficient information to produce a robust strategic cost estimate
- Use its best endeavours to:
  - optimise the southern route to minimise property impacts and land severance
  - engineer a cost-effective southern route solution
  - apply any benefits found on the southern route to the northern route where applicable, and vice versa
- Complete investigations required for both southern and current northern route to produce robust strategic cost estimate

- Evaluate the feasibility of the southern bypass route by comparing it to the currently preferred northern bypass route within the context of the whole FBB Princes Highway Upgrade.

1.3 Scope and Methodology of the External Review

SMEC Australia was engaged by RMS to carry out an independent external review of the work undertaken by the TIG. The principal objective of this review is to observe and record the nature of the TIG process to ensure it is thorough and even handed in evaluating the strategic route feasibility estimate for the southern bypass and the technical inputs required to produce it.

Specifically, this comprises considering whether:

- The technical investigations are conducted in an unbiased and even handed manner for both routes
- The TIG adequately questions and challenges the scope of work and outputs
- The scope of work and outputs are in line with community and RMS expectations
- All reasonable measures are taken to ensure a like for like comparison of the two bypass routes
- The best possible engineering solutions are applied to both routes
- Applicable suggestions from the community and others are included in developing the route designs and construction methods
- The proposed constructability methods are realistic and reasonable
- Any innovations carry a risk premium
- The appropriate risk factors and contingencies are adopted and properly documented
- The construction program is realistic and production rates are in line with construction industry norms
- The cost estimate is thorough and complete.

The review has been conducted primarily as a ‘desktop study’ that has assessed the two route options and the engineering solutions proposed. Relevant issues associated with the two bypass routes and the engineering solutions have been considered. Engagement has occurred with stakeholders external to RMS (refer Section 1.6).

Key to the review is the need for consistency of approach and consistency in the underlying assumptions associated with design matters for both routes. The External Review Team has ensured that, as far as practicable, there has been a ‘like for like’ assessment carried out between the two routes. The comparative assessment needs to have achieved the same level of detail for both bypass routes considered by the TIG with respect to development of cost estimates. Where there are substantive/material departures, appropriate justification needs to be provided.

The TIG scope items identified in Table 1 have been reviewed by the External Review Team.

Table 1 Technical Areas for Review

Scope Item	TIG Workstream Owner	Where considered in this report
Geometric alignment	AECOM	Section 2
Flood investigations and assessment	AECOM	Section 3
Geotechnical investigations	AECOM	Section 4
Earthworks	AECOM	Section 5
Structures	Aurecon	Section 6
Cost estimating	Evans and Peck	Section 7
RailCorp interface	RMS	Section 8.3
Construction programming	Evans and Peck	Section 8.4
Construction methods	Peter Stewart Consulting	Section 8.4
Mass haul analysis	AECOM	Section 8.4
Access, property severance and adjustments	RMS	Section 8.5

Where considered appropriate, the External Review Team has sought additional technical advice and guidance on design matters with regard to confirming aspects of the TIG review, and in relation to forming an opinion on the robustness of the TIG process and the validity of the conclusions reached.

1.4 External Review Team

1.4.1 Dan Reeve (Review Director)

Dan Reeve is General Manager for SMEC's Australian Transport Group and reports directly to the Managing Director Australia. He has more than 30 years experience in civil engineering construction with direct and extensive expertise in the delivery of large design and construct ('D&C') transport infrastructure projects, particularly on the Pacific Highway Upgrade over recent years.

Dan is very experienced in the management of civil engineering and transport projects in both on-site and senior off-site management roles. Prior to joining SMEC, Dan worked for major construction contractors in both on site project management and head office lead estimating roles. In recent years Dan has had experience in the leadership of a number of significant Highway Design Projects. He is currently on the Alliance Leadership Teams for the Ballina Bypass Project and Banora Point Upgrade for the Pacific Highway. He was on the ALT's for the Northern Hume and Tarcutta Hume Alliances plus Erskine Park Link Road Design Alliance. Previously he has been the SMEC Design Project Director on the Pacific Highway Bulahdelah Bypass and Bonville Upgrade projects.

1.4.2 Derrick Hitchins (Technical Leader)

Derrick Hitchins has over 26 years engineering experience in the civil and transportation sectors in Australia, New Zealand, South Africa and the United Kingdom. He has a high level of specialist expertise in traffic engineering, transport modelling, transport strategy, policy development, and integrated transport planning. He has managed a range of significant civil engineering projects, strategic planning studies and public transport initiatives involving multi-disciplinary teams and government stakeholders.

Over the past decade, Derrick has been part of the consultant teams delivering many of Australia's most complex transport infrastructure projects. These have been mainly in Victoria, Queensland and South Australia. Specific projects of note requiring his skills include: Eastlink Motorway, Brisbane Airport Link, Ipswich Motorway, Pacific Motorway Upgrade, M1 West Gate Freeway Widening and the South Road Superway in Adelaide.

1.4.3 Chris Masters (Review Support)

Chris Masters manages SMEC's NSW Environment Group. He has over 25 years experience in the environmental planning and management fields in both the private and public sectors, with a substantial amount relating to the delivery and operation of major infrastructure projects, including transport projects such as the FBB Highway Upgrade.

Chris has been involved at a senior level, including as Project Leader, in various major public infrastructure assessment projects requiring the balanced, integrated and holistic consideration of community, engineering design and environmental issues to deliver project outcomes. Most recently he was Project Leader for the environmental assessment of Hunter Water Corporation's Tillegra Dam project.

Chris has conducted and/or participated in a substantial number of independent reviews and assessments for a range of infrastructure project while working for the then NSW Departments of Planning and Public Works and Services, and as an environmental consultant. He is currently involved in the independent assessment of an alternative alignment for a section of the Pacific Highway upgrade from Warrell Creek to Urunga.

1.4.4 Specialist Flood Review Input

Brian Lyall – Principal, Lyall and Associates Consulting Water Engineers

Brian Lyall has over 40 years experience with public authorities and consulting engineers in the water resources field. He has specialist expertise in the mathematical modelling of catchment hydrology and river hydraulics for urban and rural flooding projects, including floodplain management and highway drainage works. Projects undertaken include the resolution of a wide range of hydrologic and steady state and unsteady flow hydraulic modelling problems using one and two-dimensional models for the management of flood liable areas.

Brian was project manager for hydraulic investigations undertaken over the past 10 years assessing the impacts of major infrastructure projects on floodplains in the Sydney area including the M7 Motorway, M5 East extension and Parramatta-Liverpool Bus Transitway.

Scott Button –Principal, Lyall and Associates Consulting Water Engineers

Scott Button has 20 years experience in the field of water resources engineering, with extensive experience in hydraulic modelling of urban and rural floodplains, floodplain management, drainage investigation and design. Recent projects involved extensive use of the RORB and RAFTS catchment modelling software, along with steady state and dynamic flow modelling of rivers and floodplains using the TUFLOW, RMA2, HEC-RAS (steady state and unsteady flow versions), MIKE 11 and FPLAIN modelling systems.

Recent projects undertaken on behalf of RMS include peer reviews of the water engineering components of major highway upgrade designs including the M7 Motorway, Great Western Highway (Lawson, Bullaburra and Wentworth Falls sections), Pacific Highway (Sapphire to Woolgoolga section), Camden Valley Way (Cowpasture Road to

Cobbitty Road section), Princes Highway (Gerringong to Bomaderry Tender Assessment) and the Hunter Expressway (Black Creek crossing).

1.5 Line of Reporting to RMS

By necessity, the External Review Team has had close and regular engagement with the TIG, and feedback has been provided to the TIG where it was considered to be of value to the review process. Reporting, however, has been directly to the RMS General Manager, Project Development and completely separate from the TIG reporting process.

1.6 Structure of this Report

This report is structured as follows:

Section 1: Provides the context for the review and the establishment of the TIG; outlines the scope of the TIG activities; outlines the context for the engagement of SMEC Australia for the external review and the specific matters for consideration; presents the External Review Team members and their experience of relevance to an external review role; details the line of reporting by the External Review Team to RMS (separate to the TIG reporting process).

Section 2: Presents the findings of the External Review Team with regard to the matters that form the scope of the external review.

Section 3: Presents a consolidated summary and the conclusions of the External Review Team's findings.

Appendix A Glossary of terms an definitions relevant to the review

Appendix B Notes of meetings attended by External Review Team

Appendix C Issues raised by Berry community members with External Review Team at public meeting of 30 April 2012

Appendix D Register of meetings attended by the External Review Team

Appendix E Lyall & Associates flooding review report

The focus of this report is to present the findings of the External Review Team and to achieve the objective set by the RMS General Manager Project Development. This review has been desktop only and has not included the preparation of any specialist studies. It has not reassessed any aspects of the route concept design, nor undertaken any new investigations. SMEC has relied on the input of Lyall & Associates for the review of the flood investigations.

2 REVIEW OF TIG PROCESS

This section discusses the findings of the External Review Team with regard to the manner in which the TIG process has been undertaken (as stated in Section 1.2). This is done with regard to the specific matters listed in Section 1.3. These are expanded on where considered of value to the discussion with respect to the External Review Team's findings. Where considered relevant or beneficial to readers, specific comment is made on a particular technical investigation area or areas, ie:

- Geometric alignment
- Flood investigations and assessment
- Geotechnical investigations
- Earthworks
- Structures
- Cost estimating
- RailCorp interface
- Construction programming
- Construction methods
- Mass haul analysis
- Access, property severance and adjustments.

For each matter, a concluding statement is provided as to the External Review Team's view on the TIG's performance.

2.1 Conduct of the Technical Investigations

2.1.1 Review Focus

Extensive discussion regarding what constituted a 'like for like' comparison on this issue occurred at numerous meetings attended by members of the External Review Team. It was agreed that key to the review was the need for consistency of approach and consistency in the underlying assumptions associated with design for both routes. To this end, the External Review Team has ensured that, as far as practicable, there has been a 'like for like' assessment carried out between the two routes.

2.1.2 Findings

Geometric Alignment

In many respects, it is the selection of the geometric alignment that most affects the success or failure of any project. Key questions that were asked during the review of this aspect of the investigation were:

- Have the best engineering solutions being applied to both routes?
- Has the TIG taken into consideration all of the information supplied to them by the community?

The TIG has produced a preliminary design of the bypass route to the south based on a version of the original design provided to the RMS by the community. The alignment was further refined and modified to minimise the community impacts and improve the engineering design. A number of subsequent amendments were produced during the review period. These were accompanied with a request from the External Review Team that these suggested changes be taken into account by the TIG. This was done by separately identifying the design and costs impact and noting the differences in the strategic cost estimate.

Flood Investigations and Assessment

The issue of flood protection for the town of Berry is not directly related to the construction of the new highway. However, it is a requirement of RMS that any new highway be adequately protected against flooding, typically up to the 1 in 100 year ARI flood event. This would also benefit the town of Berry by providing a flood-immune access via the Kangaroo Valley Road interchange. It is therefore an important requirement that the southern route provide a similar adequate level of flood-immune access irrespective of the level of flood immunity currently being enjoyed by the town of Berry.

Both bypass routes cross a floodplain traversed by Broughton Mill Creek and Broughton Creek. It was agreed that in order to facilitate a like for like comparison, the southern route would require some upgrading of the existing Princes Highway between the proposed southern interchange and Kangaroo Valley Road to provide flood-immune access for Berry.

The underlying reason for the level of uncertainty regarding the flood modelling was due to the existence of three different flood assessment models that had been developed for previous projects. Each covered a slightly different area of Berry and was developed to address slightly different investigation objectives. A decision to extend the best available 2D model to address this concern was agreed.

Geotechnical Investigations

Broughton Creek and its tributaries make up a large portion of the suggested southern bypass route. Field investigations provided the TIG with a more detailed understanding of the ground conditions relatively late in the review process. Poor foundation conditions under short sections of the alignment have given rise to additional foundation costs in the southern bypass route cost estimate.

Settlement is likely the greatest concern due to the presence of large deposits of alluvial soils where earthworks embankments are proposed. The nature and degree of settlement has been assessed as significant enough to require a number of very specialised ground treatments at locations along the route. All investigations indicate that there is a higher risk in terms of the geotechnical conditions the further south the alignment is located.

Earthworks

RMS has been liaising with relevant property owners for some time regarding their access requirements should the southern route (including the embankment option) be taken further. The TIG has gathered a significant amount of feedback from members of the community regarding their need for unimpeded access.

The TIG demonstrated a thorough understanding of the technical complexities associated with the sourcing and importing of large quantities of fill. The review of the southern route was very detailed and included many ongoing design refinements in pursuit of a balanced cut to fill outcome.

It was agreed that although it would be technically possible to construct an embankment in lieu of a structure at the mid-point of the Berry Bridge, this would also incur the risk associated with the construction of two additional bridge abutments and the increased costs of construction to bring imported fill over two river crossings alongside the design.

Structures

Various pier and deck designs have been considered by the TIG. The External Review Team was presented with designs for different examples involving a larger number of piles, exposed or buried capping beams, profiled blade piers and shrouded decking structures. Various bridge column, pier and deck designs have been considered by the TIG.

The External Review Team queried the selection of Super-T bridge beams for the main viaduct, as opposed to the use of shorter span 'planks', which could be considered to be more appropriate for long viaduct type structures or other options. It is noted that Super-Ts are being used successfully on the Kempsey Bypass which will include Australia's longest bridge (3200 metres in length). The use of Super-Ts is a recognised technology which has been proven to be a cost effective solution by the industry for long structures. The External Review Team concur that the use of Super-Ts is appropriate for this comparative cost estimate.

2.1.3 Conclusion

From observations and review of the material provided by the TIG, the External Review Team considers the technical investigations have been conducted in an unbiased and even handed manner. To be acceptable, the comparative assessment needs to have achieved the same level of detail for both bypass routes considered by the TIG with respect to development of cost estimates. Where substantive/material departures from the conforming design where identified, appropriate justification has been provided.

