NOTICE OF MEETING

BYRON SHIRE FLOODPLAIN RISK MANAGEMENT COMMITTEE MEETING

A Byron Shire Floodplain Risk Management Committee Meeting of Byron Shire Council will be held as follows:

Venue	**Conference Room, Station Street, Mullumbimby**
Date	**Thursday, 14 June 2018**
Time	**9.00am**

Phillip Holloway
Director Infrastructure Services

I2018/1093
Distributed 07/06/18

CONFLICT OF INTERESTS

What is a "Conflict of Interests" - A conflict of interests can be of two types:

Pecuniary - an interest that a person has in a matter because of a reasonable likelihood or expectation of appreciable financial gain or loss to the person or another person with whom the person is associated.

Non-pecuniary – a private or personal interest that a Council official has that does not amount to a pecuniary interest as defined in the Local Government Act (eg. A friendship, membership of an association, society or trade union or involvement or interest in an activity and may include an interest of a financial nature).

Remoteness – a person does not have a pecuniary interest in a matter if the interest is so remote or insignificant that it could not reasonably be regarded as likely to influence any decision the person might make in relation to a matter or if the interest is of a kind specified in Section 448 of the Local Government Act.

Who has a Pecuniary Interest? - a person has a pecuniary interest in a matter if the pecuniary interest is the interest of the person, or another person with whom the person is associated (see below).

Relatives, Partners - a person is taken to have a pecuniary interest in a matter if:

- The person's spouse or de facto partner or a relative of the person has a pecuniary interest in the matter, or
- The person, or a nominee, partners or employer of the person, is a member of a company or other body that has a pecuniary interest in the matter.

N.B. "Relative", in relation to a person means any of the following:

(a) the parent, grandparent, brother, sister, uncle, aunt, nephew, niece, lineal descends or adopted child of the person or of the person's spouse;

(b) the spouse or de facto partners of the person or of a person referred to in paragraph (a)

No Interest in the Matter - however, a person is not taken to have a pecuniary interest in a matter:

- If the person is unaware of the relevant pecuniary interest of the spouse, de facto partner, relative or company or other body, or
- Just because the person is a member of, or is employed by, the Council.
- Just because the person is a member of, or a delegate of the Council to, a company or other body that has a pecuniary interest in the matter provided that the person has no beneficial interest in any shares of the company or body.

Disclosure and participation in meetings

- A Councillor or a member of a Council Committee who has a pecuniary interest in any matter with which the Council is concerned and who is present at a meeting of the Council or Committee at which the matter is being considered must disclose the nature of the interest to the meeting as soon as practicable.
- The Councillor or member must not be present at, or in sight of, the meeting of the Council or Committee:
  (a) at any time during which the matter is being considered or discussed by the Council or Committee, or
  (b) at any time during which the Council or Committee is voting on any question in relation to the matter.

No Knowledge - a person does not breach this Clause if the person did not know and could not reasonably be expected to have known that the matter under consideration at the meeting was a matter in which he or she had a pecuniary interest.

Participation in Meetings Despite Pecuniary Interest (S 452 Act)

A Councillor is not prevented from taking part in the consideration or discussion of, or from voting on, any of the matters/questions detailed in Section 452 of the Local Government Act.

Non-pecuniary Interests - Must be disclosed in meetings.

There are a broad range of options available for managing conflicts & the option chosen will depend on an assessment of the circumstances of the matter, the nature of the interest and the significance of the issue being dealt with. Non-pecuniary conflicts of interests must be dealt with in at least one of the following ways:

- It may be appropriate that no action be taken where the potential for conflict is minimal. However, Councillors should consider providing an explanation of why they consider a conflict does not exist.
- Limit involvement if practical (eg. Participate in discussion but not in decision making or vice-versa). Care needs to be taken when exercising this option.
- Remove the source of the conflict (eg. Relinquishing or divesting the personal interest that creates the conflict)
- Have no involvement by absenting yourself from and not taking part in any debate or voting on the issue as if the provisions in S451 of the Local Government Act apply (particularly if you have a significant non-pecuniary interest)

RECORDING OF VOTING ON PLANNING MATTERS

Clause 375A of the Local Government Act 1993 – Recording of voting on planning matters

(1) In this section, **planning decision** means a decision made in the exercise of a function of a council under the Environmental Planning and Assessment Act 1979:
  (a) including a decision relating to a development application, an environmental planning instrument, a development control plan or a development contribution plan under that Act, but
  (b) not including the making of an order under Division 2A of Part 6 of that Act.

(2) The general manager is required to keep a register containing, for each planning decision made at a meeting of the council or a council committee, the names of the councillors who supported the decision and the names of any councillors who opposed (or are taken to have opposed) the decision.

(3) For the purpose of maintaining the register, a division is required to be called whenever a motion for a planning decision is put at a meeting of the council or a council committee.

(4) Each decision recorded in the register is to be described in the register or identified in a manner that enables the description to be obtained from another publicly available document, and is to include the information required by the regulations.

(5) This section extends to a meeting that is closed to the public.

BUSINESS OF MEETING

STAFF REPORTS - INFRASTRUCTURE SERVICES

Report No. 4.1	**North Byron Floodplain Risk Management Study and Plan - Committee Meeting Two**
Directorate:	Infrastructure Services
Report Author:	James Flockton, Drain and Flood Engineer
File No:	I2018/896
Theme:	Community Infrastructure Emergency Services and Floods

Summary:

WMA Water have completed further works on various parts of the North Byron Floodplain Risk Management Study and Plan. This work is provided for committee review, consideration, discussion and approval.

RECOMMENDATION:

That the Byron Shire Floodplain Management Committee recommend:

1. **Council approve the recommended changes to the North Byron flood model as recommended in Attachments one (E2018/40963), two (E2018/40965) and three (E2018/41015) of this report.**

2. **Council approve the following flood mitigations options as part of the phase one flood mitigation assessment process including:-**

   - **Dredging of the key areas of the creek system**
   - **Changes to key parts of the rocks wall at Brunswick Heads (2 options)**
   - **One Flood Outlet through the dunes north of South Golden Beach**
   - **One Flood Outlet between New Brighton and the Brunswick River mouth**
   - **A combination of the two Flood Outlets**
   - **A Flood Levy for Mullumbimby**
   - **A Flood Levy for Billinudgel**

Attachments:

1 North Byron FRMS&P - WMA Water - Bend Loss Sensitivity memo, E2018/40963 , page 8⇩
2 North Byron FRMS&P - WMA Water - Initial Loss and Continuing Loss Sensitivity memo, E2018/40965 , page 22⇩
3 North Byron FRMS&P - WMA Water - Model Review memo, E2018/41015 , page 31⇩

Report

WMA Water have been working towards finalising various tasks to be completed in the early phases of this project. The following is provided as an update and seeks committee agreement to proceed with the recommendations from the memo's attached.

The information provided will be presented at the Committee meeting and all members will have the opportunity to comment.

Bend Losses

WMA Water have prepared a memo providing the results of their Bend Loss sensitivity investigation for the river bend in Mullumbimby. The memo is provided in attachment 1 for the committee's consideration.

The memo has various findings and recommends some changes be made to the flood model for the purposes of running design flood events and the flood mitigation options assessment.

WMA Water will answer questions regarding the results of this assessment at the committee. Staff recommend that the proposed changes be implemented as recommended.

Initial Loss and Continuing Loss

WMA Water have prepared a memo providing the results of their Initial Loss and Continuing Loss sensitivity investigation. This investigates rainfall losses into the ground at the begining of an event and during an event The memo is provided in attachment 2 for the committee's consideration.

The memo has various findings and recommends some changes be made to the flood model for the purposes of running design flood events and the flood mitigation options assessment.

WMA Water will answer questions regarding the results of this assessment at the committee. Staff recommend that the proposed changes be implemented as recommended.

Finalise Model Review / Update

WMA Water have now finalised the flood model review memo that was provided in draft form at the previous committee meeting. The memo is provided in attachment 3 for the committee's consideration.

The memo has various findings and explains a number of changes that have been made to the flood model. These changes are complete and will be used when running design flood events and the flood mitigation options assessment.

Additional to this discussion with OEH have led to Council submitting a small variation to the contract which involves nesting a smaller sized cell grid over Ocean Shores and South Golden Beach area. A smaller cell grid will increase model accuracy in these urban areas and therefore improve the accuracy of design flood level and the results of mitigation option assessment. Staff are awaiting OEH to approve this variation before instructing WMA to nest the smaller cells.

WMA Water will answer questions regarding the results of the update at the committee.

March 2017 Event Review

WMA Water have begun reviewing and modelling the March 2017 flood event, this includes the calibration of the model using the survey marks from this event.

Finalisation of this stage is awaiting OEH approval of the nested grids variation discussed above. WMA will be developing this work in the days before the planned committee meeting and this will potentially include the nested grids, therefore, all information will be provided to the committee at the meeting, in order to ensure the committee receive the most up to date information.

Community Survey

The community survey for this project is currently available on Council's website. Submissions close at the end of June 2018.

Flood Mitigation Options – Phase One

It is proposed to complete the flood mitigations option investigation in two parts. Initially phase one completes assessments on the options which are considered imperative to the success of the project. Phase two will consider additional options once the community survey process is complete and the results discussed with the committee.

During phase one the following mitigation options are proposed and are open for discussion at the committee meeting:

1. Dredging of the key areas of the creek system
2. Realignment and changes to rock wall between Marshalls Creek and Brunswick River
3. One Flood Outlet through the dunes north of South Golden Beach
4. One Flood Outlet between New Brighton and the Brunswick River mouth
5. A combination of the two Flood Outlets
6. A Flood Levy for Mullumbimby
7. A Flood Levy for Billinudgel
8. Overland flowpath for Avocado Crs and Grevillia Ave
9. No Fill Zones
10. Billinudgel – Drainage Improvements

It is recommended that the phase one assessment consider options 1 – 7. Further options can be considered in the phase 2 assessment.

Floor Level Survey

The costs and survey methods for the floor level survey were discussed at the previous committee meeting. Following these discussions, WMA Water, OEH and Council staff agreed upon the most cost effective way of obtaining the required floor level data. This data is key to the project because it is used to calculate the average annual damages for flood events and in turn provides and cost benefit analysis of the modelled flood mitigation options.

Completion of the floor level survey is currently awaiting OEH approval due to the works requiring a grant variation. Works will began as soon as practical, once this approval has been provided by OEH.