The TIG produced a concept design based on the design provided by Mr Bruce Ramsay (referred to as 'BR5') that complied with RMS policy and the relevant AustRoads guidelines to a level suitable for preparation of a strategic cost estimate. Adjustments to this concept design were made through the investigation and design process to take into account further suggestions from Mr Ramsay, where practicable, and developments from within the TIG.

The TIG produced a map showing the extent of the three flood models that were available to the TIG. Lyall & Associates undertook a peer review of each model to confirm the most appropriate 100 year ARI flood design level to be used for each route. As noted previously, the need for flood-immune access for Berry was acknowledged by TIG; this is included in the strategic cost estimate as a cost to enhance the cross drainage structures on the existing highway south of Berry at selected locations to achieve the required level of flood protection.

2.2 TIG Scope of Work and Outputs

2.2.1 Review Focus

The External Review Team was asked to consider whether the TIG has adequately questioned and challenged the scope of work and outputs. This is necessary to ensure that all of the technical investigations were fully understood and thoroughly reported upon.

2.2.2 Findings

In August 2011, RMS commenced consultation with the community to re-examine the preferred Berry Bypass northern route announced by RMS in December 2009. These community meetings focussed on reducing the visual and noise impacts of the preferred route mainly along the section of North Street and Berry Bridge. The outcome of this process informed the development of the northern bypass route and was presented to the community in December 2011 as the preferred route. The External Review Team had not been appointed at this time. Instead the associated documentation has been reviewed and the External review Team is satisfied that an appropriate level of rigor consistent with RMS practice and policy has been applied with regard to the process that was followed.

In December 2011, members of the community submitted an alternative route bypassing the town of Berry to the south. As a result of this submission, the TIG was established to review and compare the cost of this southern route to the currently preferred northern route. This review follows a request from the Minister for Roads and Ports to investigate the robustness of the estimates and assumptions which have informed past decisions by RMS not to pursue a southern bypass route.

In addressing this issue it is noted that a key part of the TIG's role was to use its best endeavours to:

- Optimise the southern route to minimise property impacts and land severance
- Engineer a cost-effective southern route solution
- Apply any benefits found on the southern route to the northern route where applicable, and vice versa.

The TIG's brief included the requirement to undertake complete investigations for both the southern and current northern route to produce robust strategic cost estimate. Given the timeframe involved it was not practical to undertake complete investigations, however enough were undertaken to produce a concept design for the southern route to allow the development of a strategic estimate and a 'like for like' comparative estimate.

The TIG has been tasked with the specified Scope of Work as outlined in the Table 2.

Table 2 TIG Scope of Work

Task	Outputs	Refinements
Develop a route to the south in sufficient detail to be able to produce a robust strategic cost estimate	Horizontal and Vertical designs and structural designs produced for both alignments in detail and costed accordingly.	Southern route modified further to include minor improvements and cost savings suggested by the community
Use best endeavours to minimise property impacts and land severance	Preferred southern alignment determined through a value engineering and multi-criteria workshop process	Further revisions to southern alignment recognised as adjustment sums in cost estimate.
Use best endeavours to engineer a cost effective southern solution	RMS policies, and best practice guidelines applied during the preparation of a preferred design	Southern design subjected to additional design constraints due to specific Railcorp requirements and the Broughton Creek Floodplain and Shoalhaven River
Use best endeavours to apply any benefits found for the southern route to the northern route	Detailed construction method statements developed for both routes to inform early design decisions and cost estimates	Differences in design, quantities, geotechnical impacts, access and site-specific conditions cross referenced throughout
Complete investigations required for both the routes to produce a robust strategic cost estimate	Geotechnical, soil testing, flood modelling and noise investigations extended to include the southern route.	Consistent structural solutions applied. 6-lane future proofing of carriageway applied to both routes
Evaluate the feasibility of the route by comparing the estimates within the context of the whole Foxground to Berry Bypass Princes Highway Upgrade	RMS cost estimating principles applied throughout. Major cost components analysed in greater detail. Provisional items applied in sufficient detail to produce a comparable estimate	Major realignment changes required to win material from other parts of the project to balance earthworks mass haul overall. All excavated material used on the project in embankments or to replace unsuitable material.

The External Review Team considers the TIG has undertaken all reasonable endeavours to identify the key investigations necessary for significant items such as flooding, geotechnical issues, earthworks, construction methods, program and structures. The TIG has utilised independent resources (of the TIG) undertaking the work on the northern route. The TIG also drawn upon appropriate experts to assist with the peer review of its work.

2.2.3 Conclusion

The External Review Team has been given full and unrestricted access to all of the outputs produced by the TIG. The External Review Team has attended TIG meetings, as well as a community meeting and any other meetings deemed appropriate during the course of the review process. It is considered that the TIG has adequately challenged the scope of works and outputs to prepare a concept design for a southern route that with the inclusion of adjustment items could be compared to the current concept design of the northern route.

2.3 Community Inputs and Expectations

2.3.1 Review Focus

The External Review Team has been requested to examine whether the scope of work and outputs are in line with community expectations and whether applicable suggestions from the community and others have been included in developing the route designs and construction methods.

2.3.2 Findings – Previous Reports

Reference has also been made to the *Gerringong to Bombaderry Route Options Submissions Report* dated September 2008 in preparing this summary of community concerns.

Functional Issues

A review of the submissions received in early 2008 focussed on topics related to the appropriate provision of access on and off the highway, into and between properties and to towns during both construction and operation. Submissions highlighted the need for the preferred option to address road safety for vehicles, pedestrians and cyclists.

A large number of submissions also suggested that the potential of using the existing highway corridor as much as possible be examined thereby minimising the impacts on new residential areas and agricultural land, together with the possibility of retaining the existing highway corridor as a 'slow road' for tourism and local access.

Environmental Issues

A large number of submissions requested that the design respond to the area's environmental values and natural assets in an appropriate and sensitive manner. Specifically, submissions highlighted the need to protect the biodiversity values of the region.

Many submissions also reinforced the need to carefully consider the flooding characteristics of the estuary and the history of flooding in the region.

A key issue raised by the majority of submissions was the potential for noise impacts, the reduction in social amenity and the impact of any road and/or elevated structures on the views over the escarpment enjoyed by the many rural and residential residents.

Economic Issues

A number of submissions expressed concern for maintaining the economic viability of the region through ongoing business, agriculture and tourism activities. Local access and the location of grade-separated interchanges where considered important in this regard.

Fragmentation of individual farms, access arrangements and property acquisition were also seen as key considerations. Broadly speaking, the community viewed the area's natural and environmental issues as key economic assets to be preserved.

Social Issues

The majority of submissions clearly stated the importance of protecting the village character and heritage of the region. This included ensuring that the community cohesion, networks and support which currently exists within communities were not compromised.

Concerns were also raised about the impact on property values. Submissions referred to personal stress, the importance of communicating clear project timeframes and the implementation of a fair property acquisition process.

Process Issues

Reference was also made to the need for a southern option to continue to be part of the route option analysis process. Emphasis was placed upon, the importance of transparency in the selection process and the high value attached to ongoing community and stakeholder involvement in each stage of the project.

A small number of submissions extended the discussion of process to include issues surrounding the appropriateness of comparing options without the support of a detailed environmental assessment of each.

2.3.3 Findings – Recent Consultation

Discussion on whether suggestions from Mr Bruce Ramsay and others have been included in developing the southern route design and construction methods, is provided elsewhere in this report.

With respect to the views of the general community, members of the External Review Team attended the Berry Bypass review Community Session on 30 April 2012. Issues raised by the community were logged and are included as Appendix C to this report. Other issues were also raised directly to the External Review Team.

Issues raised included:

- Why are we assessing the southern route now, was it not properly assessed previously
- Have reasonable suggestions from the community and others been included in developing the route design and construction methods
- Consistency of urban design and landscaping principles
- Are the social aspects of the southern route being assessed
- What is the effect on the dairy industry of the southern route
- Fauna and flora preservation
- The northern route bisects the town, how is that being assessed
- Are the flooding issues being assessed for both routes
- When will the decision be made so RMS can get on with building the bypass.

Inclusion of Community-Supplied Information

The TIG has produced a preliminary design of the bypass route to the south based on the design provided by Mr Ramsay. It is understood that Mr Ramsay made a number of amendments to his initial design during the review period and that these were communicated to RMS with the request that they be taken into consideration in the review process. It is further noted that concern was expressed by at least one member of the local community as to the robustness and fairness of the decision-making process for either a northern or southern bypass route.

Fauna and Flora Preservation

More than 120 mature age, very large trees (150+ years old and more than one metre in diameter) are earmarked for removal as part of the northern option. This cost has been included in the strategic cost estimate for the northern option.

While not usual practice, an issue that can be captured in any strategic cost estimate for the southern route, the benefit of not having to remove this many trees is considered to be an important issue for some community members. The removal of these old growth trees will therefore need to be addressed in any future environmental assessment. Specific mention was made to their value from the point of view of their carbon sink/carbon storage capacity however, this would likely be relatively minor given their maturity. It is noted this issue would be further examined as part of the environmental assessment.

Landscaping and Urban Design

The suggestion has been made by some community members that the southern option is not within an urban design area and therefore not subject to the same urban design principles. It is noted that RMS guidelines encompass not just urban design but also landscape design and apply equally to urban and non-urban areas. As such it is appropriate to consider landscape treatments for both routes.

Based on community feedback received during the review, the External Review Team suggested publication of 'Fact Sheets' prior to the publication of the TIG report would assist in addressing aspects of the investigations that were of concern to the community, but not necessarily covered by the above scope of works.

Severance of Berry by the northern route

Compared to the southern route which passes to the south of the town and across mainly agricultural land, the northern option utilises the existing Princes Highway corridor which now runs through Berry at its southern end. It is noted that the corridor pre-dates the development to the northwest of the older township.

The severance caused by the upgrade of the existing highway corridor is perceived by many residents to be major issue and something which is likely to affect the future connectivity of the town to the newly established residential areas to the north-west. Severance of the agricultural land to the south of Berry by the southern option has however also an important issue from the point of view of the rural community and whilst not directly comparable, is likely to have a greater effect on the commercial viability of the dairy industry in the area as a whole.

It is worth noting, that in many cases where bypass roads have been constructed around smaller towns in other parts of Australia, while heavy vehicle traffic has been diverted around the town, the commercial viability of the town has also been negatively affected by the relocation of the passing traffic.

2.3.4 Conclusion

It is noted there are multiple views and opinions in the community about the bypass and the alternative routes. The TIG has undertaken consultation to better understand the key issues so that those issues could be taken into consideration in the comparative study.

It is noted that there are perceptions that the information forwarded by some community members has not been fully considered, however it is the view of the External Review Team that all reasonable steps have been taken to consider such information provided. The TIG has not directly relied on any concept design or costings developed by members of the public but has used the information provided as a basis for the development of a concept design with sufficient detail to allow a 'like for like' comparison of the northern and southern routes.

2.4 Comparison of the Two Bypass Routes

It is noted that some members of the community believe that a southern route option for the Berry bypass should still be pursued as opposed to the northern option which is currently being developed as the preferred route for the Berry Bypass. In February 2012 the NSW Government, through the Member for Kiama, announced that RMS would review costings related to a possible southern bypass of Berry.

Community members had requested that the following important issues should be taken into account for any southern option. The southern route should:

- Follow the railway corridor to the south of Berry as closely as possible, thereby utilising land already affected by the railway
- Avoid the destruction of high value agricultural land
- Completely bypass the scenic town of Berry, therefore not impact on Berry Township
- Provide the safest route around Berry, ie no increased traffic in close proximity to local traffic, pedestrians and cyclists
- Minimise disruption to the existing highway during construction
- Retain the use of the existing Princes Highway corridor for rail and gas.

It is worth noting that the 2006/2007 Berry bypass route selection process reviewed a number of route options and noted that no single issue lead to the southern route being discarded, including cost. On balance, the disadvantages outweighed the advantages on the following points:

- Two grade-separated railway crossing in relatively flat terrain
- The need for large structures to span Tannery Road, the railway line, Broughton Creek, Wharf Road and to provide flood relief
- Relatively poor geotechnical conditions, including potential acid sulphate soils Significant impact on high value agricultural land
- Adverse influence on potential flooding upstream and downstream due to the gating effect on overland drainage and river flows
- Upgrade of North Street to cater for increased local and through traffic demand has already been identified as being required at a future date.

Other reasons for discarding the southern options at an early stage included:

- Visual and noise impacts
- High cost of construction

- Large amount of fill material required
- Access to Berry could be more difficult which could reduce the commercial viability of the town.

2.4.1 Review Focus

For the comparative cost estimate to be considered meaningful, it is important that all reasonable measures have been taken by the TIG to ensure a like for like comparison of the two bypass routes has been achieved. The process has many facets ranging from the obvious physical features of any road through to compliance with standards and the achievement of any community goals and objectives. The use of weighted multi-criteria analysis tools is usually the most effective way to deal with these often difficult to quantify demands.

2.4.2 Findings

To allow for a comparative assessment the tie-in point to the existing Princes Highway were extended to the same point for both options.

Table 3 Comparative Assessment

Assessment criterion	Sub-criteria	Northern	Southern
Structures	Flooding impacts	100 year ARI flood immune access to be provided between upgraded highway and the town of Berry	100 year ARI flood immune access has been achieved for the southern route by upgrading the existing highway south west of Berry
	Required bridge length	600 m	1200 m
	Structures	Total deck area: 15,795 m^2	Total deck area: 30,882 m^2 Significant ground improvements required.
Earthworks	Earthworks (total volume)	1,300,863 m^3	1,984,212 m^3
	ASS/Soft soils	No ASS identified	Some ASS present. Localised treatment required
Pavement	Route length excluding bridges	257,400 m^2	243,452 m^2
Property	Property Acquisition / Disposal Costs to the overall project	$22M	$19M

Assessment criterion	Sub-criteria	Northern	Southern
Other	Property adjustments Road geometry Functionality Constructability Utility interfaces Future proofing Ease of maintenance	Identified as part of the community consultation for the northern route	General reduction in scope for the southern route for items such as • traffic control • drainage • noise walls

The estimated cost of the Foxground to Berry Bypass incorporating the northern route is $545.4 million. The cost of the Foxground to Berry Bypass incorporating the southern route is $710.7 million.

2.4.3 Conclusion

Based on non-cost criteria, there are many advantages and disadvantages for both routes. The southern route would have a number of technical challenges to overcome to be viable, and these add costs to the southern option, which make the southern option less viable. The External Review Team is satisfied that all reasonable measures have been taken within the time available to facilitate a 'like for like' comparison of both routes.

2.5 Use of Optimum Engineering Solutions

2.5.1 Review Focus

To allow a fair comparison of both the northern and southern routes, the External Review Team was requested to assess whether the TIG had applied the optimum engineering solutions to both routes.

There are four key areas where the External Review Team can comment with respect to the use of optimum engineering solutions:

- Concept alignment design for the Southern Route
- Design for future widening across the floodplain - 4 lanes Vs 6 lanes;
- Review of the Flood Study
- Rail provisions – clearance to the rail line and provision for rail electrification for road overbridges on the southern route.

2.5.2 Findings

Concept Design for the Southern Route

A concept design was prepared independently by Mr Bruce Ramsay which the TIG was requested to use as the basis for development and preparation of a comparative estimate. Mr Ramsay updated his original design, providing improvements and his concept design (BR5) was used as the basis for the concept design developed by the TIG. There were a number of areas where Mr Ramsay's design was not fully compliant with the AustRoads Guidelines and not fully in accordance with the RMS Policies.

The TIG has reviewed the concept designs and refinements provided by Mr Ramsay and developed a concept design based on that design that complies with the AustRoads

Guidelines and RMS Policies. The TIG concept design has been used as the basis for the estimate comparison with the concept design for the northern route.

Some of the adjustments suggested by Mr Ramsay were deemed to have merit and able to be incorporated into the TIG concept design within the available timeframe. These are incorporated in the TIG comparative report as adjustment sums.

Design for Future Widening Across the Floodplain - 4 Lanes Vs 6 Lanes

The concept design developed by Mr Ramsay for the southern route across the flood plain is for four traffic lanes (two lane, dual carriageway) with limited provision for future widening. It is noted that for the Princes Highway Upgrade - Gerringong to Bombaderry RMS has decided to allow for future widening to six lanes in line with other recent major highway projects.

The TIG has allowed for this in the concept design it has developed. This requires slightly wider bridge decks and wider earthwork formations that allow for future pavement widening in the median.

This may not be considered as an optimum engineering solution by some parties as it may be many years before the future widening is undertaken. However, provision for this is considered good policy by the RMS. The TIG has provided for this in the concept designs and strategic estimates for both the northern and southern route options.

Review of the Flood Study

Flood studies were prepared as part of the TIG's concept design development to nominate the flood immunity levels for the southern route. A review of the flood studies for the southern route was undertaken by Lyall & Associates and those findings are summarised as follows.

The key findings of the review of the flooding investigation undertaken by AECOM (on behalf of the TIG) for the Southern Bypass Route (SBR) were as follows:

i. The use of the RAFTS hydrologic modelling software package and the HEC-RAS and TUFLOW hydraulic modelling software packages as part of AECOM's current investigation into the SBR is considered appropriate.

ii. AECOM's adoption of the "flood envelope" approach to defining flood behaviour on the lower floodplain of Broughton Creek is considered more appropriate than the approach that was adopted by previous flooding investigations undertaken on behalf of Shoalhaven City Council at Berry.

iii. Although a rigorous review of the models should be undertaken during the detail design of the Foxground and Berry Bypass, it is the Reviewer's opinion that the models being relied upon by AECOM as part of the current investigation are sufficiently detailed to provide a reasonable estimate of flooding patterns along the route of the SBR. The key reason for this opinion is that flood behaviour on the lower floodplain of Broughton Creek is heavily influenced by backwater flooding from the Shoalhaven River and minor changes to hydrologic and hydraulic model parameters would not have a major impact on predicted flood behaviour along the route of the SBR for a 100 year ARI event.

iv. The adoption of peak 20 and 100 year ARI flood levels of RL 4.3 m AHD and RL 5.0 m AHD for application to the downstream boundary of the AECOM TUFLOW model is considered appropriate. Although we consider that the 20 year ARI flood level of RL 4.3 m AHD may be conservatively high, the adoption of a lower tailwater level would not in our opinion result in changes to the critical drainage elements of the SBR.

v. The Reviewers consider that Figures A5 and A6 contained in Appendix C1 of the TIG report should show the results of modelling the SBR without the Island Embankment Option.

vi. The water surface contour information shown on Figures A5 and A6 is shown incorrectly where the SBR crosses the lower floodplain of Broughton Creek.

vii. There is no information given in the TIG report on the impact of the SBR on the upper envelope of 100 year ARI flooding where it crosses the lower floodplain of Broughton Creek. There is a concern that the impacts on flooding that would result from the construction of the road project may extend further north (upstream) than is presently shown on Figure A7 of the TIG report. If it is found that changes in flood behaviour will occur on land which has been developed for residential purposes, then it may be necessary to lengthen the bridge which crosses Hitchcocks Lane Creek in order to mitigate the impacts of the SBR on flood behaviour.

viii. There is a concern that the obstruction to flow caused by the Island Embankment Option will exacerbate flooding conditions in existing development which is located on the eastern (left) overbank of Broughton Mill Creek immediately south (downstream) of the South Cost Railway Line.

ix. A review of the HEC-RAS model developed for the Southern Interchange indicated that the required 0.5 m minimum freeboard to the soffit level of the road bridges had not been incorporated in the design of the SBR. After being advised of this finding, AECOM forwarded an updated set of HEC-RAS model files which incorporated the required amount of freeboard (AECOM, pers. comm. 28 May 2012).

x. A review of the longitudinal section of the SBR where it crosses the lower floodplain of Broughton Creek shows that the required 0.5 m minimum freeboard to the soffit level of the bridges has been incorporated in the design of the SBR.

xi. We consider that the minimum freeboard requirement of 0.5 m need not be increased to allow for the future impact of sea level rise given that peak 100 year ARI flood levels on the lower Broughton Creek floodplain are predicted to rise by only 50 mm by 2100.

xii. We consider that there is sufficient allowance in the current minimum freeboard requirement of 0.5 m to accommodate possible changes in flood behaviour should rainfall intensities increase as a result of climate change. Based on current estimates of the impact climate change will have on rainfall patterns, peak 100 year ARI food levels could increase by a maximum of about 0.2 m along the route of the SBR by 2100 (also allowing for the impacts of sea level rise). This would reduce the available freeboard to about 0.3 m which is considered sufficient to account for other uncertainties/inaccuracies in design flood estimation.

A full copy of the Lyall & Associates Report is included in Appendix E.

Rail Provisions

The TIG has incorporated the minimum clearances to the rail line and provision for rail electrification for road overbridges on the southern route. RailCorp has advised that planning for the future rail is under the jurisdiction of Transport for NSW, which means current practices and policies are to be applied.

The railway line currently provides a commercial rail link to the Manildra complex at Bomaderry and Manildra currently utilise diesel trains on this line. There is currently a regular passenger service provided between Bomaderry and Kiama, which is replaced by a CityRail Bus service during times of track maintenance.

RailCorp has indicated that any southern alignment would need to allow for possible future duplication and include an allowance for continued maintenance to occur from either side of the line. In addition, RMS has received formal advice from RailCorp that a further allowance for electrification via an additional clearance under any bridge structures would need to be made. This future overhead electrification may not be fixed to the underside of any bridge.

This may not be considered an optimum engineering solution by some parties, however given this comparative study is for a concept design, then it is normal practice to allow for standard RailCorp provisions at this stage. This was confirmed by the Rail Corridor Management Group on 1 May 2012.

If the southern route is selected then the design may be optimised during detailed design and after further consultation with RailCorp.

2.5.3 Conclusion

The TIG has generally applied the optimum engineering solutions to both routes. These requirements of the brief were recognised by the TIG and, subject to RMS policy, good engineering solutions have been included in the concept design and the strategic cost estimate for the southern route.

2.6 RMS Expectations

2.6.1 Review Focus

The External Review Team has been asked to comment on whether the scope of work and outputs by the TIG are in line with RMS expectations.

2.6.2 Findings

The RMS expectations were set out in the brief for the TIG. In summary it was asked to develop an optimal and cost effective concept design to allow comparison with the northern route, then evaluate the feasibility of the southern route in comparison to the northern route. The TIG has followed RMS procedures and within the available timeframe has developed a comparable southern route option. While independent of the RMS and reporting directly to the RMS General Manager Project Development, the External Review Team understand the RMS procedures and are thus in a position to comment on this matter.

2.6.3 Conclusion

The External Review Team considers that the work undertaken by the TIG has been completed in accordance with RMS procedures and the brief given to the TIG.

2.7 Constructability

2.7.1 Review Focus

When a comparison is made of two different routes for a bypass it is important that the proposed construction methods are realistic and reasonable. In reviewing this aspect the External Review Team has examined the development of the proposed construction methods and assessed their appropriateness for the purposes of the comparative review.

2.7.2 Findings

The construction methodology is addressed in detail within the route feasibility report. Method statements have been prepared for both the bridge construction and the earthworks and a comparison has been presented for both routes. The constructability has not just been reviewed for the actual bypass section, but the study has covered the complete Foxground to Berry Bypass routes including a full comparison of the earthworks mass haul. This is important and provides a like for like comparison based on the concept designs that have been developed.

The significant differences between the two routes are:

- The Berry Bridge for the northern route has a deck area of about 15,800 m^2 while the southern route bridge has a deck area of about 30,900 m^2. Based on the experience of the SMEC External Review Team and other recent highway projects, the choice of the Super-T bridge design is appropriate for the Berry Bridge.
- The earthworks have been balanced approximately for both options, however the southern route has significantly more earthworks overall. To obtain a balanced cut to fill the designers have developed a concept design that will deepen the main Toolijooa cutting
- There are limited soft soils encountered on the northern route but there are significant soft soils on the southern route which will require ground treatment and preloading
- There are no potential acid sulphate soils (PASS) on the northern route but there is evidence that PASS will be encountered on the southern route.

While the TIG has developed a concept design for the southern route so that a comparative cost estimate and construction method statements could be produced, the following options have been treated as an adjustment to the estimate:

- Realignment of the southern route to the south of the STP
- An embankment island and shorter main bridge on the southern alignment
- Realignment of the northern interchange
- Changes to the vertical alignment to generate extra fill material
- Adjustment to the southern interchange design.

Given that these options have been considered in the construction methodology, this is a reasonable approach for the production of a strategic level comparative cost estimate based on concept designs. Should the southern route be selected then the alignment would need further design development.

2.7.3 Conclusion

The External review Team considers that the assessment undertaken of the constructability has been thorough and that this information has been appropriately taken into account in the preparation of the strategic cost estimates.

2.8 Treatment of Innovation

2.8.1 Review Focus

The External Review Team was asked to consider and report on any innovations considered by the TIG, and that they carry an appropriate risk premium.

2.8.2 Findings

For the northern option, three additional improvements/innovation were considered:

- Addition of North Street pedestrian footbridge
- Land reserved for possible future provision for a second northbound off ramp
- Relocation of Kangaroo Valley Road interchange towards Schofields Lane.

For the southern option, five additional improvements / innovation were considered:

- Diversion of route south of the sewage treatment plant (STP)
- Inclusion of an island embankment to replace part of the viaduct in the southern route
- Alternative earthworks design for the northern interchange
- Lowering of the vertical alignment north of the Berry north interchange to generate additional fill for the earthworks
- Alternative alignment for the southern route to reduce embank fill requirements.

These have been considered by the TIG and commentary on these issues is included elsewhere in this report particularly in the section on risk and contingency.

2.8.3 Conclusion

The External Review Team considers that all innovations considered by the TIG include an appropriate risk consideration in the strategic cost estimates.

2.9 Risk factors and contingencies

2.9.1 Review Focus

When preparing strategic cost estimates for projects such as the Berry Bypass it is important to produce an estimate that gives decision-makers a high degree of confidence. Accordingly, amounts to cover risk and contingency are included in the comparative cost estimate consistent with RMS policy.

The objective of this section of the review is to comment on the appropriateness of the risk factors and contingencies that have been adopted and are whether or not they have been properly documented.

2.9.2 Findings

The TIG has followed the RMS estimating guidelines and applied risk and contingencies in accordance with RMS policies for both route options for the strategic cost estimates. The level of contingency is consistent with other projects at the strategic concept development phase. A slightly higher level of contingency has been applied to the southern option because the available level of detail and certainty is greater for the northern route at this time and there is more risk associated with the southern route.

During the process of the compilation of the TIG report the External Review Team was involved in reviews of the estimate at different stages to ensure that the level of detail was consistent for both route estimates. At the request of the External Review Team, the TIG undertook a sensitivity analysis on the contingency and risk allocation on the three major items. The results of that analysis are tabulated as follows.

Table 4 Sensitivity Analysis Results

Contingency Sensitivity Analysis	High Contingency 2012 $M	Low Contingency 2012 $M	Estimate Allowances 2012 $M
Northern route (32 months)	$552.4	$545.4	$545.4
Southern route (42 months)	$710.7	$696.6	$710.7
Difference	$158.3	$151.2	$165.3

A question that could be asked with respect to the comparison of contingencies is, if an equal amount of design information was available for the southern route as for the northern route, then would not the contingency be the same? The simple answer to that question is no, because the southern route has more bridgeworks, more earthworks, soft soils and generally more complexities. Even if the quantum of work was the same, the southern route has the higher risk.