Financial Implications

There are no financial implications.

Statutory and Policy Compliance Implications

NSW Councils are expected to prepare Floodplain Risk Management Studies and Plans for flood prone catchments within their local government areas. These documents must be prepared in accordance with State Government Policy.

The NSW Floodplain Development Manual 2005 is the current policy used by State Government for the preparation of such documents.

This project is following the methods prescribed in the NSW Floodplain Development Manual for completing Floodplain Risk Management Studies and Plans.

Memorandum

wma water

TO: James Flockton
FROM: Ella Harrison
DATE: 11 May 2018
SUBJECT: North Byron FRMS&P – Mullumbimby Bend Loss Sensitivity Test
PROJECT NUMBER: 117098

1. INTRODUCTION

As part of the peer review undertaken by WMA Water (March 2018) of the hydraulic model developed by BMT WBM for the North Byron Shire Flood Study (2016), it was identified that the bend loss values upstream of Mullumbimby were high considering the river morphology does not change significantly in this area. As such, a sensitivity test on these values was recommended to determine the influence it may have on the flood level.

This area is subject to high development pressures and there is a known discrepancy between Council flood levels (based on the 2016 Flood Study) and those generated by the developer's consultant, of up to 500m difference in the 1% AEP event (with the Council flood study predicting higher levels).

This memo presents the findings of the sensitivity analysis on the bend loss values of the 1D modelled Brunswick River in Mullumbimby in the TUFLOW hydraulic model.

Three different scenarios have been modelled (see Table 1, Figure 1, Figure 2 and Figure 3):

- Scenario 1 - 'No Bend Loss': The 1D section of the Brunswick River around Mullumbimby is modelled without bend losses. This represents a lower limit scenario.
- Scenario 2 – 'March 2017' event: Bend losses have been calibrated for the March 2017 event. Values upstream of Federation Bridge are between 0 and 1, and are set to 0 downstream.
- Scenario 3 – 'Flood Study': Bend losses are the same as those used for the 2016 North Byron Flood Model developed by BMT WBM (between 1.0 and 1.75 upstream of Federation Bridge and between 2.0 and 3.0 downstream). This represents an upper limit scenario.

Table 1: Assessed manning's values range

Scenario	Adopted Bend Loss
1 - No Bend Loss	0 for the whole Brunswick River in Mullumbimby
2 – March 2017 event	Between 0 and 0.5 upstream of Federation Bridge, 0 downstream
3 - Flood Study	between 1.0 and 1.75 upstream of Federation Bridge and between 2.0 and 3.0 downstream

2. BEND LOSSES PARAMETERS

Any significant bend or change in a river shape leads to changes in velocity, magnitude and flow direction. It provokes energy dissipation and thus increases the water level upstream of the bend. In a 1D Flood Model this energy dissipation is modelled via a Form Loss, or Bend Loss. This unit-less number is adjusted via calibration, within the identified 'best practice' range. No value (or 0) means that the rivers profile is regular and that the river has no significant bends. When a significant change in the rivers profile occurs or when the river meanders, a bend loss value may be applied. A value of 1 or 2 is usually used for significant bends like an abrupt 180^o turn.

Bend Loss is mainly used as a calibration parameter. Initial values are estimated based on the best practice values and previous experience of the modeller. The calibration process is then used to validate or refine the estimations.

In Mullumbimby, the rivers profile is regular upstream of Federation Bridge. There are slight bends in the river but they are not sudden nor sharp. Thus, a reasonable bend loss value of 0.5/1 is recommended here.

3. SENSITIVITY ANALYSIS

As bend losses are considered calibration parameters, the sensitivity analysis has been initially undertaken based on the historical event from March 2017. A significative portion of Mullumbimby was flooded for this event with 0.5m to 1m flood depths in some residential areas.

Council has identified and surveyed 34 flood marks / calibration points in Mullumbimby. Four of these are inconsistent with surrounding flood marks and have not been included in the analysis. The results of the three bend loss scenarios have been compared with the remaining 30 flood marks.

3.1. Scenario 1 – 'No Bend Loss'

Of the 30 flood marks, 17 are located outside the modelled peak flood extent in this scenario. Two of the remaining flood marks are within ±100mm of the modelled peak levels, and 10 are within ±300mm. Flood levels are shown in Figure 1 and Figure 4 (see appendices).

Globally, the modelled flood extent is not coherent with flood marks and photos taken during the event. This is particularly apparent upstream of Federation Bridge where 16 out of 21 flood marks (76%) are outside modelled flood extent. The model under-predicts flood levels by 400/500mm in Mullumbimby upstream of Federation Bridge.

3.2. Scenario 2 – 'March 2017 event'

For this scenario, bend loss has been optimized to minimize the difference between modelled flood levels and surveyed flood marks. Bend loss has been set to 0 for the whole Brunswick River except for 5 sectors upstream of Federation Bridge in Mullumbimby where the river bends. On these sectors, bend loss values are set between 0.5 and 1.

In upstream Mullumbimby, two flood marks are outside modelled flood extent. The other flood marks located upstream of Federation Bridge (21) are well aligned, with the majority of flood marks within ±100mm (67%) and 81% of them within ±200mm (see Figure 5 and Table 5).

In downstream Mullumbimby, 2 out of 9 flood marks are within ±100mm (22%) and 8 are within ±300mm (89%).

3.3. Scenario 3 – 'Flood Study'

The Flood Study bend loss scenario uses the same bend losses for the Brunswick River in Mullumbimby as the 2016 North Byron Flood Study Model. Bend loss are higher than in the previous scenario, they are set to 1.0 and 1.75 upstream of Federation Bridge and between 2.0 and 3.0 downstream.

As shown on Figure 6, the model over-predicts flood levels in Mullumbimby by 200mm or 300mm. 10% of the flood marks are within ±100mm. 19 modelled flood level are at least 200mm higher than the recorded level (63%).

4. VERIFICATION WITH OTHER HISTORICAL EVENTS

Five other historical flood events have been modelled to calibrate the hydraulic model. The model has been changed to match historical ground conditions and hydraulic configurations for every event. For Tallowood Estate, the ground level is set as it was in 2010 for all historical events including the June 2012 flood event.

Table 2 compares the observed level and modelled level derived from Scenario 3 (Flood Study) and Scenario 2 (March 2017 update.)

Table 2: Observed and Modelled flood level in Tallowood Estate

Tallowood Estate	March 2017	June 2012	June 2005	March 1987	May 1978	March 1974
Observed	7.30	5.94	No data	No data	6.41	No data
Scenario 2 – March 2017 event	7.37 (+1%)	6.15 (+4%)	6.13	6.68	6.54 (+2%)	6.90
Scenario 3 - Flood Study	7.60 (+4%)	6.24 (+5%)	6.32	6.78	6.60 (+3%)	6.92

Historical flood levels have been recorded at Tallowood for the June 2012 and May 1978 flood events. For both events, the Scenario 2 (March 2017) compares better than Scenario 3 (Flood Study). The model still over predicts flood levels in this area but by a lower margin (+150/200mm instead of +200/300mm).

Table 3 compares level at the Federation Bridge.

Table 3: Observed and Modelled flood level at Federation Bridge

Federation Bridge	March 2017	June 2012	June 2005	March 1987	May 1978	March 1974
Observed	4.36*	4.02	4.14	4.62	≈4.80**	No data
Scenario 2 – March 2017 event	4.94	4.44 (+10%)	4.02 (-3%)	4.75 (+3%)	4.62 (-4%)	4.79
Scenario 3 - Flood Study	4.90	4.39 (+9%)	4.28 (+3%)	4.64 (+<1%)	4.53 (-6%)	4.73

Discrepancy between gauges
**based on adjacent flood mark*

There is no consistent recorded level at Federation Bridge for the March 2017 flood event. For June 2012 and March 1987, Scenario 2 (March 2017) compares worse than Scenario 3 (Flood Study) but it compares better with the May 1978 and June 2005 flood events.

5. IMPACT ON DESIGN EVENTS

Adopting the Scenario 2: "March 2017" bend losses will lower the flood level and reduce the flood extent in Mullumbimby upstream of Federation Bridge. Whilst the design events have not yet been modelled, evidence from the historical events suggest that for a 1%AEP design event:

- In the area of the Tallowood estate development, flood levels would decrease by 200/250mm. The flood extent would likely reduce north of the development area, and remain similar on the rest of the Tallowood estate.
- The modelled flood level between Main Arm Road and Garden Avenue should decrease and the flood extent in this area will likely reduce.
- There is unlikely to have any significant impact downstream of Federation Bridge.

6. CONCLUSION

The sensitivity tests on bend losses undertaken show that this parameter can significantly affect flood levels in Mullumbimby, with a global difference of 600/700mm between the different scenarios tested. It also has significant impact on flood extent due to the flat topography in Mullumbimby. The total flood extent for Scenario 1 (No bend loss) is 1.4 km^2, compared to 2.2km^2 under Scenario 3 (Flood Study).

Scenario 2 (March 2017 update) reproduces most of the recorded flood levels in this area within ±100mm difference, and is more consistent with the river morphology in this area. It is thus recommended to use these bend loss values for calibration and design events.

List of Figures

Reference

North Byron Shire Flood Study (BMT WBM, 2016)

Byron Shire Flood Review for Ex-Tropical Cyclone Debbie (BMT WBM, 2017)

Figure 1: Bend losses in Mullumbimby – Scenario 1: No Bend Loss

Figure 2: Bend losses in Mullumbimby – Scenario 2: March 2017 values

Figure 3: Bend losses in Mullumbimby – Scenario 3: Flood study

Figure 4: Calibration Results – March 2017, Scenario 1: No Bend Loss

Figure 5: Calibration Results – March 2017, Scenario 2: March 2017 Bend Loss

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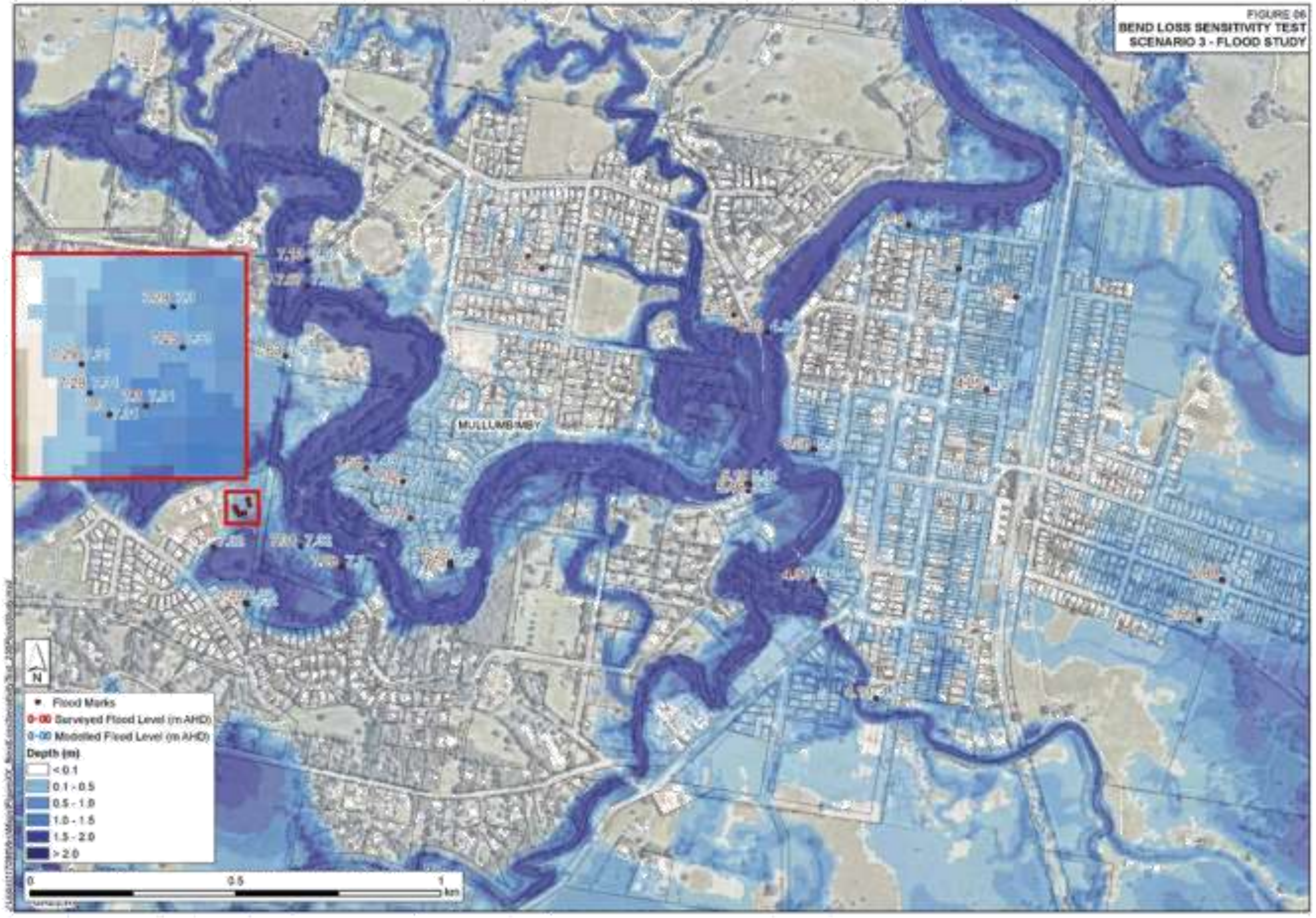

Figure 6: Calibration Results – March 2017, Scenario 3: Flood Study Bend Loss

Table 4: Mullumbimby flood marks for the No Bend loss scenario

ID	Surveyed Flood Level (m AHD)	Modelled flood Level (m AHD)	Difference (m)
2	2.99	3.16	0.165
3	6.7	Not Flooded	Not flooded
7	7.58	Not Flooded	Not flooded
13	4.91	5.16	0.249
18	7.17	6.76	-0.407
39	4.13	4.22	0.095
40	4.14	3.93	-0.215
47	2.98	3.14	0.164
48	7.28	6.74	-0.545
50	4.25	Not Flooded	Not flooded
51	7.12	Not Flooded	Not flooded
B1	8.52	Not Flooded	Not flooded
B10	7.63	Not Flooded	Not flooded
B11	7.2	6.76	-0.437
B12	7.39	Not Flooded	Not flooded
B14	7.29	6.76	-0.53
B15	7.29	6.76	-0.531
B16	7.29	Not Flooded	Not flooded
B17	7.29	Not Flooded	Not flooded
B18	7.3	6.76	-0.539
B19	7.3	6.76	-0.54
B20	5.46	5.20	-0.261
B21	5.19	5.20	0.008
B30	7.67	7.29	-0.377
B32	7.315	Not Flooded	Not flooded
B33	7.31	6.77	-0.535
B34	6.29	Not Flooded	Not flooded
B35	5.08	5.21	0.125
B8	6.29	6.27	-0.023
B9	6.3	6.27	-0.025

Table 5: Mullumbimby flood marks for the March2017 Calibrated scenario

ID	Surveyed Flood Level (m AHD)	Modelled flood Level (m AHD)	Difference (m)
2	2.99	3.14	0.152
3	6.7	Not Flooded	Not flooded
7	7.58	7.53	-0.053
13	4.91	5.11	0.201
18	7.17	7.36	0.188
39	4.13	4.17	0.036
40	4.14	3.90	-0.242
47	2.98	3.13	0.153
48	7.28	7.34	0.059
50	4.25	4.13	-0.117
51	7.12	7.06	-0.056
B1	8.52	8.19	-0.329
B10	7.63	7.60	-0.026
B11	7.2	7.36	0.156
B12	7.39	7.36	-0.034
B14	7.29	7.34	0.047
B15	7.29	7.34	0.049
B16	7.29	7.34	0.051
B17	7.29	7.35	0.057
B18	7.3	7.35	0.049
B19	7.3	7.34	0.045
B20	5.46	5.14	-0.315
B21	5.19	5.16	-0.028
B30	7.67	7.69	0.017
B32	7.315	7.33	0.014
B33	7.31	7.36	0.046
B34	6.29	Not Flooded	Not flooded
B35	5.08	5.15	0.07
B8	6.29	6.44	0.147
B9	6.3	6.45	0.149

Table 6: Mullumbimby flood marks for the BMT WBM Bend Loss Scenario

ID	Surveyed Flood Level (m AHD)	Modelled flood Level (m AHD)	Difference (m)
2	2.99	3.24	0.25
3	6.7	6.28	-0.419
7	7.58	7.73	0.15
13	4.91	5.23	0.318
18	7.17	7.60	0.426
39	4.13	4.30	0.165
40	4.14	4.34	0.197
47	2.98	3.23	0.252
48	7.28	7.58	0.304
50	4.25	4.21	-0.036
51	7.12	7.37	0.251
B1	8.52	8.33	-0.185
B10	7.63	7.69	0.057
B11	7.2	7.59	0.394
B12	7.39	7.59	0.204
B14	7.29	7.55	0.257
B15	7.29	7.55	0.264
B16	7.29	7.56	0.267
B17	7.29	7.57	0.277
B18	7.3	7.57	0.272
B19	7.3	7.57	0.266
B20	5.46	5.27	-0.186
B21	5.19	5.29	0.099
B30	7.67	7.86	0.189
B32	7.315	7.52	0.203
B33	7.31	7.60	0.286
B34	6.29	6.14	-0.146
B35	5.08	5.28	0.202
B8	6.29	6.73	0.443
B9	6.3	6.74	0.443

Memorandum

TO: James Flockton
FROM: Ella Harrison
DATE: 11 May 2018
SUBJECT: North Byron FRMS&P – Initial and Continuing Loss Sensitivity Test
PROJECT NUMBER: 117098

1. INTRODUCTION

As part of the peer review undertaken by WMA Water (March 2018) of the hydrologic model developed by BMT WBM for the North Byron Shire Flood Study (2016), it was identified that a review of the initial and continuing losses would be undertaken.

The Initial Loss (IL) parameter represents the loss of rainfall prior to the commencement of surface runoff. It is related to land type (e.g. urban, rural topography) and is used to represent antecedent conditions. The Continuing Loss (CL) represents the average loss rate during the remainder of the storm.

In the North Byron Shire Flood Study, the Forested area IL values adopted for design events were significantly lower than those used in calibration events, and are also considered low compared to ARR2016 recommended median values. The CL adopted in the Flood Study are also high compared to ARR recommendations. Table 1 below summaries the variables used.

Table 1: Initial loss adopted for calibration and design events

Ground cover	Initial Loss (mm)			Continuing Loss (mm/hr)		
	Calibration events	Design Events	ARR Recommended Median Values	Calibration events	Design Events	ARR Recommended Median Values
Urban	0	0		1	1	
Rural	30 (*May 1987*) 15 (*June 2005*) 5 (*Jan. 2012*)	5	38 (*ARR2016*) 10 to 35 (*ARR1987*)	4	4	2.5 (*ARR2016 and ARR1987*)
Forested	100 (*June 2005, May 1987*) 80 (*Jan. 2012*)	20		6	6	

28% of the total catchment area is classed as 'forested; land use, located mainly in the upper Brunswick River catchment. Thus, Forested IL and CL values may have an impact on modelled flows in upper Brunswick River localities such as Main Arm and Mullumbimby. Sensitivity analysis on this value has been undertaken to determine the influence it may have on the resulting flows.

This memo presents the findings of the sensitivity analysis on the IL and CL values of the XP-RAFTS hydrologic model. Four different IL values were studied: 20, 40, 80 and 100 mm. Three different CL values were studied: 4, 5 and 6 mm/hr. Results are analysed for the 20% AEP, 1% AEP and PMF design flood events.

2. INITIAL LOSS SENSITIVITY ANALYSIS

2.1. 1% AEP DESIGN EVENT

Table 2 and Figure 1 show the modelled flow at various locations in the catchment, for the four IL scenarios, for the 1% AEP design event.

Adjustment to the 'forested' IL value has a significative impact on Brunswick River flow. At Durrumbul, flow varies from 440m^3/s to 740 m^3/s depending on IL. It corresponds to a flow increase of 41% for an IL value decrease from 100mm to 20mm. A similar difference is calculated at Federation Bridge in Mullumbimby (730m^3/s to 1140 m^3/s, 36%) and on Brunswick Mouth (830m^3/s to 1250 m^3/s, +34%).

The impact is less for Marshalls Creek (±40m^3/s, 12% difference at Billinudgel) and for Yelgun Creek (±30m^3/s, 27% difference at Kallaroo Circuit). There is no impact on Simpsons Creek flow as the catchment is almost exclusively classed as Rural.