2.9.3 Conclusion

The TIG has followed RMS procedures to address the risks and contingencies for both options. A consistent approach has been applied to both route options. The level of contingency is appropriate for the strategic estimates which have been developed for these comparative estimates.

2.10 Construction Program

2.10.1 Review Focus

The objective for the External Review Team with respect to the construction program is to review the process undertaken to prepare the construction programs prepared for the design and construction of both the northern and southern routes and to make comment

on whether or not the programs are realistic and that production rates used to derive these programs are in line with construction industry norms.

2.10.2 Findings

The TIG has prepared construction programs for each option to an appropriate level of detail. These are presented in summary format in the TIG Report and the outcomes summarised in Table 6.15 *Construction program summary* which is reproduced below.

Table 5 Comparison of Construction Programs

	Northern	Southern
Overall construction completion*	Month 32	Month 40
Bypass opening milestone*	Month 29	Month 35
Program critical path	Zone 1a earthworks & pavements (north of Austral Park Road)	Berry Bridge over Broughton Mill Creek & floodplain embankments
Allowance for soft soil consolidation	6 months (embankment west of Berry Bridge)	9 months (embankment over floodplain, between rail corridor and Broughton Mill Creek)

* Includes provision for inclement weather

These results are considered realistic and the most significant difference between the two programs is the duration of the construction of the Berry Bridge over Broughton Mill Creek and the associated floodplain embankments.

The construction program has been prepared on the basis of the construction investigations as reported in Chapter 6 of the TIG report and the associated construction method statements. A consistent approach has been adopted for both options and appropriate production rates used. The more detailed program the TIG team has prepared using the P3 software has been produced to a level consistent with industry norms and a good summary presented in the TIG Report.

2.10.3 Conclusion

The External Review Team concurs with the findings of the TIG Report and agrees the southern option would take approximately six months longer to open the bypass and eight months longer for the overall D&C contract.

2.11 Cost Estimate

2.11.1 Review Focus

The principal objective of the external independent review is to observe the TIG process and record the nature of the process to ensure it has been thorough and even handed when evaluating the strategic route feasibility estimate for the southern bypass and the technical inputs required to produce it. In particular, as part of this review, the External Review Team is to consider whether the cost estimates developed by the TIG are thorough and complete.

It should be noted that the External Review Team was not commissioned to prepare any estimates in parallel to those produced by the TIG. The role is an assurance role to review the robustness of the process and undertake an independent check of the estimates.

Section 7 of the TIG Report on preparation of route feasibility comparative cost estimates presents the TIG's strategic estimate for both the northern and southern options. These results are reproduced below.

Table 7.1 High Level Summary of Cost Estimates

Item Description	Northern Route	Southern Route	Difference	Comment
Structures	$138m	$183m	$45m	Greater length of bridges and area of retaining walls in the southern route: Southern Route: • Total bridge deck 46,400m²; and • Total area of retaining walls 2,800m² Northern Route: • Total bridge deck area 31,200m²; and • Total area of retaining walls 1,400m²
Earthworks	$97m	$238m	$141m	Greater volume of earthworks, further travelling time, imported fill. Southern Route: • Total volume of earthworks 1,984,000m³ • Total area of retaining walls 2,800m² Northern Route: • Total volume of earthworks 1,301,000m³
Pavements	$67m	$63m	-$4m	Reduction in pavement areas because of shorter length of embankments. Southern Route: • Total pavement area 243,000m² Northern Route: • Total pavement area 257,400m²
Balance of construction costs	$151m	$118m	-$33m	General reduction in scope for items such as noise walls, Traffic Control, Drainage etc for Northern vs Southern routes
Land Acquisitions	$24m	$23m	-$1m	
Project management and design	$68m	$86m	$18m	
TOTAL $m	**$545m**	**$711m**	**$166m**	

NOTE: Above amounts are inclusive of contingency

The application of risk and contingency has been discussed previously in this report.

2.11.2 Findings

The TIG has followed the RMS estimating guidelines to produce a strategic estimate for both route options for these comparative cost estimates. Both the External Review Team and the independent RMS PMO representatives have been active in reviewing the estimating process and the actual estimate itself. A number of meetings were held with the estimators to ensure that the RMS Procedures have been followed and a true comparable estimate has been produced for both route options.

The External Review Team have asked questions and sought clarifications throughout the process to ensure that the results are directly comparable, balanced and clearly presented in the TIG Report. Both the RMS PMO representatives and members of the External Review Team have reviewed the actual estimates in detail. It is considered they are reasonable and comparable for a strategic estimate.

A key element of this review has been to ensure that the TIG report provides directly comparable estimates so that the decision-makers can be fully informed of the strategic estimate for both route options. As the two route options are at different stages of development adjustment sums have been included as additional line items in the estimate for the southern option, so that the direct comparison can be made. The estimate was prepared on the strategic concept design prepared by the TIG. During the process of undertaking the comparative study and preparing the TIG Report and based on further community consultation, a number of adjustments were made to the concept design for the southern route.

Given the timeframe available, it was not practical to prepare a full, revised concept design, so the TIG decided to include suitable adjustment sums in the estimate to cover proposed changes to the initial southern route concept design.

These adjustment sums cover:

- Costs to re-route the current strategic concept design alignment south of the Sewage Treatment Plant
- Costs for an island embankment to shorten the Berry Bridge viaduct
- Cost for the realignment of the northern interchange to generate additional fill material
- Changes to the vertical alignment to generate additional fill material and balanced mass haul earthworks for the southern option
- Costs for the adjustments to the Southern Interchange.

These adjustments, which include a factor for the contractors on-costs etc, allow the two route options to be directly compared at a strategic level. The External Review Team considers this approach is acceptable and reasonable within the available timeframe. Should the southern route be selected then more design development work would be required to allow the inclusion of these items directly into the concept design.

2.11.3 Conclusion

The TIG has followed the RMS estimating guidelines to produce a strategic estimate for both route options for these comparative cost estimates. The two estimates provided by the TIG are directly comparable, balanced and reasonable for strategic estimates.

Adjustment Sums have been included in the estimate for the southern route to allow for a number of developments to the concept design during the comparative cost estimate preparation process. The end result being the strategic estimate for the northern option is approx. $165.3 million less than the estimate for the southern option based on a reasonable like for like comparison.

2.11.4 Additional Comment

An estimate was prepared independently by Mr Bruce Ramsay based on his concept design (BR5). The estimate provided nominates $23 million in savings based on the comparison of the northern option and his southern option. There were a number of areas where Mr Ramsay's design was not compliant with the AustRoads guidelines and also not fully in accordance with the RMS policies.

The TIG has reviewed the concept designs provided by Mr Ramsay and used these to develop a concept design that complies with the AustRoads guidelines and RMS policies. The TIG concept design has been used as the basis for the estimate comparison with the concept design for the northern route. Some of the adjustments noted above have been suggested by Mr Ramsay and are now incorporated into the TIG report as adjustment sums.

The External Review Team has monitored this process and is satisfied that the development of the TIG concept design has adequately considered Mr Ramsay's design with respect to applicable AustRoads guidelines and RMS policies.

3 SUMMARY AND CONCLUSION

In February 2012, the NSW Government through the Member for Kiama announced the RMS would review costings related to a possible southern bypass of Berry. A Technical Investigation Group was formed to develop a concept design for a southern route with sufficient detail to also produce a comparative strategic cost estimate, so that the feasibility of the southern bypass route could be compared to the currently preferred northern route, in conjunction with the whole Foxground and Berry Bypass Princes Highway Upgrade.

In March 2012, the RMS General Manager Project Development requested SMEC Australia to lead an Independent Review with the principal objective to observe and record the nature of the process undertaken by the TIG to ensure it has been thorough and even handed when evaluating the strategic route feasibility estimate for the southern bypass and the technical inputs required to produce it.

The concept design that was developed by the TIG was based on the submission of Mr Bruce Ramsay, who is an interested member of the public. The TIG undertook the investigations and prepared a concept design and comparative cost estimates. A final draft of the Foxground and Berry Bypass - Report on the route feasibility comparative cost estimates was forwarded to the External Review Team on 1 June 2012, with previous drafts being forwarded earlier.

The External Review Team has attended the last seven weekly review meetings held by the TIG and has provided ongoing critique, feedback and suggested improvements at each meeting; these actions are noted in the minutes of those meetings.

The External Review Team concludes that:

- The technical investigations have been undertaken in an unbiased and even-handed manner to allow a ‘like for like’ comparison of concept design for both northern and southern bypass routes of Berry.
- Based on information provided by members of the community, the TIG has developed a concept design for a southern route to a level suitable for a gateway cost estimate, and which includes adjustment items to facilitate comparison with the current concept design of the northern route.
- The External Review Team has been given access to all of the outputs produced by the TIG. The External Review Team has been able to attend all TIG meetings, community meetings and any other meetings deemed appropriate during the course of the investigation process. The TIG has adequately challenged the scope of works and outputs to prepare a concept design for a southern route that with the inclusion of adjustment items could be compared to the current concept design of the northern route.
- There are mixed feelings in the community about the Bypass and the alternative routes. The TIG has undertaken consultation to better understand the key issues such that they could be taken into consideration in the comparative study.
- An adequate comparative route design and cost estimate has been prepared in the available time.

- Based on non-cost criteria, there are many advantages and disadvantages for both routes. The southern route would have a number of technical challenges to overcome to be viable; these add significant costs which make the southern option uneconomical. All reasonable measures have been taken within the time available to ensure a 'like for like' comparison of both routes.
- The TIG has applied the optimum engineering solutions to both routes. These requirements of the brief were recognised by the TIG and subject to RMS policy, good engineering solutions have been included in the concept design and the strategic cost estimate for the southern route.
- The work undertaken by the TIG has also been completed in accordance with relevant RMS procedures and the brief given to the TIG.
- A thorough assessment of the constructability has been undertaken and that this information has been taken into account in the preparation of the comparative estimates.
- All innovations considered by the TIG have included an appropriate risk consideration in the comparative estimates;
- The TIG has followed RMS procedures to address the risks and contingencies for both options. A consistent approach has been applied to both route options. The level of contingency is appropriate for the strategic estimates which have been developed for these comparative estimates.
- The TIG has followed the RMS estimating guidelines to produce a strategic estimate for both route options for these comparative cost estimates. The two estimates provided by the TIG are directly comparable, balanced and reasonable for strategic estimates. Adjustment sums have been included in the estimate for the southern route to allow for a number of developments to the concept design during the comparative cost estimate preparation process. The External Review Team have not prepared independent estimates but have undertaken a robust review of the estimating process and completed independent checks of the estimates prepared by the TIG.
- The end result being the strategic cost estimate for the northern option is approximately $166 million less than the estimate for the southern option, based on a reasonable 'like for like' comparison.

APPENDICES

Appendix A **Glossary of Terms**

Appendix B **Notes of Meetings held with Members of the Independent Review Group**

Appendix C **Issues Register from Berry Bypass Community Session 30/04/12**

Appendix D **Meetings Register**

Appendix E **Report by Lyall & Associates**

APPENDIX A :GLOSSARY

Ambient	The background level at a specified location, being a composite of all sources. Examples of the use of this term include 'ambient noise' or 'ambient air pollutants.
Average recurrence interval	The average recurrence interval (ARI) (measured in years) is a term used to describe the frequency or probability of floods occurring. Large floods occur rarely, whereas small floods occur more frequently. For example, a 100 year ARI flood is a flood that occurs or is exceeded on average once every 100 years.
Background noise	The underlying level of noise present in the ambient noise, excluding the noise source under investigation, when extraneous noise is removed. This is described using the L_{A90} descriptor.
Berm	This consists of earth or overburden to serve a specific purpose. For example, stabilising berms are used for stabilising purposes.
Bund	A bund is an embankment or wall of brick, stone, concrete or other impervious material, which may form part or all of the perimeter of a compound and provides a barrier to retain liquid.
Culvert	A pipe, drain or channel which allows facilitates drainage and allows water to pass beneath the road.
Curvilinear alignment	The alignment is a continuous curve with constant, gradual and smooth changed of direction
D&C	Design and construct contract
Floodplain	Extensive flat area of alluvium adjacent to a watercourse, characterised by frequent erosion and aggregated by channelled and overbank stream flow.
Intrusive noise	Refers to noise that intrudes above the background level by more than 5 dB(A).
$L_{A(XX)}$	The $L_{A(XX)}$ refers to statistical indicators that represent the percentage of time that a noise level is exceeded. These levels are commonly the L_{A1}, L_{A10}, and the L_{A90}, and are graphed to show how these levels change over the course of a 24 hour period.
L_{A90}	An important statistical indicator that represents the A-weighted sound pressure level that is exceeded for 90 per cent of the time over which the noise is measured. This is often termed the background noise.
L_{Aeq}	Although the L_{Aeq} is not a statistical indicator, it is probably one of the most important of the noise descriptors. It represents the equivalent continuous A-weighted noise level for the measurement period. This is the level of noise energy averaged over the measurement period.
L_{Amax}	Maximum noise level. The highest noise level during a specified time period or during a specified number of events expressed as the absolute maximum value of the root-mean-square (rms.) sound pressure level using time weighting 'F'.
L_{Amin}	Minimum noise level. The lowest noise level during a specified time period or during a specified number of events, expressed as the absolute minimum value of the root-mean-square (rms.) sound pressure level using time weighting 'F'.
Longitudinal	Along the alignment (of road or bridge)
Longitudinal section	A vertical section, usually with an exaggerated vertical, scale, showing the existing and design levels along a road line or another specified line
PMF	Probable maximum flood, the largest flood that may reasonably be expected to occur at a given point on a stream from the most severe combination of critical meteorological (rainfall) and hydrological (runoff) conditions that are reasonably possible on a particular watershed
RMS	NSW Roads and Maritime Services
Sag curve	A concave vertical curve in the longitudinal profile of a road

Select fill	Soil that is placed directly onto geosynthetic materials
Site compound	Area enclosing construction machinery, stockpiles and site offices
Spoil	Soil or materials arising from excavation activities
Stakeholder	An individual or group that has an interest in the project.
Stockpile	Temporarily stored materials, eg soil, sand, gravel, spoil/waste
TIG	Technical Investigation Group
Transverse	Perpendicular to the alignment (of road or bridge)
Vertical alignment	The longitudinal profile along the design of a road
Vertical curve	A curve (generally parabolic) in the longitudinal profile of a carriageway to provide for a change of grade at a specified vertical acceleration.
Visual effect	The degree of contrast the alignment will have within its setting. It is determined by the way of highway integrates with the topography, the mount of cut and fill required and the amount of contracts with the existing vegetation, the local villages and towns and other land uses and the scale of the landscape.
Visual sensitivity	The degree to which the highway is visible and is determined by the potential observer or viewer to the project. Sensitivity is determined by the nature of the viewer's activity, the expectation of viewers while undertaking that activity and by the distance of the project.