Forested IL values have an important impact on Brunswick River modelled flow that lead to a reduction of 420m^3/s for the 1% AEP design event.

Table 2: Impact of Initial Loss values on 1%AEP Flow for different location

1% AEP Flow (m^3/s)	Forested IL 20	Forested IL 40	Forested IL 80	Forested IL 100
Durrumbul Gauge (Brunswick River)	740	670	520	440
Federation Bridge (Brunswick River)	1140	1060	840	730
Brunswick Head (Brunswick River)	1250	1170	950	830
Billinudgel (Marshalls Creek)	360	350	330	320
Kallaroo Circuit (Yelgun Creek)	110	110	90	80
Sth Beach Rd (Simpsons Creek)	520	520	520	520

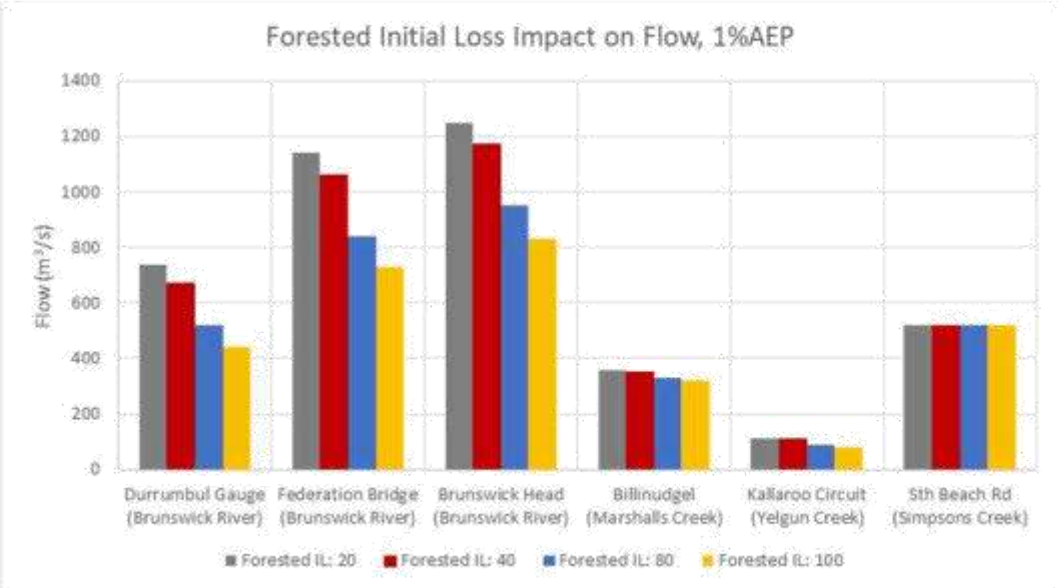

Figure 1: Initial Loss Sensitivity Analysis, 1%AEP

2.2. 20% AEP DESIGN EVENT

For the 20% AEP design event, the impact on flow is still substantial in the Brunswick River. Flow varies from 170m^3/s to 280m^3/s at Durrumbul.

Similar to the 1% AEP event, flow is less sensitive to IL changes for Marshalls Creek and Yelgun Creek and is non-existent for Simpsons Creek.

Table 3: Impact of Initial Loss values on 20%AEP Flow for different location

5% AEP Flow (m^3/s)	Forested IL 20	Forested IL 40	Forested IL 80	Forested IL 100
Durrumbul Gauge (Brunswick River)	280	260	210	170
Federation Bridge (Brunswick River)	470	440	340	290
Brunswick Head (Brunswick River)	540	500	400	350
Billinudgel (Marshalls Creek)	170	170	150	150
Kallaroo Circuit (Yelgun Creek)	50	50	40	30
Sth Beach Rd (Simpsons Creek)	260	260	260	260

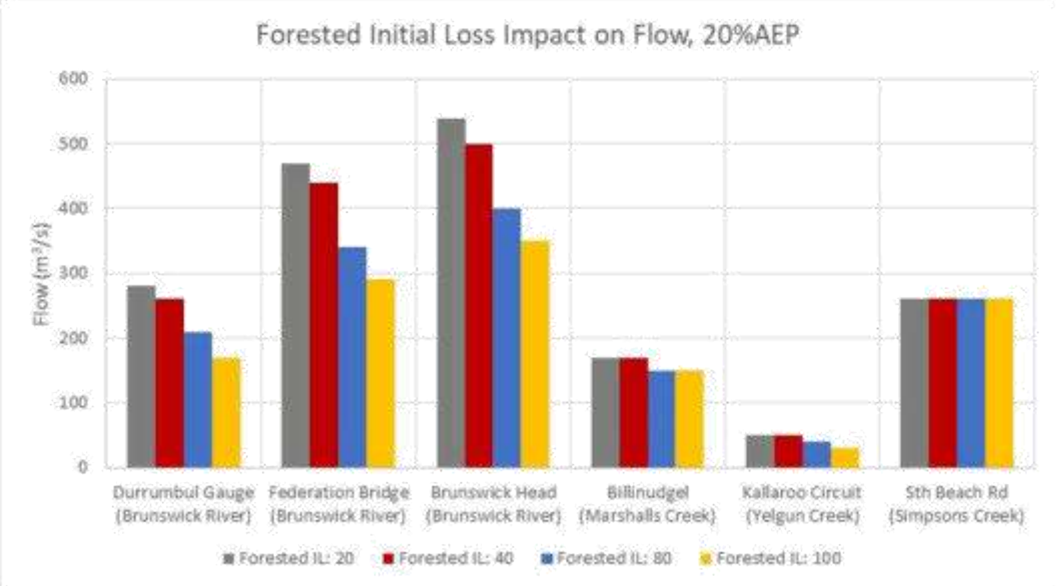

Figure 2: Initial Loss Sensitivity Analysis, 20%AEP

2.3. PMF DESIGN EVENT

For the PMF event, sensitivity tests show that whilst an IL value change can cause an increase of 250m^3/s on the downstream part of Brunswick River (Brunswick Head), this only represents 5% of the total flow. Thus, changes in IL values results in a less significant flow change (varying between 4750m^3/s and 5000m^3/s). There is almost no impact on Marshalls Creek and Yelgun Creek.

Table 4: Impact of Initial Loss values on PMF Flow for different location

PMF AEP Flow (m^3/s)	Forested IL 20	Forested IL 40	Forested IL 80	Forested IL 100
Durrumbul Gauge (Brunswick River)	2930	2910	2830	2780
Federation Bridge (Brunswick River)	4450	4440	4390	4360
Brunswick Head (Brunswick River)	5000	4960	4840	4750
Billinudgel (Marshalls Creek)	1510	1490	1460	1450
Kallaroo Circuit (Yelgun Creek)	470	460	440	420
Sth Beach Rd (Simpsons Creek)	2510	2510	2510	2510

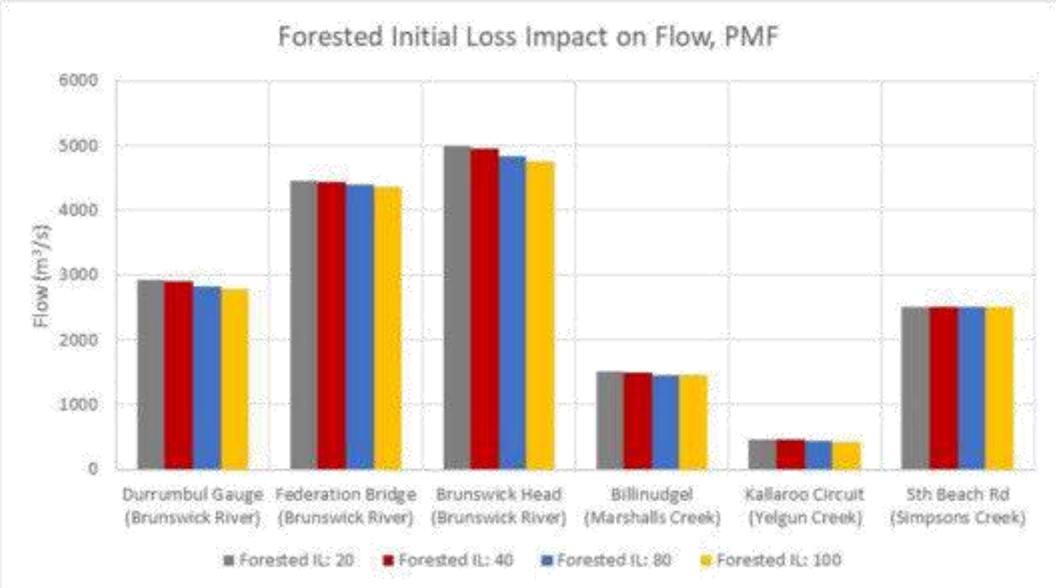

Figure 3: Initial Loss Sensitivity Analysis, PMF

3. CONTINUING LOSS SENSITIVITY ANALYSIS

3.1. 1% AEP DESIGN EVENT

Table 5 and Figure 4 show the modelled flow at various locations in the catchment, for the three CL scenarios, for the 1% AEP design event.

Adjustment to the Forested CL value doesn't have a significative impact on Brunswick River flow. At Durrumbul, flow varies from 670m^3/s to 690m^3/s depending on CL. It corresponds to a flow increase of only 3% between 6mm/hr and 4mm/hr. A similar difference is calculated at Federation Bridge in Mullumbimby (1060m^3/s to 1090m^3/s, 3%) and on Brunswick Mouth (1170m^3/s to 1200m^3/s, 3%).

The impact is zero for Marshalls Creek, Yelgun Creek and Simpsons Creek.