APPENDIX B – MEETING NOTES

	Berry Bypass Southern Route – Independent Review Notes of Meeting with Mr Bruce RamsayRamsay, 17/04/12 – 4:00pm
Present	Dan Reeve & Derrick Hitchins
1	Meeting was arranged at the request of Mr Bruce Ramsay to brief SMEC as the Independent Reviewer on the Southern Route Option that had been proposed by the community. .
2	Mr Ramsay provided some background as to his involvement in the development of the northern option based on his engineering experience and his interest in the project. He placed into context his working relationship with Mt Stuart Coghlan who had assisted him with the costings.
3	Note : All information that Mr Ramsay tabled for discussion had previously been sent to the RMS / TIG for their attention. No new information was presented or received by the Independent Reviewer prior to the meeting or on the day.
4	Mr Ramsay went through some of the issues that he believed were of concern to the residents of Berry he had spoken to and how this had shaped his thinking and the development of the design that he had prepared and put to the TIG. He also showed the Independent Reviewer how he had developed his cost estimate for the southern route.
5	Mr Ramsay was concerned that the TIG was not comparing apples with apples between the cost of the northern and southern routes. He expressed the view that the southern alignment being costed by the TIG was not being refined along the way to reflect his further modifications to the design and hence not adequately reflecting the additional savings he was able to identify.
6	Mr Ramsay was especially concerned how the extra earthworks required for the southern route was being assessed by the TIG and how the overall available cut & fill balance for the project was being overlooked during the costing of the imported fill component in the final layout of the southern viaduct.
7	DR & DH reiterated SMEC's independence on this project and assured Mr Ramsay that we would undertake a robust independent review of the process to ensure transparency so that whatever the decision, the decision is made on the best information available.

	Berry Bypass Southern Route – Independent Review Notes of Meeting with Gareth Ward, MP for Kiama, 20/04/12 – 10:30am
Present	Dan Reeve & Chris Masters
1	First and foremost is the need to get a Bypass for Berry, this has been in planning for a long time.
2	No personal preference for either a northern or southern route
3	Looking at best value for the taxpayer
4	There has been a considerable consultation process to date especially on the northern route
5	There has been an expectation from back in the 1950s and onwards that the Bypass would be a northern route.
6	The TIG process needs to quantify if there is a saving to the taxpayer
7	The community is looking for a robust process and achieve an outcome
8	There was some discrepancies in the 2007 (need to check) estimate with respect to the southern route
9	He is looking for a robust independent review of the process to ensure transparency so that whatever the decision the is made the decision is made on the best information available (within the time constraints).

APPENDIX C

Berry Bypass Review
Community Session Q/A #4
Monday 30th April 2012
Berry School of Arts 1/5/2012

Issues Register

Below are the issue raised by community members during the time allocated to address the technical specialists (TIG) and Independent reviewers.

No.	Issue	Description
1.	Survey/questionnaire	Has a questionnaire ever been carried out to capture the considerations and issues the community has?
2.	Social Impacts	Are social impacts assessed or is this reviews purely engineering technical aspects? If social impacts have been assessed, what was the weighting to their consideration?
3.	Technically not a "Bypass"	How is a route (Northern Route) that bisects the town, that is a "through route" and that bisects the town for future development, a "Bypass"? The Southern route bisects the town and avoids community severance. It also prevents issues with children going to school across the Northern route highway, safety issues etc. North = "Near miss" South = "Bypass"
4.	Documents available to community	What documents are made available to the community in regards to previous submissions and previous analysis of route assessment etc?
5.	Accessibility issues with the Northern route	Will ambulances have issues getting into the town with the Northern Route, as all Hospital facilities are in Nowra which is South of Berry?
6.	Example of Seacliff Road	Why can't the route (southern) be built out and up like Seacliff Rd?
7.	Kangaroo Valley Interchange	What amenity is gained from the large interchange at Kangaroo Valley?
8.	Flood event risk	The Northern route creates a "flood wall" to the town in the event of a severe flood.
9.	Orientation	Why would you go north (northern route) to go south in general direction?
10.	Community consultation process	Has the extensive community outside of Berry (the people who use the highway) been asked about the route?
11.	Perception	Has the decision been made? The perception is that the decision has been made and that the Northern route has been chosen.
12.	Heavy vehicles near town	Why have the fuel tankers and B-Doubles not been moved away from the town as per the Northern route?

13.	TIG recognition of issues raised	How does the TIG capture issue raised and how do they recognise these? A: Issues will be recorded in the minutes of the TIG meetings There must be a better/other way of representing these issues? A: Chris Masters said we will take back to RMS
14.	Cost Review	Does the cost review consider other elements such as Heritage, social aspects etc?
15.	Safety	The town will growth to the North (high side away from flood plains), so why is the Southern route not safer?
16.	Local Council's preference	Does the local council have preference or did they make the decision to go with the Northern?
17.	Independent Reviewers & Minister	Do the independent reviewers take their work and go to the Minister with a decision?
18.	Final decision	Is the final decision based only on the cost and the cheaper route chosen? North route = $X and Southern route = $Y
19.	Southern route assessment	The Northern route went through the route selection process, was the southern route even given the same assessment and critique? If assessed what were the reasons for eliminating it (to avoid ASS)?
20.	Design parameters	Are the design parameters for the like-for-like assessment the same?
21.	Reporting Hierarchy	Who do the Independent Reviewers report to? A: Separate to TIG, report to GM Major Projects (RMS)
22.	Timeframe	When will Duncan Gay make a decision? A: TIG finishes and then SMEC but no definite date? Is the timeline realistic with all the continual questioning?
23.	Community interaction with Independent Reviewer	Do the External Review Team talk to the community directly? Can we have a contact from SMEC? A: All community issues go through the Website/hotline and no one should go directly to the Independent reviewer team.
24.	Flood immunity	Is access in the case of flooding the same for both routes? What level of flood protection will RMS supply? Can this be separated and identifiable in the cost estimate?
25.	Capability Statement	Is there anywhere that has a profile/capability statement (examples of projects, experience etc) on the External Review Team? A: SMEC yes, but Lyall & Associates should have a similar thing
26.	Bruce Ramsay's Earthworks Calcs	External Review Team to cross reference Bruce's folder with earthworks calculations
27.	North St level	Why was the decision made on the North Street level?
28.	Southern Interchange	Can the southern interchange move further south?

APPENDIX D - MEETINGS REGISTER

Register of meetings attended by the External Review Team

Meeting Date	Details	Attendees	Key Actions/ Outcomes Achieved
12 March 2012	Inception meeting	Derrick Hitchins	Project background briefing by RMS Project Manager and preliminary document exchange.
14 March 2012	Weekly TIG project meeting # 6	Derrick Hitchins Chris Masters	Super –T bridge beams over a single capping beam on three round columns agreed to as preferred viaduct structure design. Refer to Minutes of Meeting for details
21 March 2012	Weekly TIG project meeting # 7	Derrick Hitchins Chris Masters	The provision for the cost of a separate pedestrian footbridge will be retained as a provisional item in the northern design Refer to Minutes of Meeting for details
21 March 2012	Strategic Cost Estimate meeting – Northern Route	Derrick Hitchins	Review of northern option cost estimate and construction program assumptions
28 March 2012	Meeting with RMS Internal Review Team	Derrick Hitchins Chris Masters	Agreed on level of detail to be provided for comparison purposes in accordance with RMS published estimating guidelines Refer to Minutes of Meeting for details
28 March 2012	Weekly TIG project meeting # 8	Derrick Hitchins Chris Masters	RailCorp decision on future rail corridor widening provisions received Refer to Minutes of Meeting for details
4 April 2012	Weekly TIG project meeting # 9	Dan Reeve Derrick Hitchins	Agreement on the use of a low flow pipe solution and straight alignment for the overland creek realignment agreed.
17 April 2012	Meeting with Bruce Ramsay (Nominated Community Rep.)	Dan Reeve Derrick Hitchins	Meeting notes prepared and distributed
18 April 2012	Weekly TIG project meeting # 10	Dan Reeve Derrick Hitchins Chris Masters	Refer to Minutes of Meeting for details
20 April 2012	Meeting with Gareth Ward MP (State Member for Kiama)	Dan Reeve Chris Masters	No personal preference for either a northern or southern route. Looking for best value for money for the taxpayer recognizing that the northern option has been in the planning phase for some time.
23 April 2012	Strategic Cost Estimate meeting – Northern and Southern Route	Derrick Hitchins	Review of southern option cost estimate and construction program assumptions
24 April 2012	Weekly TIG project meeting # 11	Chris Masters	Refer to Minutes of Meeting for details
30 April 2012	Berry Community Consultation Meeting	Derrick Hitchins Chris Masters	Refer to Minutes of Meeting for details
16 May 2012	Weekly TIG project meeting # 12	Dan Reeve Chris Masters	Refer to Minutes of Meeting for details

APPENDIX E – REPORT BY LYALL & ASSOCIATES

PRINCES HIGHWAY UPGRADE
GERRINGONG TO BOMADERRY
FOXGROUND AND BERRY BYPASS

REVIEW OF FLOODING INVESTIGATION UNDERTAKEN BY AECOM FOR THE SOUTHERN BYPASS ROUTE

JUNE 2012

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1 Introduction

1.1 Background and Purpose of this Review

The development of route options for the Princes Highway upgrade program began in March 2006, with a preferred Foxground and Berry Bypass (FBB) route including a bypass to the north of Berry, announced by the NSW Roads and Traffic Authority (now the NSW Roads and Maritime Services (RMS)) in December 2011. In February 2012, RMS was directed by the Minister for Roads to undertake a detailed cost evaluation of a southern Berry bypass route (denoted herein as the "Southern Bypass Route" or "SBR" for short) following a suggestion submitted by a community member in December 2011.

In response to the Minister's direction, RMS commissioned a series of technical investigations (flood modelling being one of them) to develop the SBR to a sufficient level of detail to undertake a "like for like" cost comparison with the preferred northern route option. The investigation process was carried out between January 2012 and June 2012 by a Technical Investigation Group (TIG) comprising RMS personnel as well as several consultants from the private sector.

In addition to the TIG, RMS also formed an Independent Review Team (IRT) to oversee the investigation process. The IRT's scope covered testing the robustness of information to be published in the report prepared by the TIG on the SBR. In doing so, the Reviewer:

a. had access to all information sources the TIG had relied in preparing its report;

b. were able to request meetings with any members of the TIG to investigate and potentially challenge assumptions made; and

c. were required to produce an independent report on the information contained in the TIG report.

To maximise their input, the IRT were able to attend TIG, community and any other meetings as required during the investigation process.

This report is a technical review of information contained in Chapter 5 of the TIG's report which deals with the flooding investigation undertaken by consultants AECOM for the Southern Route. AECOM's investigation had three principal objectives:

- To define flooding behaviour on the lower Broughton Creek floodplain under current climatic and floodplain conditions. The findings of this investigation were used by the TIG to set minimum road levels and waterway openings for the SBR.
- To assess the impact future sea level rise and possible increases in rainfall intensity linked to climate change would have on flooding behaviour. The findings of AECOM's investigation were used by the TIG to determine whether additional "freeboard" (i.e. increase in road embankment levels to cater for increased water levels, or increase in waterway openings to accommodate increase in flood discharges) was needed in the design of the highway upgrade in order to accommodate changes in flooding behaviour associated with future climate change.
- To assess the impacts of the SBR on local flooding patterns. The findings of AECOM's investigation were used by the TIG to refine the design of the SBR such that existing development was not impacted by the road works for a flood with an ARI of 100 years.

Figure 1.1 shows the route of the SBR where it crosses the lower floodplain of Broughton Creek south of Berry.

1.2 Flood Mechanisms

The section of the Broughton Creek floodplain which the SBR would cross is subject to both local catchment flooding as well as backwater flooding from the Shoalhaven River. Local catchment flooding occurs when intense rain of relatively short duration occurs over the catchment of Broughton Creek and its tributaries. Flooding of this type is characterised by relatively fast rising and moving floodwater which inundates the floodplain for periods of less than a day. Local catchment flooding can occur separately to the occurrence of elevated water levels in the Shoalhaven River, for example as a result of localised thunderstorm activity on the Broughton Creek catchment.

By comparison, backwater flooding from the direction of the Shoalhaven River occurs when more general and widespread heavy rain falls over a period of several days. Flooding of this nature generally occurs as a result of large scale meteorological events such as East Coast Lows, which occur on average several times each year off the eastern coast of Australia. Flooding of this type is characterised by relatively slow moving and rising flood water in the Shoalhaven River which extends into and inundates the lower floodplain of Broughton Creek for several days.

Although these two flood mechanisms can occur independently of each other, it is more likely that major flooding of one type will occur coincident with a flood event of the other type. When coincident local catchment and Shoalhaven River flooding occurs, flooding conditions can be more severe than when one type of flooding occurs in isolation of the other.

However, given the major differences in the climatic conditions which cause these two types of flooding, it is generally accepted that the simultaneous occurrence of each flood mechanism with the same ARI will generate conditions representative of a flood event with a much larger ARI. For example, conditions in the lower Broughton Creek floodplain resulting from a 100 year ARI local catchment flood coincident with a 100 year ARI Shoalhaven River flood, are representative of a flood which is much less frequent than 100 years (i.e. has a much larger ARI) and if adopted for design purposes are likely to yield conservatively high estimates of levels and flows.

Two previous investigations[1] have assumed coincident 100 year ARI local catchment and Shoalhaven River flooding when defining 100 year ARI flooding conditions in the township of Berry. However, the alternative “flood envelope” approach adopted by AECOM for its current investigation is considered by the Reviewer to be more appropriate. The flood envelope approach assumes that the 100 year ARI flood level at a particular location should be based on the higher level resulting from either: the 100 year ARI local catchment flood in combination with a 20 year ARI Shoalhaven River flood, or a 20 year ARI local catchment flood in combination with a 100 year ARI flood on the Shoalhaven River. With this approach there is a “crossover” of the two water surface profiles, with flooding from the Shoalhaven River dominating in the lower reaches of the floodplain and local catchment flooding controlling flooding further upstream. Further details on the approach adopted by AECOM are contained in **Section 2** of this Review.

[1] SMEC, 2008 and Cardno, 2011

1.3 Issues Considered in the Review

The Review is based on the coverage and content of AECOM's reporting in regard to the following flood related issues:

- Was the modelling approach adopted by AECOM suitable for modelling the SBR? i.e. RAFTS rainfall runoff modelling of the catchment to assess flows + TUFLOW two dimensional + HEC-RAS one dimensional hydraulic modelling to convert flows to flood levels, velocities and patterns of flow in the floodplains.
- Are the model layouts adequate for their purpose? (i.e. a preliminary study to compare present day versus post-SBR conditions and provide data for a cost comparison with the Northern route, to be refined for detailed design in the event the SBR is selected).
- Was the model testing procedure adequate for the purposes of the study? (and given the constraints imposed by the study timetable).
- Were the model boundary conditions adopted for design flood estimation appropriate and in accordance with Government Policy and accepted standards? (i.e. the combination of backwater influences from the Shoalhaven River for the downstream boundary and local catchment flows for the upstream boundaries).
- Were the analyses undertaken to assess the impacts of future climate change in accordance with accepted standards and Government Policy?

1.4 Previous Investigations Used by AECOM

The following investigations have been used by AECOM in the derivation of flood behaviour along the SBR:

- **Lower Shoalhaven River Flood Study** (PWD, 1990). The study defined design flood levels in the Lower Shoalhaven River for floods with ARI's of 20, 50 and 100 years. The study defined flood behaviour along a 2 km reach of the Lower Shoalhaven River extending upstream to the Nowra Road Bridge and included the Lower Broughton Creek floodplain upstream to Coolangatta Road.
- **Broughton Creek Flood Study** (SMEC, 2008)[2]. The study defined flood behaviour along Broughton Creek and several of its tributary streams for floods with ARI's of 5, 10, 20, 50, 100 and 200 years, together with the Probable Maximum Flood (PMF). The RAFTS (hydrologic) and MIKE 11 (hydraulic) modelling software were used for this purpose.
- **Broughton Creek Stage 1 Report** (Cardno, 2011). The study used the RAFTS hydrologic model developed as part of SMEC, 2008 as the basis for generating design discharge hydrographs for input to a two-dimensional (in plan) hydraulic model which was developed for the township of Berry. The TUFLOW hydraulic modelling software was used as the basis for re-defining flood behaviour in the town. The study formed the first step in the preparation of a Floodplain Risk Management Study and Plan for Berry.
- **Lower Shoalhaven River Floodplain Management Study & Plan – Climate Change Assessment** (WMAwater, 2011). The main objective of this study was to amend the then

[2] Note that only a final draft version of this document dated April 2007 was able to be downloaded from Shoalhaven City Council's web site.

existing Lower Shoalhaven Floodplain Risk Management Study and Plan (WM&A, 2008) to incorporate the predicted impacts of climate change.

It is noted that the three most recent studies were prepared on behalf of Shoalhaven City Council (SCC) with funding assistance from the NSW State Government and are being used to inform planning decisions in the township of Berry and on the Lower Broughton Creek floodplain. It is also noted that the Floodplain Risk Management Study and Plan for the Lower Shoalhaven River relies on the findings of PWD, 1990 for design flood level information. For these reasons, it is considered appropriate that AECOM relies on the information contained in these reports for the purpose of undertaking its current investigation. Further discussion on AECOM's adopted approach for flood modelling is contained in **Section 2** of this report.

2 Review of hydrologic and hydraulic models

2.1 General

The study required the use of a computer based hydrologic model of the study catchments to define flood flows and a hydraulic model of the channel and overland flow areas of the floodplain to convert these flows into flow patterns and water surface levels. The hydraulic model also provided information on the extent of inundation and distribution of flow and velocities across the floodplain.

AECOM has generally relied on the use of hydrologic and hydraulic models which were developed originally as part of SMEC, 2008 and later updated as part of Cardno, 2011 for undertaking its flooding investigation of the SBR. The following sections of the report deal with our review of the structure of these models and their application to the current flooding investigation.

Also included in this section of the report are details of original flood modelling which was undertaken by AECOM to define flood behaviour in the vicinity of the Southern Interchange and along the section of the old Princes Highway which crosses Hitchcocks Lane Tributary.

2.2 Adopted Modelling Approach

2.2.1 Hydrologic Modelling

For hydrologic modelling, the practical choice is between the catchment models known as RAFTS, RORB and WBNM. Each of these models converts storm rainfall to discharge hydrographs using a procedure known as runoff-routing.

AECOM has relied on flows generated by the RAFTS model which was originally developed by SMEC as part of the Broughton Creek Flood Study (denoted herein as the SMEC RAFTS model) and later amended as part of Cardno, 2011 (denoted herein as the Cardno RAFTS model) as the basis for undertaking its flood assessment.

Reviewer's Comment:
As there is little to choose technically between the three abovementioned modelling packages, the use of the RAFTS hydrologic modelling software for generating discharge hydrographs for input to a hydraulic model is considered appropriate.

2.2.2 Hydraulic Modelling

AECOM has used both one and two-dimensional (in plan) hydraulic modelling approaches to define flood behaviour along the route of the SBR.

The HEC-RAS one-dimensional hydraulic modelling software package has been used to define flood behaviour in the vicinity of the Southern Interchange and along the section of the old Princes Highway which crosses Hitchcocks Lane Tributary, while the TUFLOW one and two-dimensional (in plan) hydraulic modelling software package has been used to define flood behaviour where the SBR crosses the lower floodplain of Broughton Creek.

The HEC-RAS software has been developed by the Hydrologic Engineering Centre of the US Army Corps of Engineers, while the TUFLOW software has been developed in Australia. Both software packages have seen widespread application in Australia in recent years.

Reviewer's Comment:
The application of both the HEC-RAS and TUFLOW software packages to defining flood behaviour in selected areas is considered appropriate for the current investigation.

2.3 Model Structure

2.3.1 Hydrologic Model

Figure 2.1 shows the layout of the SMEC RAFTS model. The model comprises the catchment of Broughton Creek to Coolangatta Road, as well as those tributary streams which drain immediately to the north and south of Berry.

Figure 2.2 shows the layout of the Cardno RAFTS model and is taken from Cardno, 2011. Although it is not clear from the figure what changes were made to the SMEC RAFTS model, the Cardno, 2011 report does state the following:

"The hydrological model XP-RAFTS was used to generate the inflow hydrographs to the study area. A XP-RAFTS model was constructed as part of the previous SMEC (2008) study. The model required minor adjustments to catchment areas due to the new 2D domain, but all other parameters remained unchanged."

Although a copy of the Cardno RAFTS model was not available for the current review, it is believed that the sub-catchments shaded green in **Figure 2.2** (which correspond with several of the sub-catchments within the SMEC RAFTS model) were reduced in area so that their downstream boundary corresponded with the upstream boundary of the Cardno TUFLOW model.

Reviewer's Comment:
Provided the lag times in the reaches which link the blue shaded catchments with the outlets of the green shaded catchments in **Figure 2.2**, then the Cardno RAFTS model should generate discharge hydrographs similar to those of the SMEC RAFTS model.

2.3.2 Hydraulic Model (TUFLOW)

The TUFLOW model which was originally developed as part of Cardno, 2011 (denoted herein as the Cardno TUFLOW model) was used by AECOM as the basis for defining flood behaviour on the lower floodplain of Broughton Creek. The Cardno TUFLOW model comprises the main arm of Broughton Creek and its floodplain were it runs to the east of Berry, in addition to the tributary streams which drain immediately to the north and south of the township. **Figure 2.3** shows the layout of the Cardno TUFLOW model.

Both the inbank and overbank areas of Broughton Creek and its tributary streams were modelled in the two-dimensional model domain using a 3 m grid, with the use of one-dimensional elements limited to the definition of the piped and channel reaches comprising the existing stormwater drainage network within Berry.

Reviewer's Comment:
We are of the view that the inbank area of Broughton Creek and its tributary streams should have been modelled as one-dimensional elements in order to more accurately define the conveyance capacity of these streams. This omission would in our opinion probably result in an increase in the magnitude of flow conveyed by the overbank area and possibly lead to a conservatively high estimate of peak flood levels.

In discussions with the Reviewer, it was agreed by AECOM that the downstream boundary of the Cardno TUFLOW model needed to be shifted toward the south in order to better define flood behaviour in the vicinity of the SBR. The layout of the adjusted TUFLOW model (denoted herein as the AECOM TUFLOW model) is shown on **Figure 2.3**.

Reviewer's Comment:
The downstream boundary of the AECOM TUFLOW model is considered to be located a sufficient distance downstream so as not to affect flooding patterns in the vicinity of the SBR.

In discussions between AECOM and the Reviewer, it was agreed that the "flood envelope" approach to defining 100 year ARI flood behaviour on the lower floodplain of Broughton Creek should be adopted, rather than the approach adopted as part of the SMEC, 2008 and Cardno, 2011 studies. These two previous investigations have assumed coincident 100 year ARI local catchment and Shoalhaven River flooding when defining 100 year ARI flooding conditions in the township of Berry. However, the alternative "flood envelope" approach adopted by AECOM for its current investigation is considered by the Reviewer to be more appropriate. The flood envelope approach assumes that the 100 year ARI flood level at a particular location should be based on the higher level resulting from either: the 100 year ARI local catchment flood in combination with a 20 year ARI Shoalhaven River flood, or a 20 year ARI local catchment flood in combination with a 100 year ARI flood on the Shoalhaven River. With this approach there is a "crossover" of the two water surface profiles, with flooding from the Shoalhaven River dominating in the lower reaches of the floodplain and local catchment flooding controlling flooding further upstream.

As the upstream boundary of the AECOM TUFLOW model did not differ from that of the Cardno TUFLOW model, the same inflow hydrographs derived as part of Cardno, 2011 were used for the current investigation.

Peak flood levels for application to the downstream boundary of the AECOM TUFLOW model were taken from PWD, 1990. Although the CELLS model developed as part of PWD, 1990 comprises the lower floodplain of Broughton Creek as far upstream as Coolangatta Road (refer **Figure 2.4** for CELLS model layout), AECOM has adopted peak flood levels in CELL No. 34 as being representative of peak flood levels at the downstream boundary of the AECOM TUFLOW model. The peak 20 and 100 year ARI flood levels adopted by AECOM for application to the downstream boundary of the AECOM TUFLOW model are RL 4.3 m AHD and RL 5.0 m AHD, respectively.

Reviewer's Comment:
Although the Cardno RAFTS model was not available for the current Review, a check of the inflow hydrographs used as input to the AECOM TUFLOW shows that they are comparable to those generated by the SMEC RAFTS model, a copy of which was available for the Review.

Reviewer's Comment (Cont'd):

Based on a review of the peak height contours presented in PWD, 1990, the adoption of RL 5.0 m AHD as the peak 100 year ARI Shoalhaven River flood level at the downstream boundary of the AECOM TUFLOW model is considered reasonable.

The peak 20 year ARI Shoalhaven River level in the vicinity of Coolangatta Road may be about 700 mm lower than that adopted by AECOM for the current investigation based on information presented in PWD, 1990. However, the application of the higher peak flood level of RL 4.3 m AHD to the downstream boundary of the AECOM TUFLOW model would not alter the findings of the current investigation as they relate to the SBR.

The main physical parameter for TUFLOW is the hydraulic roughness. Hydraulic roughness is required for each of the various types of surfaces comprising the overland flow paths, as well as for the cross sections representing the geometric characteristics of the creek. In addition to the energy lost by bed friction, obstructions to flow also dissipate energy by forcing water to change direction and velocity and by forming eddies. Hydraulic modelling traditionally represents all of these effects via the surface roughness parameter known as "Mannings n". Flow in the piped system also requires an estimate of hydraulic roughness.

Table 2.2 presents the of hydraulic roughness values which were used as input to the Cardno TUFLOW model and later adopted by AECOM for its current investigation. **Figure 2.5** shows the spatial variation in hydraulic roughness values over the extent of the two-dimensional model domain (defined as different "Roughness Zones" in Cardno, 2011).