Table 5: Impact of Continuing Loss values on 1%AEP Flow for different location

1% AEP Flow (m^3/s)	Forested CL 4 mm/hr	Forested CL 5 mm/hr	Forested CL 6 mm/hr
Durrumbul Gauge (Brunswick River)	690	680	670
Federation Bridge (Brunswick River)	1090	1080	1060
Brunswick Head (Brunswick River)	1200	1180	1170
Billinudgel (Marshalls Creek)	350	350	350
Kallaroo Circuit (Yelgun Creek)	110	110	110
Sth Beach Rd (Simpsons Creek)	520	520	520

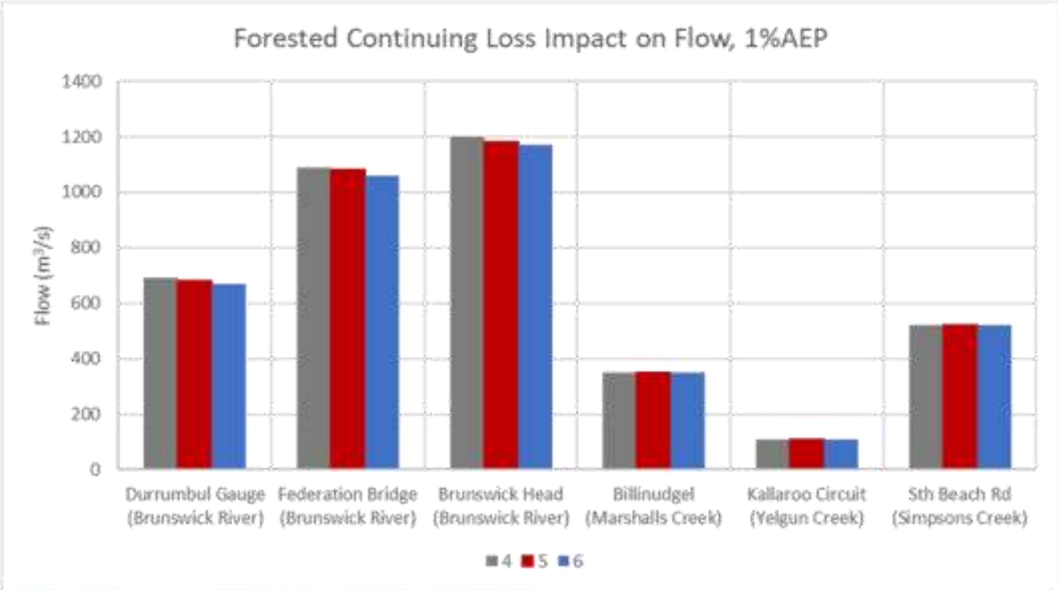

Figure 4: Continuing Loss Sensitivity Analysis, 1%AEP

3.2. 20% AEP DESIGN EVENT

For the 20% AEP design event, there is almost no impact on flow. The most important impact occurs at Durrumbul Gauge (260m^3/s to 270m^3/s, 4%).

Table 6: Impact of Continuing Loss values on20%AEP Flow for different location

5% AEP Flow (m^3/s)	Forested CL 4 mm/hr	Forested CL 5 mm/hr	Forested CL 6 mm/hr
Durrumbul Gauge (Brunswick River)	270	270	260
Federation Bridge (Brunswick River)	450	440	440
Brunswick Head (Brunswick River)	510	500	500
Billinudgel (Marshalls Creek)	170	170	170
Kallaroo Circuit (Yelgun Creek)	50	50	50
Sth Beach Rd (Simpsons Creek)	260	260	260

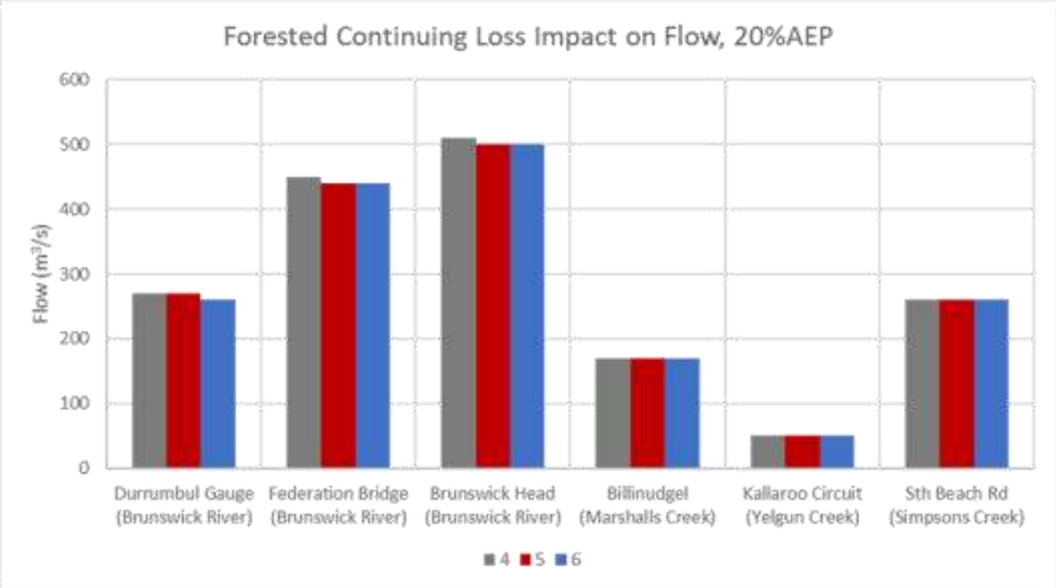

Figure 5: Continuing Loss Sensitivity Analysis, 20%AEP

3.3. PMF DESIGN EVENT

For the PMF, sensitivity tests show that a CL value change can cause an increase of only 20m^3/s on Brunswick River. It represents less than 1% of the total flow.

Table 7: Impact of Continuing Loss values on PMF Flow for different location

PMF AEP Flow (m^3/s)	Forested CL 4 mm/hr	Forested CL 5 mm/hr	Forested CL 6 mm/hr
Durrumbul Gauge (Brunswick River)	2930	2920	2910
Federation Bridge (Brunswick River)	4460	4450	4440
Brunswick Head (Brunswick River)	4980	4970	4960
Billinudgel (Marshalls Creek)	1500	1490	1490
Kallaroo Circuit (Yelgun Creek)	460	460	460
Sth Beach Rd (Simpsons Creek)	2510	2510	2510

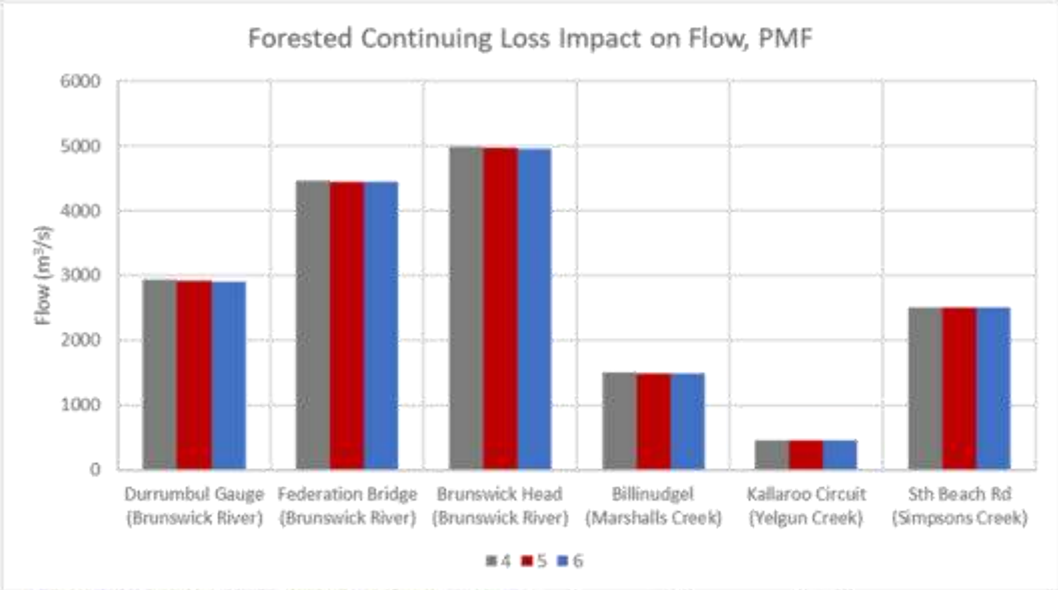

Figure 6: Continuing Loss Sensitivity Analysis, PMF

4. CONCLUSION

4.1. Initial Loss values

Sensitivity tests on the XP-RAFTS hydrologic model show that altering 'forested' IL value has a greater impact on the flows of smaller design events, than the larger more extreme events like the PMF. They also show that the impact is significant for Brunswick River as the majority of forested areas are located on upper Brunswick River catchment.

For the Brunswick River, an IL value decrease from 100mm to 20mm causes a 41% flow increase in Main Arm and 36% in Mullumbimby for the 1% AEP design event.

Forested IL adopted by BMT WBM for calibration and design events are significantly different. For calibration events, the IL values are often an artefact of limited rainfall temporal pattern data and the adopted high IL values may be compensating for rainfall data limitations. Thus, IL values adopted for the design events are lower to ensure an element of conservatism. However, the hydrologic model is particularly sensitive to changes in the 'forested' IL value especially in the Brunswick River. An IL value of 20mm is not only much lower than the calibration values (80mm and 100mm) but also lower than ARR2016 recommended value for the area (38mm). The heavily vegetated tropical nature of the vegetation in the North Byron catchment also suggests that the IL value should be higher.

It is recommended to use an IL value of 40mm for forested area for the design events. This value is still conservative regarding the adopted value for calibration events and is more consistent with the ARR2016 adopted value and the type of vegetation in the area.

4.2. Continuing Loss values

Sensitivity tests show that the 'forested' CL value does not have a significant impact on. A CL decrease from 6mm/hr to 4mm/hr only results in a 3% flow increase for the 1%AEP design event. As such, it is recommended that the CL vale is unchanged.

List of Figures

Reference

North Byron Shire Flood Study (BMT WBM, 2016)

Memorandum

TO:	James Flockton
FROM:	Ella Harrison
DATE:	28 March 2018
SUBJECT:	North Byron FRMS&P –Hydrologic and Hydraulic Model Review
PROJECT NUMBER:	117098

1. INTRODUCTION

Byron Shire Council have engaged WMA Water to complete a Floodplain Risk Management Study and Plan (FRMS&P). The primary objective of this FRMS&P is to provide an improved understanding of the flood behaviour and impacts throughout the North Byron catchments in order to better inform the management of flood risk. As part of the initial stages of the study, WMA Water have undertaken a peer review of the hydrologic and hydraulic models developed in the North Byron Shire Flood Study (BMT WBM, 2016).