TABLE 2.2
HYDRAULIC ROUGHNESS VALUES
ADOPTED FOR TUFLOW MODELLING

Roughness Zone	Mannings n Value
Road	0.015
Low Residential	0.09
Medium Residential/Commercial	0.11
Low Density Vegetation	0.06
High Density Vegetation	0.1
Waterway	0.05

Source: Cardno, 2011

Reviewer's Comment:

The hydraulic roughness values adopted for TUFLOW modelling appear reasonable and lie within generally accepted ranges for land use of the type present on the floodplain of Broughton Creek and its tributary streams.

2.3.3 Hydraulic Model (HEC-RAS)

The structure of the HEC-RAS model which was developed for the purposed of sizing the water openings on Anderson Lane Creek and one of its tributaries is considered appropriate for the purpose of the current assessment, with the exception that there is insufficient freeboard available to the soffit level of the proposed bridges on the Northern On-Ramp and Southern Off-Ramp.

A review of the HEC-RAS model which was developed for the purpose of sizing the water openings on Hitchcocks Lane Creek and one of its tributaries showed that the post-upgrade geometric model does not contain the number of 1350 mm diameter pipes set out in Table 5.4 of the TIG report. It was also noted that the railway embankment which lies downstream of the highway has been modelled as an inline structure with no provision made for the waterway openings which are present in the embankment.

After being advised of the above findings, AECOM forwarded an updated set of HEC-RAS model files which resolved these issues (AECOM, pers. comm. 28 May 12).

2.3.4 Hydraulic Analyses using Bentley Culvertmaster and HY-8 Software Packages

No details were provided on the analyses which were undertaken using the Bentley Culvertmaster and HY-8 software packages referred to in Section 5.1.3.2 of the TIG report.

2.4 Model Calibration

The process of calibrating both the hydrologic and hydraulic models which is presently being used by AECOM as the basis for its current investigation has its origins in the work that was originally carried out as part of SMEC, 2008. As no historic stream flow records were available to allow SMEC to undertake a formal calibration of the SMEC RAFTS model, a process often referred to as "tuning" was undertaken, whereby adjustments were made to both the hydrologic and hydraulic model parameters until good correspondence with observed flood behaviour was achieved.

Following on from the work undertaken by SMEC, Cardno compared peak flood levels generated by the Cardno TUFLOW model with several historic flood marks, as well as peak 100 year ARI flood levels derived as part of SMEC, 2008. In regards the model calibration process, Cardno, 2011 states the following:

"For the 2002 historical event, the TUFLOW model reports values within +/-0.2m of the recorded historical values, with the majority within +/-0.1m.

For the 2005 historical event, the TUFLOW model reports values within +/-0.3m of the recorded historical values, with the majority within +/-0.1m.

This is considered sufficiently accurate given the sources of the historical data which were generally flood marks, or resident observations, which were surveyed after the flood had past.

Most of the historical marks were focused on Town Creek and Broughton Mill Creek. In order to verify the accuracy of the wider model, locations were taken from across the study area from the 1% AEP Mike11 model, and compared to the TUFLOW results.

For the 1% AEP design event, TUFLOW predicted flood levels that were generally within +/-0.2m of the Mike 11, with the majority within +/-0.1m."

Reviewer's Comment:

A rigorous review of the work carried out as part of SMEC, 2008 and Cardno, 2011 does not appear to have been undertaken by AECOM as part of its current investigation. AECOM has simply accepted the models which were developed on behalf of Shoalhaven City Council as being capable of defining behaviour which is representative of a flood with an ARI of 100 years.

Although a review of the models and their structure should be undertaken during the detail design of the FBB, it is the Reviewer's opinion that the models being relied upon by AECOM as part of the current investigation are sufficiently detailed to provide a reasonable estimate of flooding patterns along the route of the SBR. The key reason for this conclusion is that flood behaviour on the lower floodplain of Broughton Creek is heavily influenced by backwater flooding from the Shoalhaven River and minor changes to hydrologic and hydraulic model parameters would not have a major impact on predicted flood behaviour along the route of the SBR for a 100 year ARI event.

As a check on the design flows used as input to the hydraulic model, flows generated by the SMEC RAFTS model were compared to peak flows derived using the Probabilistic Rational Method, procedures for which are set out in Book IV of Australian Rainfall & Runoff (IEAust, 1998). By inspection of the values given in **Columns 2** and **3** of **Table 2.1**, peak 100 year ARI flows generated by the SMEC RAFTS model are generally higher than those derived using the PRM.

TABLE 2.1
COMPARISON OF PEAK FLOWS
100 YEAR ARI
(m^3/s)

Stream	Location	Catchment Area (km^2)	Peak Flow	
			PRM	SMEC RAFTS Model[1]
		(1)	(2)	(3)
Broughton Creek	Immediately upstream of confluence with Broughton Mill Creek	42.6	860	935[2]
Broughton Mill Creek	Immediately upstream of confluence with Bundewallah Creek	22.5	540	640
	Immediately downstream of confluence with Bundewallah Creek	43.6	880	1130
Bundewallah Creek	Immediately upstream of confluence with Broughton Mill Creek	21.1	500	490

1. Unless otherwise noted, peak flows are for design storm of 2 hours duration
2. Peak flow relates to critical storm of 6 hours duration.

Reviewer's Comment:

The SMEC RAFTS model generates peak flows which are generally in agreement with the PRM, an accepted alternative approach to design flood estimation.

Provided only minor changes were made to the structure of the SMEC RAFTS model as part of Cardno, 2011, then it would be reasonable to assume that the Cardno RAFTS model would also generate peak flows similar to those given in **Table 2.1**.

3 REVIEW OF FLOOD RELATED ISSUES - CURRENT CLIMATIC CONDITIONS

3.1 Design Flood Levels

3.1.1 TUFLOW Hydraulic Modelling

Figures A5 and A6 of the TIG report (refer **Annexure A** of this report for a copy) appear to show peak flood levels and depths of inundation for the case where the Island Embankment Option has been modelled.

Reviewer's Comment
Figures A5 and A6 are first introduced in Section 5.1.4.1 of the TIG report, whereas the Island Embankment Option and its impacts on flood behaviour are not introduced to the reader until the end of Chapter 5 (refer Section 5.1.5.4). The Reviewers consider that Figures A5 and A6 should show flood behaviour for the case where the Island Embankment Option has not been modelled.

Figure A5 shows the result of modelling the combination of Shoalhaven River and Broughton Creek flooding which is critical for maximising peak flood levels along the SBR where it crosses the lower floodplain of Broughton Creek (i.e. for the case where 100 year ARI Shoalhaven River flood is assumed to coincide with a 20 year ARI Broughton Creek flood). Water surface contours shown on Figure A5 at the location where the SBR crosses Broughton Mill Creek and Hitchcocks Lane Creek are not consistent with the peak flood levels given in Table 5.2 of the TIG report. For example, an RL 6.8 m AHD water surface contour is shown on the northern abutment of the Broughton Mill Creek bridge crossing, whereas Table 5.2 states that the peak 100 year ARI flood level at the crossing is RL 5.3 m AHD. In the case of the Hitchcocks Lane Creek crossing, an RL 5.4 m AHD water surface contour is shown on the western bridge abutment, whereas Table 5.2 states that the peak 100 year ARI flood level is RL 5.0 m AHD.

Reviewer's Comment
A review of the TUFLOW model output files provided by AECOM confirmed that the peak 100 year ARI flood levels at the three main creek crossings are as per Table 5.2 in the TIG report. The contour labels shown on Figure A5 are therefore incorrect. The same comment applies to the water surface contour information shown on Figure A6.

3.1.2 HEC-RAS Hydraulic Modelling

A review of the HEC-RAS model output files provided by AECOM on 28 May 2012 confirmed the findings set out in Section 5.1.4.1 of the TIG report which deals with peak 100 year ARI flood levels at the Southern Interchange and along the proposed access route into Berry (i.e. along the section of existing highway which runs north from the Southern Interchange).

3.2 Impacts of SBR on Flood Behaviour

3.2.1 TUFLOW Hydraulic Modelling

Unlike Figures A5 and A6 which show flood behaviour for the case where a 100 year ARI Shoalhaven River flood coincides with a 20 year ARI local catchment flood event, Figures A7 to A10 (refer **Annexure A** of this report for a copy) show the impact the SBR will have on

flood behaviour for the case where a 100 year ARI Broughton Creek flood occurs in the absence of elevated water levels in the Shoalhaven River. [3]

Figure A7 shows that peak 100 year ARI flood levels will be increased in the range 0.21-0.5 m where the SBR crosses Hitchcocks Lane Tributary west of Wharf Road for the case where a 100 year ARI Broughton Creek flood occurs in the absence of elevated water levels in the Shoalhaven River. It is noted that the resulting peak 100 year ARI flood level under these conditions is about RL 2.5 m AHD, which is 2.5 m below the 100 year ARI Shoalhaven River flood level of RL 5.0 m AHD.

Figure A7 also shows that peak 100 year ARI flood levels will be increased in the range 20-50 mm north of the South Coast Railway Line where it crosses Broughton Creek for the case where a 100 year ARI Broughton Creek flood occurs in the absence of elevated water levels in the Shoalhaven River. The impact is a result of the road embankment which extends onto the floodplain north of the rail corridor. A review of the TUFLOW model output files provided by AECOM shows that flood behaviour north (upstream) of the South Coast Rail Line on Broughton Creek is not sensitive to changes in tailwater conditions for events up to 100 year ARI.

Reviewer's Comment

It is noted that no information is provided on the impact of the SBR on the combination of Shoalhaven River and Broughton Creek floods which is critical for maximising peak 100 year ARI where it crosses the lower floodplain of Broughton Creek (i.e. a 100 year ARI Shoalhaven River flood coincident with a 20 year ARI Broughton Creek flood).

While the Reviewer agrees that the relative impacts of the SBR will be greater under the conditions shown on Figures A7 to A10 (i.e. for the case where a 100 year ARI Broughton Creek flood occurs in the absence of elevated water levels in the Shoalhaven River), the report should also have included details of the impact of the SBR on the combination of floods which is critical for maximising peak 100 year ARI flood levels along the SBR where it crosses the lower floodplain of Broughton Creek. The principal reason for this is that the impacts of the SBR may extend further north (upstream) than that shown on the report figures, since depths (and hence extents) of inundation will be greater for the case where a 100 year ARI Shoalhaven River flood coincides with a 20 year ARI Broughton Creek flood.

One concern is that Figure A7 shows that the SBR will not impact flood behaviour in several rural residential properties which are located immediately to the south of the South Coast Railway Line west of Berry Station. However, by inspection of the available aerial photography and ground surface elevation data, several structures located within these properties have been built on land which lies below the peak 100 year ARI Shoalhaven River flood level of RL 5.0 m AHD. It follows that if the SBR has an impact on peak flood levels for the case where the 100 year ARI Shoalhaven River flood occurs coincident with a 20 year ARI Broughton Creek flood, then flooding conditions in the vicinity of these structures could be exacerbated. If it were to be shown that the SBR will increase peak 100 year ARI flood levels in these properties, then it may be necessary to increase the length of the bridge over Hitchcocks Lane Creek in order to mitigate these impacts

[3] It is also noted that unlike Figures A5 and A6, Figures A7 to A10 show the impact of the SBR on flood behaviour for the case where the Island Embankment Option was not modelled.

Increases in flow velocities will generally be confined to the right overbank of Broughton Creek north of the South Coast Railway Line and in the vicinity of the bridge over Hitchcocks Lane Creek (refer Figure A10 in Appendix C1 of the TIG report). Increases in flow velocities are generally in the range 0-0.4 m/s, however, increases of up to 1 m/s would be experienced at the bridge abutment located near Tannery Road underpass through the bridge opening on Hitchcocks Lane Creek.

Reviewer's Comment
The cost estimate for the SBR should include provision for scour protection measures in the form of appropriately sized rock rip rap at the bridge abutments.

By inspection of Figures A11 to A13 (refer **Annexure A** of this report for a copy), the impacts of the Island Embankment Option will generally be confined to the eastern (left) overbank of Broughton Mill Creek immediately south (downstream) of the South Cost Railway Line.

Reviewer's Comment
There is a concern that the obstruction to flow caused by the Island Embankment Option will exacerbate flooding conditions in existing development which is located on the eastern (left) overbank of Broughton Mill Creek immediately south (downstream) of the South Cost Railway Line.

3.2.2 HEC-RAS Hydraulic Modelling

A review of the amended HEC-RAS model output files provided by AECOM on 28 May 2012 confirmed the findings set out in Section 5.1.5.2 of the TIG report which deals with changes to flood behaviour in the vicinity of the Southern Interchange. It is noted that the relatively large increases in peak 100 year ARI flood levels which are shown to occur upstream of the Southbound On-Ramp and the Main Alignment (refer Table 5.10 in the TIG report for details) do not extend upstream of the road corridor.

The findings set out in Section 5.1.5.3 of the TIG report, which deals with the impacts of the upgrade of two culvert crossings located along the southern access route into Berry on flood behaviour, were also confirmed by inspection of the amended HEC-RAS model output files provided by AECOM on 28 May 2012.

Reviewer's Comment
The cost estimate for the SBR should include provision for scour protection measures in the form of appropriately sized rock rip rap at the bridge abutments, as well as at the outlets of the upgraded cross drainage structures located along the Princes Highway.

3.3 Freeboard Considerations

A longitudinal section of the SBR[4] shows that a minimum 0.5 m minimum freeboard is to be built into the road bridges where they cross Broughton Creek and Hitchcocks Creek. A second drawing showing typical details of the SBR[5] also shows that a 0.5 m freeboard is to be incorporated in the design of the bridge where it crosses the lower floodplain of Broughton Creek.

As mentioned in **Section 2.3.3** of this report, a review of the HEC-RAS model developed for the Southern Interchange indicated that the required 0.5 m minimum freeboard to the soffit level of the bridges on the Northern On-Ramp and Southern Off-Ramp may not have been incorporated in the road design. After being advised of this finding, AECOM forwarded an updated set of HEC-RAS model files which incorporated a series of bridges which incorporated the required amount of freeboard (AECOM, pers. comm. 28 May 2012).