The purpose of this report is to outline the assessment of these models and determine their readiness for use within this FRMS&P. The review established that:

- The hydrologic model which has been developed using XP-RAFTS is fit-for-purpose and appropriately set up.
- The hydraulic model, developed using TUFLOW (version 2013-12AE-w64), is running and working well and meets standard quality criteria.
- Notwithstanding this, it is recommended the following updates are undertaken:
  - Incorporate latest topographic features and detail of missing structures into the hydraulic model configuration;
  - Incorporate the March 2017 event into model calibration and verification;
  - Further sensitivity tests of the form losses upstream of Mullumbimby;
  - Sensitivity tests on the initial losses for forested areas in design events.
  - Sensitivity tests on the manning's n values adopted in the hydrologic model.

2. BACKGROUND

The North Byron Shire Flood Study (herein referred to as the Flood Study) was completed by BMT WBM in April 2016. This Flood Study was commissioned in response to the Tweed-Byron Coastal Creeks Flood Study (BMT WBM, 2010) that recommended the development of a model to assess both the Brunswick River and Marshalls Creek catchments.

The following reports have also been considered background information as part of this review:

- Byron Shire Flood Review for Ex-Tropical Cyclone Debbie (BMT WBM, 2017)
- Hydrologic and Hydraulic Study at Bilinudgel (SMEC, 2005)

2.1. Study Area

The area of interest is located in northern New South Wales within the Byron Shire Local Government Area (LGA) and includes the towns of Mullumbimby, Brunswick Heads, Ocean Shores, New Brighton, South Golden Beach and Billinudgel. The study area includes Marshalls Creek catchment to the north, the Brunswick River catchment and the Simpsons Creek catchment to the south.

Marshalls Creek is a tributary to the Brunswick River and enters the Brunswick River just upstream of the mouth of Brunswick River at Brunswick Heads. Simpsons Creek flows into the Brunswick River just downstream of the Marshall Creek and Brunswick River confluence.

Figure 1 shows the hydrologic and hydraulic boundaries used within the Flood Study.

3. HYDROLOGIC MODEL REVIEW

The hydrologic model developed for the Flood Study was built using XP-RAFTS software. XP-RAFTS is a non-linear rainfall/runoff routing model and is widely used throughout Australia for both rural and urban catchments. The review looked at the catchment delineation, model setup and the appropriateness of adopted hydrologic parameters. The model was successfully run for the 12 hour and 24 hour storms for the 1% AEP and produced the same results as provided.

3.1. Catchment Delineation

The hydrologic study area consists of four catchments and are listed in Table 1.The delineation of the catchment and sub-catchment boundaries has been checked and is considered fit-for-purpose and appropriately defined. The sub catchment delineation is shown in Figure 2.

Table 1: Catchment areas

Catchment Name	Total Area (km^2)	Sub catchments
Brunswick River	112	47
Marshalls Creek	42	24
Yelgun Creek	11	13
Simpsons Creek	66	32

3.2. Model Input

The hydrologic model is built by delineating the catchment into sub catchments and connecting these using nodes and channel reaches to simulate creeks and rivers. XP-RAFTS requires geographical input data and hydrologic parameters for each sub catchment including the following:

- Slope (%)
- Area
- Fraction impervious
- Travel time between nodes
- Manning's n
- Storage Coefficient Multiplication Factor
- Initial Loss

- Continuing Loss

Terrain data and aerial data have been used to check the sub catchment slope, area and the fraction impervious. Appropriate values have been used for each sub catchment. The travel time between nodes was determined by assuming an average velocity. For a 1% catchment slope an average velocity of between 0.5m/s and 1m/s is considered normal. This approach was not adopted for all sub catchments. For the sub catchments in the Upper Main Arm area, the Muskingum-Cunge (defined in XP-RAFTS) method was adopted for the wide floodplain with significant potential storage, which is considered appropriate

Table 2 shows the adopted manning's n values to represent the roughness for each sub catchment. While these manning's n values are considered standard (ARR2016, Book 6, Chapter 2, Table 6.2.2), they are marginally lower than the recommended XP-RAFTS values, however are still considered to be appropriate roughness values. While, this is not thought to be an issue WMA Water recommend undertaking some sensitivity testing on these values.

Table 2: Manning's values

Ground cover	Manning's n
Urban	0.025
Rural	0.04
Forested	0.06

3.2.1. Storage Coefficient Multiplication Factor (B_X)

The Durrumbul Gauge is the only stream gauge in the area with a rating curve (see location in Figure 3) and thus is the only calibration gauge available for the hydrologic model. BMT WBM's calibration runs indicated that additional storage was required at this point. It is most likely due to the model inability to represent the wide floodplain with significant potential storage in the upper catchments.

Two distinct methods have been used to increase the storage:

- A local storage has been added at Williams Bridge upstream of the Main Arm Road Embankment in Main Arm (see location in Figure 3),
- A Storage Coefficient Multiplication Factor (Bx) of 1.5 instead of 1 was used to modify the calculated storage time delay in all sub-catchments except Marshalls Creek and Yelgun Creek catchments. This value of 1.5 has been chosen for calibration purposes. It is recommended the March 2017 event is used to verify the appropriateness of this parameter.

Those changes have helped to reach a better calibration for the simulated events (mainly January 2012, June 2005 and May 1987). Marshalls Creek and Yelgun Creek sub-catchments were modelled with a Bx factor of 1.0. This value was most likely adopted due to the lack of calibration data to show evidence of floodplain storage for these sub-catchments. Incorporating the March 2017 event will help verify and recalibrate these values.

3.2.2. Initial and Continuing Losses

The amount of rainfall that will result in runoff is highly dependent on the antecedent conditions and type of ground cover, particularly the infiltration capacity. These conditions are represented in a hydrologic model using initial and continuing loss parameters. Table 3 shows the initial and continuing loss parameters adopted during the calibration events.

ARR (Book5, Ch.3, Figures 5.3.18 and 5.3.19) discusses typical loss values seen throughout Australia and for Mullumbimby, recommended rural initial and continuing losses are 38mm and 2.5 mm/h. The continuing loss factor adopted for rural areas is higher than recommended by ARR (2016). It is recommended the March 2017 event is used to verify parameters.

The initial loss conditions adopted for the design events are low in comparison to the calibration events (see Table 4). It is common when calibrating a hydrologic model to an actual event to alter this value significantly. This accounts for the antecedent conditions within the catchment and can be used to better match the peak flow observed. The Flood Study notes that the design event initial losses were chosen deliberately to ensure an element of conservatism.

However, the forest initial loss adopted for the design event is significantly lower than the calibration loss (from 80 – 100 mm to 20mm) and the continuing losses are high. WMA Water suggests using a conservative value of 40mm instead of 20mm and a lower continuing loss and to check the impact of this change via a sensitivity test.

Table 3: Initial loss and continuing loss adopted for the calibration events

Ground cover	Initial Loss (mm)	Continuing Loss (mm/h)
Urban	0	1
Rural	30 (*May 1987*) 15 (*June 2005*) 5 (*Jan. 2012*)	4
Forested	100 (*June 2005, May 1987*) 80 (*Jan. 2012*)	6

Table 4: Initial loss and continuing loss adopted for the design events

Ground cover	Initial Loss (mm)	Continuing Loss (mm/hr)
Urban	0	1
Rural	5	4
Forested	20	6

3.3. Rainfall Sensitivity Assessment

The North Byron Flood Study was developed prior to the release of the 2016 ARR design rainfalls, as such the study used the 1987 Intensity-Frequency-Durations (IFDs). The 1987 ARR design rainfalls are expected to have an accuracy of +/- 30% and as such it is standard practice to compare the at-site rainfall data to the ARR IFDs.

The Flood Study estimated the 1% AEP event for eight storm durations for each gauge used in the rainfall frequency investigation. FLIKE, a widely used statistical program, was used for this statistical analysis and three statistical distributions were chosen; Lognormal, Log Pearson Type III and Generalised Extreme Value (GEV). Section 4.3 of the Flood Study discusses the results in detail and provides a comparison of the ARR 1987 IFDs against each gauge for the 1% AEP for three durations. The results highlighted where there was a +-10% discrepancy between the at-site gauge data and the 1987 ARR IFD.

These results show the ARR IFDs both over and underestimate the design rainfall when compared to the at-site gauge data. The report discusses the results from the gauges Main Arm, Huonbrook and Myocum in more detail. Main Arm and Myocum are within the catchment boundary and Huonbrook is the next closes to the Brunswick River catchment. While the Myocum gauge indicates the 1987 ARR IFD overestimates rainfall depths (17% - 55%), the results for Main Arm and Huonbrook show the 1987 ARR IFD are within +-30% and have no bias for over or underestimation.

The report concludes the rainfall frequency investigation does not provide justification to adopt a local correction factor and the 1987 ARR IFDs were used. Prior to the release of the 2016 IFDs, use of the 1987 ARR IFD was considered industry standard. While the assessment did show some differences between the at-site data and the 1987 IFD, there was no significant bias for over or underestimation. Given this, WMA Water concludes use of the 1987 ARR IFD to be defensible and fit-for-purpose.

4. HYDRAULIC MODEL REVIEW

The hydraulic model was built using the hydrodynamic package TUFLOW. TUFLOW is a widely used modelling package both nationally and internationally. The Flood Study model was configured using TUFLOW version 2013-12-AD TUFLOW_iDP_w64.exe and requires a multi domain license.

Figure 4 shows the hydraulic model boundary and the domain configurations. The hydraulic model covers 52 km^2 in total. The default 2D domain was represented with a 12.5m grid with a north-south grid orientation. For the areas of South Golden Beach and Brunswick Heads a 5m grid with no rotation was adopted. Mullumbimby was also represented using a 5m grid size, however a 19.5 degree grid rotation was applied. This rotation digitises the grid perpendicular to the dominant flow and is handled properly by TUFLOW.

There are two different TUFLOW simulation control files available to run *NBFS_~e1~_166.tcf* and *NBFS_~e1~_168_ext.tcf*. The former is used for all design events except for the PMF which used the second file. The reason for the separate files is due to the downstream boundary conditions. The coastal dunes are only overtopped in the PMF event, and therefore for this event, a wider downstream boundary condition is required than in all other design events. This is a relatively common practice.

WMA Water were able to successfully run the model for the 1% AEP events and results were consistent with the 2016 BMT WBM report.

4.1. Boundary Conditions

4.1.1. Tidal Conditions

Figure 5 shows the inflow and downstream boundaries included in the Flood Study model. The downstream boundary has been setup up as a water level versus time boundary to represent the tidal conditions. This tidal condition is variable and the timing of the peak of the tide has been aligned to coincide with the peak of the flood. Table 5 describes the corresponding peak tidal conditions for each AEP and climate change conditions. Byron Shire Councils policy on Climate Change Strategic Planning discusses the adopted 2050 and 2100 and are 0.4m and 0.9m respectively.

Table 5: Tidal downstream boundary condition

AEP	Peak Water Level (mAHD)
20%	0.8
10%	1.5
5%	2.2
2%	2.48
1%	2.6
5% CC2050	2.4
1% CC2050	2.6
5% CC2100	2.9
1% CC2100	3.1

4.1.2. Inflow Boundaries

The inflow polygons have been represented as 2d_sa layer which applies to flow directly onto the lowest cells first and then distributing between wet cells within the defined polygons. These have been correctly identified as either local or total inflows depending on their location.

The TUFLOW boundary condition database (bc_dbase) contains hydrographs for the 12 hour and 24 hour storm durations for all AEPs and climate change scenarios.

All inflow files have been provided for the 12 hour and 24 hour storm durations.

4.1.3. 1D and 2D Boundaries

Marshalls Creek, Brunswick River and Simpsons Creek are modelled in 1D by cross sections when the 2D domain grid size is set to 12.5m (see Figure 4).

Marshalls Creek hydraulic roughness is set to 0.03 (upstream) and 0.024 (downstream). Brunswick River and Simpsons Creek Hydraulic Roughness is set to 0.02. These are standard values for sandy bed rivers.

4.2. Review of Recent Developments

Figure 6 shows the ground and terrain data used in the hydraulic model.

4.2.1. Orchid Place (Mullumbimby)

Orchid Place roughness is defined as an urban place. The recent development topography has not been included in the model.
It is recommended this information is incorporated into the model. Byron Shire Council will request and provide a survey of the area.

4.2.2. Shara Boulevard/Brunswick Valley Sportsfield (Billinudgel)

The roughness need to be updated to match the new development (from n = 0.045 to n = 0.025). Byron Shire Council has sent the latest development drawings to WMA Water and it is recommended these added to the model topography.

4.2.3. Tallow Wood Estate (Mullumbimby)

The model includes the Stage 3 development terrain data. Byron Shire Council has sent the Stage 4 development drawings to WMA Water including the Tuckeroo Avenue box culvert dimensions. It is recommended the model is updated to incorporate this information.

4.2.4. Miram Place/Rajah Road (Ocean Shores)

The model includes an older development terrain data. Byron Shire Council has sent the Stage 4 development drawings for Miram Place in Ocean Shores to WMA Water. It is recommended this information is incorporated into the model.

4.3. Bend loss

Bend loss are defined only for the Brunswick River. Values upstream of Mullumbimby are between 1.0 and 1.75 and between 2.0 and 3.0 downstream. These values are high considering the river morphology does not change significantly in these areas. These values can have a significant impact on flood level in Mullumbimby, and given the development pressures in this area, it is recommended the March 2017 event is used to verify these parameters.

4.4. Review of Hydraulic Structures

4.4.1. Model Structures

Review of structures included within the Flood Study identified the following missing structures:

- Tuckeroo Avenue Culverts (Mullumbimby),
- Orana Road Culvert and Waterlily Park survey (Ocean Shores),
- Terrara Court Culvert (Ocean Shores),
- Golf Course Bridge (Ocean Shores).
- Narooma Drive Culvert (Ocean Shores)

Bonanza Drive drainage plan have been provided by Byron Shire Council, however as the road is not flooded until the PMF event, the road drainage would not have any significant impact on the flood behaviour. This structure will still be included for completeness.

It is recommended the other structures are incorporated into the model build.

5. RECOMMENDATIONS

Following the hydrologic and hydraulic model review, we recommend the following amendments to the model:

- Incorporate the following recent developments into the model's topography:
    - Shara Boulevard/Brunswick Valley Sportsfield (Billinudgel)
    - Tallow Wood Estate (Mullumbimby)
    - Miram Place (Ocean Shores)
- Incorporate the following structures:
    - Tuckeroo Avenue Culverts (Mullumbimby)
    - Orana Road Culvert and Waterlily Park survey (Ocean Shores)
    - Terrara Court Culvert (Ocean Shores)
    - Golf Course Bridge (Ocean Shores)
    - Narooma Drive Culvert
    - Bonanza Drive
- Run the March 2017 event (Ex-Tropical Cyclone Debbie).
    - Calibration of the Hydrological Model for this event through rainfall data and Durrumbul Stream Gauge
    - Calibration of the Hydraulic Model for this event through flood marks and rivers level data
- Perform a sensitivity test of the forested Initial Loss value to assess its impact on flows and volumes.
- Perform a sensitivity test on the manning's n values adopted in the hydrologic model.
- Perform a sensitivity test of the hydraulic losses upstream of Mullumbimby to assess their impact on flood level particularly at Tallow Wood Estate.
- Update both Hydrologic and Hydraulic model based on calibration results and run the design events.

List of Figures

Reference

North Byron Shire Flood Study (BMT WBM, 2016)

Byron Shire Flood Review for Ex-Tropical Cyclone Debbie (BMT WBM, 2017)

Tweed-Byron Coastal Creeks Flood Study (BMT WBM, 2010)