[4] Dwg No. 60021933-DRG-10-02-SRO-SK004 Rev. 1.0
[5] Dwg No. 60021933-DRG-10-02-SRO-SK002 Rev. 1.0

4 Climate Change considerations

4.1 Relevance of Climate Change to the SBR

Climate change will increase sea levels and rainfall intensities. The significance of these increases on flood behaviour will vary depending on geographic location and local topographic conditions. The principal effects of climate change as far as the SBR is concerned are the potential increase in flood levels along the road alignment and the potential impact of the road works on local flooding behaviour. Because the SBR is located in an area that is subject to both local catchment and backwater flooding from the Shoalhaven River, there is the potential for flood behaviour along the route to be impacted by both of the climate change effects.

The following sections of the Review provide a brief background to current State Government policy in relation to sea level rise and increased rainfalls and its findings as they relate to the SBR.

4.2 Sea Level Rise

4.2.1 Background

The NSW Government has adopted a *Sea Level Rise Policy Statement* (DECCW, 2009) to support adaptation to projected sea level rise impacts. The policy statement includes sea level rise planning benchmarks for use in assessing potential impacts of projected sea level rise in coastal areas, including flood risk and coastal hazard assessment. These benchmarks are a projected rise in sea level (relative to 1990 mean sea level) of 0.4 m by 2050 and 0.9 m by 2100 and are based on work carried out by the Intergovernmental Panel on Climate Change and the CSIRO.

The NSW Government has also released a guideline *Flood Risk Management Guide: Incorporating Sea Level Rise Benchmarks in Flood Risk Assessments* (DECCW, 2010), which is to be used as the basis for examining sea level rise in projects undertaken under the State Floodplain Management program and the NSW *Floodplain Development Manual* (NSWG, 2005). The information in this guide updates the sea level rise information contained in the guideline *Flood Risk Management Guideline: Practical Considerations of Climate Change* (DECC, 2007) and the NSW *Floodplain Development Manual* (NSWG, 2005).

4.2.2 Impacts on Flood Behaviour along SBR

WMAwater, 2011 presents the findings of an investigation into the impact sea level rise will have on flood behaviour along the Lower Shoalhaven River. The findings of this study as they relate to the SBR are summarised **Table 4.1**.

By inspection of the values given in **Table 4.1**, rises in sea level of 0.4 m and 0.9 m will translate into an increase of only 20 mm and 50 mm in peak 100 year ARI flood levels in the lower floodplain of Broughton Creek, respectively (refer ID2 and ID3 in **Table 4.1**).

It is noted that this finding is consistent with that of AECOM.

TABLE 4.1
INCREASE IN PEAK 100 YEAR ARI FLOOD LEVELS
RESULTING FROM VARIOUS CLIMATE CHANGE SCENARIOS
SHOALHAVEN RIVER FLOODING ONLY

ID	Climate Change Scenario	Impact[1,2] (m)	Peak Flood Level (m AHD)
1	**Current Climatic Conditions**	**-**	**5.0**
2	**0.4 m SLR**	**0.02**	**5.02**
3	**0.9 m SLR**	**0.05**	**5.05**
4	**10% Increase in Rainfall Intensity**	**0.16**	**5.16**
5	20% Increase in Rainfall Intensity	0.31	5.31
6	30% Increase in Rainfall Intensity	0.48	5.48
7	**0.4 m SLR and 10% Increase in Rainfall Intensity**	**0.17**	**5.17**
8	0.4 m SLR and 20% Increase in Rainfall Intensity	0.33	5.33
9	0.4 m SLR and 30% Increase in Rainfall Intensity	0.50	5.50
10	**0.9 m SLR and 10% Increase in Rainfall Intensity**	**0.20**	**5.20**
11	0.9 m SLR and 20% Increase in Rainfall Intensity	0.38	5.38
12	0.9 m SLR and 30% Increase in Rainfall Intensity	0.57	5.57

1. Source: WMAwater, 2011
2. Impacts quoted to 2 decimal places to highlight minor differences in corresponding values.

4.3 Increase in Rainfall Intensity

4.3.1 Background

Climate change impacts on flood producing rainfall events show a trend for larger scale storms and resulting depths of rainfall to increase. CSIRO prepared reports for the NSW Government on the impacts of climate change on rainfall intensities in the major river basins in the state (CSIRO, 2007). In the Study Area, the 40 year ARI, 1 day rainfall was predicted to change by between +7 per cent by 2030 and by +5 per cent by 2070.

OEH recommends that its guideline *Practical Consideration of Climate Change, 2007* be used as the basis for examining climate change in projects undertaken under the State Floodplain Management program and the *Floodplain Development Manual, 2005*. The guideline recommends that until more work is completed in relation to the climate change impacts on rainfall intensities, sensitivity analyses should be undertaken based on increases in rainfall intensities ranging between 10 and 30 per cent.

On current projections the increase in rainfalls within the service life of developments or flood management measures is likely to be around 10 per cent, with the higher value of 30 per cent representing an upper limit.

The Scope of Works and Technical Criteria developed for the Gerringong to Bomaderry section of the Princes Highway Upgrade included a provision whereby the designers needed to include an allowance for a 6% increase in design 100 year ARI rainfall intensities when assessing the

hydrologic standard of the upgraded section of road, as well as its impacts on flood behaviour.

4.3.2 Impacts on Flood Behaviour along SBR

Increases in rainfall intensity linked to future climate change will impact flood behaviour in both the Shoalhaven River and the Broughton Creek catchment. WMAwater, 2011 presents the findings of an investigation into the impact increases in rainfall intensity of 10, 20 and 30% will have on flood behaviour along the Lower Shoalhaven River. The findings of this study as they relate to the SBR are summarised **Table 4.2**.

By inspection of the values given in **Table 4.2**, increases of 10 and 30 per cent in design 100 year ARI rainfall intensities will translate into an increase in peak 100 year ARI flood levels in the lower floodplain of Broughton Creek of 0.16 to 0.48 m, respectively (refer ID4 and ID6 in **Table 4.1**).

TABLE 4.2
PEAK FLOOD LEVELS FOR VARIOUS CLIMATE CHANAGE SCENARIOS[1,2,3]
LOWER BROUGHTON CREEK FLOODPLAIN CROSSINGS
100 year ARI
(m AHD)

Location	Present Day Climatic Conditions	Climate Change Scenario			
		0.9 m SLR	0.9 m SLR + 10% Increase in Rainfall Intensity	0.9 m SLR + 20% Increase in Rainfall Intensity	0.9 m SLR + 30% Increase in Rainfall Intensity
	(1)	(2)	(3)	(4)	(5)
Hitchcocks Lane Tributary – Ch18600	5.01	5.06 (0.05)	5.20 (0.19)	5.38 (0.37)	5.57 (0.56)
Town Creek – CH17200	5.22	5.23 (0.01)	5.25 (0.03)	5.43 (0.21)	5.62 (0.40)
Broughton Mill Creek – Ch16700	5.25	5.25 (0.0)	5.28 (0.03)	5.44 (0.19)	5.63 (0.38)

1. Peak 100 year ARI flood levels taken from Chapter 5 of TIG report.
2. Number in ( ) represents the increase in the peak 100 year ARI flood level resulting from specific climate change scenario.
3. SLR = Sea Level Rise

AECOM has adopted a similar approach to that of WMAwater, 2011 when assessing the impact of climate change on local catchment flooding. This involved factoring the inflow hydrographs to the hydraulic model by 10, 20 and 30 per cent to reflect similar changes in design rainfall intensities. Although the response of a catchment to an increase in rainfall of a certain percentage in reality would be non-linear, for the purpose of undertaking a sensitivity analysis to determine the range over which flood levels may increase as a result of changes in rainfall intensity, this approach is considered to be reasonable.

We note that for those cross drainage structures which are subject to backwater flooding from the Shoalhaven River (i.e. Broughton Mill Creek, Town Creek and the Hitchcocks Lane Tributary), AECOM has incorporated the impacts of a 0.9 m rise in sea levels in its assessment of the impacts of increases in rainfall intensity on flood behaviour.

4.4 Freeboard Considerations

DECCW (2010) states that the typical 500 mm freeboard outlined in the NSW *Floodplain Development Manual* (NSWG, 2005) for general residential development provides a factor of safety to ensure that the risk exposure selected is accommodated. This freeboard includes a component related to climate change impacts on flood levels in coastal and non-coastal areas and a wide variation in sensitivity of estimated flood levels to flood flow. The freeboard provides a relatively small allowance to accommodate some of the projected increases in rainfall intensity from flood-producing storm events associated with climate change, which have currently not been accurately quantified. DECCW (2010) states that the manual's small allowance for climate change in the 500 mm freeboard figure should be considered to address only some of the uncertainty associated with estimating climate change impacts and that freeboard should therefore not be used to allow for sea level rise impacts, instead these should be quantified and applied separately.

Reviewer's Comments

SBR Crossing of the Lower Floodplain of Broughton Creek

The current investigation showed that a projected rise in sea level of 0.9 m by 2100 will result in only a 50 mm increase in peak 100 year ARI flood levels along the SBR (refer **Column 2** in **Table 4.2**). Furthermore, should rainfall intensities increase by up to 10% by this time (i.e. the likely increase that will occur within the service life of the project), then peak 100 year ARI flood levels along the SBR would only increase by about 200 mm when compared to present day conditions.

Based on the above findings, it is the Reviewer's opinion that a reduction in the available freeboard to 300 mm is acceptable and that no additional provision need be incorporated in the freeboard requirements for the project to accommodate for the impacts of future climate change.

Southern Interchange

A review of the HEC-RAS model files forwarded on 28 May 2012 showed that the available freeboard to the soffit level of the Southern Interchange bridges does not reduce below 500 mm for the case where rainfall intensities are increased by 10%. Furthermore, it is noted that the available freeboard to the soffit level of the Southern Interchange bridges does not reduce below 400 mm for the case where rainfall intensities are increased by 30%.

5 SUMMARY OF KEY FINDINGS

The key findings of the review of the flooding investigation undertaken by AECOM for the SBR were as follows:

xiii. The use of the RAFTS hydrologic modelling software package and the HEC-RAS and TUFLOW hydraulic modelling software packages as part of AECOM's current investigation into the SBR is considered appropriate.

xiv. AECOM's adoption of the "flood envelope" approach to defining flood behaviour on the lower floodplain of Broughton Creek is considered more appropriate than the approach that was adopted by previous flooding investigations undertaken on behalf of Shoalhaven City Council at Berry.

xv. Although a rigorous review of the models should be undertaken during the detail design of the FBB, it is the Reviewer's opinion that the models being relied upon by AECOM as part of the current investigation are sufficiently detailed to provide a reasonable estimate of flooding patterns along the route of the SBR. The key reason for this opinion is that flood behaviour on the lower floodplain of Broughton Creek is heavily influenced by backwater flooding from the Shoalhaven River and minor changes to hydrologic and hydraulic model parameters would not have a major impact on predicted flood behaviour along the route of the SBR for a 100 year ARI event.

xvi. The adoption of peak 20 and 100 year ARI flood levels of RL 4.3 m AHD and RL 5.0 m AHD for application to the downstream boundary of the AECOM TUFLOW model is considered appropriate. Although we consider that the 20 year ARI flood level of RL 4.3 m AHD may be conservatively high, the adoption of a lower tailwater level would not in our opinion result in changes to the critical drainage elements of the SBR.

xvii. The Reviewers consider that Figures A5 and A6 contained in Appendix C1 of the TIG report should show the results of modelling the SBR without the Island Embankment Option.

xviii. The water surface contour information shown on Figures A5 and A6 is shown incorrectly where the SBR crosses the lower floodplain of Broughton Creek.

xix. There is no information given in the TIG report on the impact of the SBR on the upper envelope of 100 year ARI flooding where it crosses the lower floodplain of Broughton Creek. There is a concern that the impacts on flooding that would result from the construction of the road project may extend further north (upstream) than is presently shown on Figure A7 of the TIG report. If it is found that changes in flood behaviour will occur on land which has been developed for residential purposes, then it may be necessary to lengthen the bridge which crosses Hitchcocks Lane Creek in order to mitigate the impacts of the SBR on flood behaviour.

xx. There is a concern that the obstruction to flow caused by the Island Embankment Option will exacerbate flooding conditions in existing development which is located on the eastern (left) overbank of Broughton Mill Creek immediately south (downstream) of the South Cost Railway Line.

xxi. A review of the HEC-RAS model developed for the Southern Interchange indicated that the required 0.5 m minimum freeboard to the soffit level of the road bridges had not

been incorporated in the design of the SBR. After being advised of this finding, AECOM forwarded an updated set of HEC-RAS model files which incorporated the required amount of freeboard (AECOM, pers. comm. 28 May 2012).

xxii. A review of the longitudinal section of the SBR where it crosses the lower floodplain of Broughton Creek shows that the required 0.5 m minimum freeboard to the soffit level of the bridges has been incorporated in the design of the SBR.

xxiii. We consider that the minimum freeboard requirement of 0.5 m need not be increased to allow for the future impact of sea level rise given that peak 100 year ARI flood levels on the lower Broughton Creek floodplain are predicted to rise by only 50 mm by 2100.

xxiv. We consider that there is sufficient allowance in the current minimum freeboard requirement of 0.5 m to accommodate possible changes in flood behaviour should rainfall intensities increase as a result of climate change. Based on current estimates of the impact climate change will have on rainfall patterns, peak 100 year ARI food levels could increase by a maximum of about 0.2 m along the route of the SBR by 2100 (also allowing for the impacts of sea level rise). This would reduce the available freeboard to about 0.3 m which is considered sufficient to account for other uncertainties/inaccuracies in design flood estimation.

6 REFERENCES

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