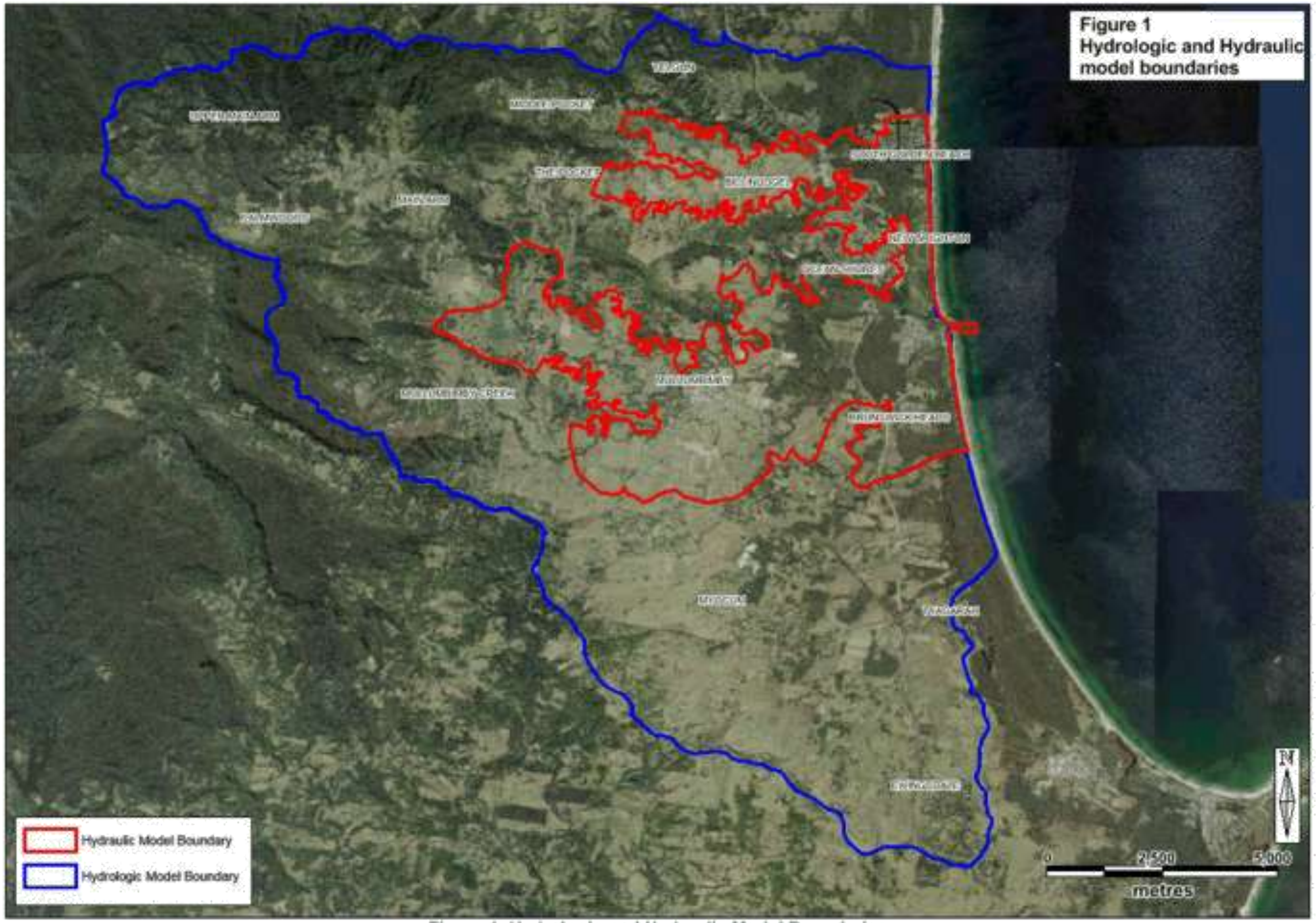

Figure 1: Hydrologic and Hydraulic Model Boundaries

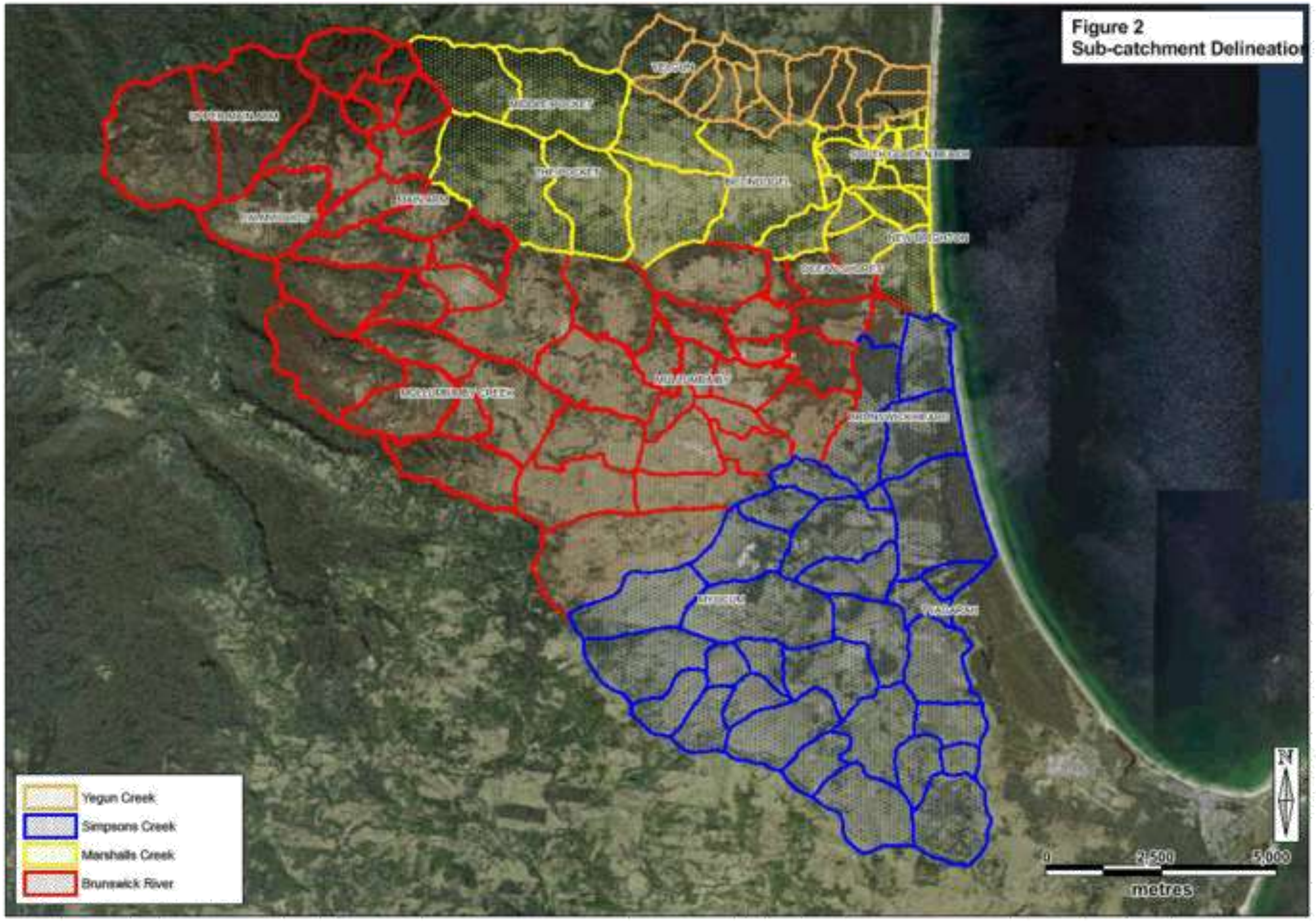

Figure 2: Sub-catchments division

Figure 3: Stream Gauge and Local Storage

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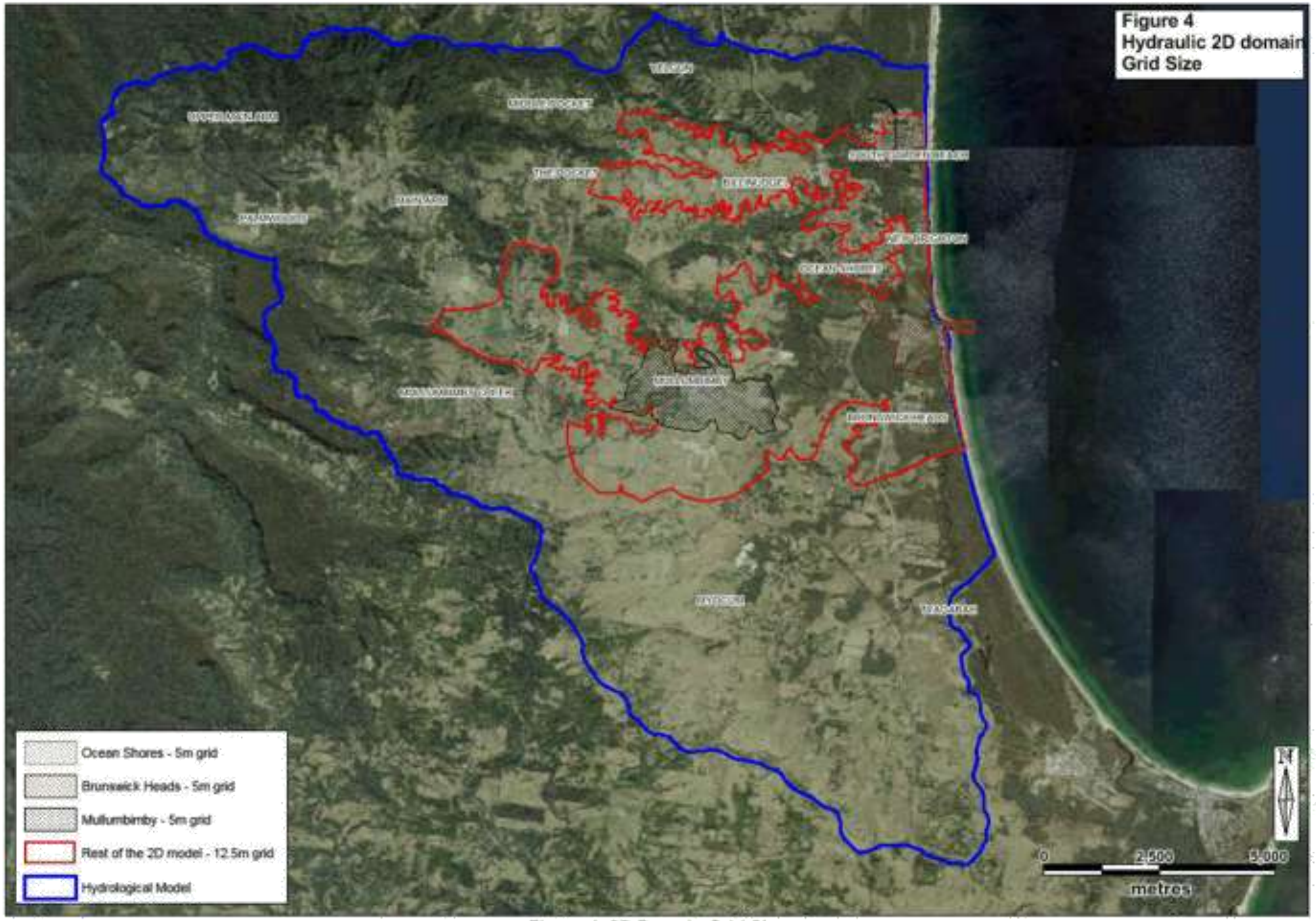

Figure 4: 2D Domain Grid Size

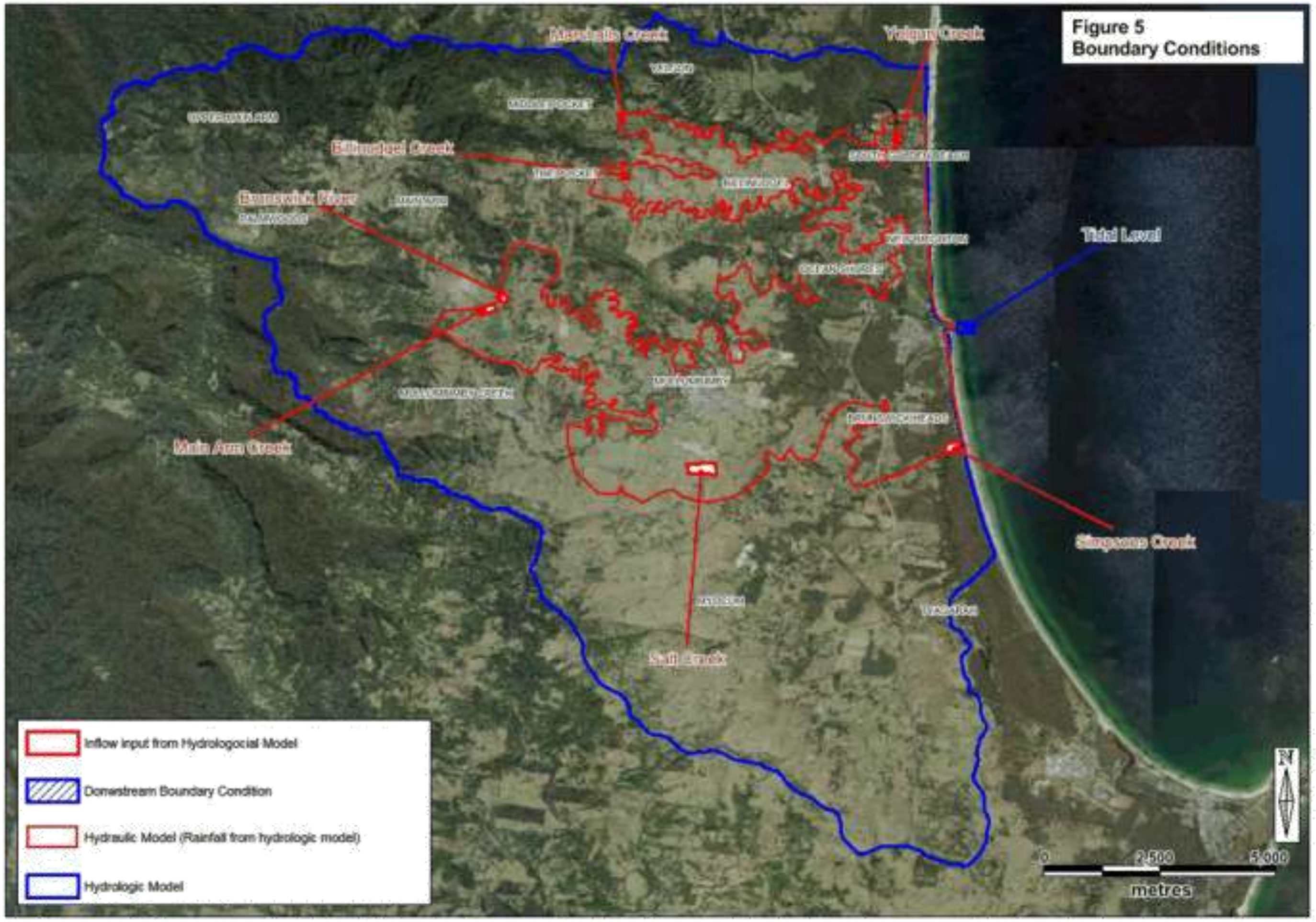

Figure 5: Boundary Conditions

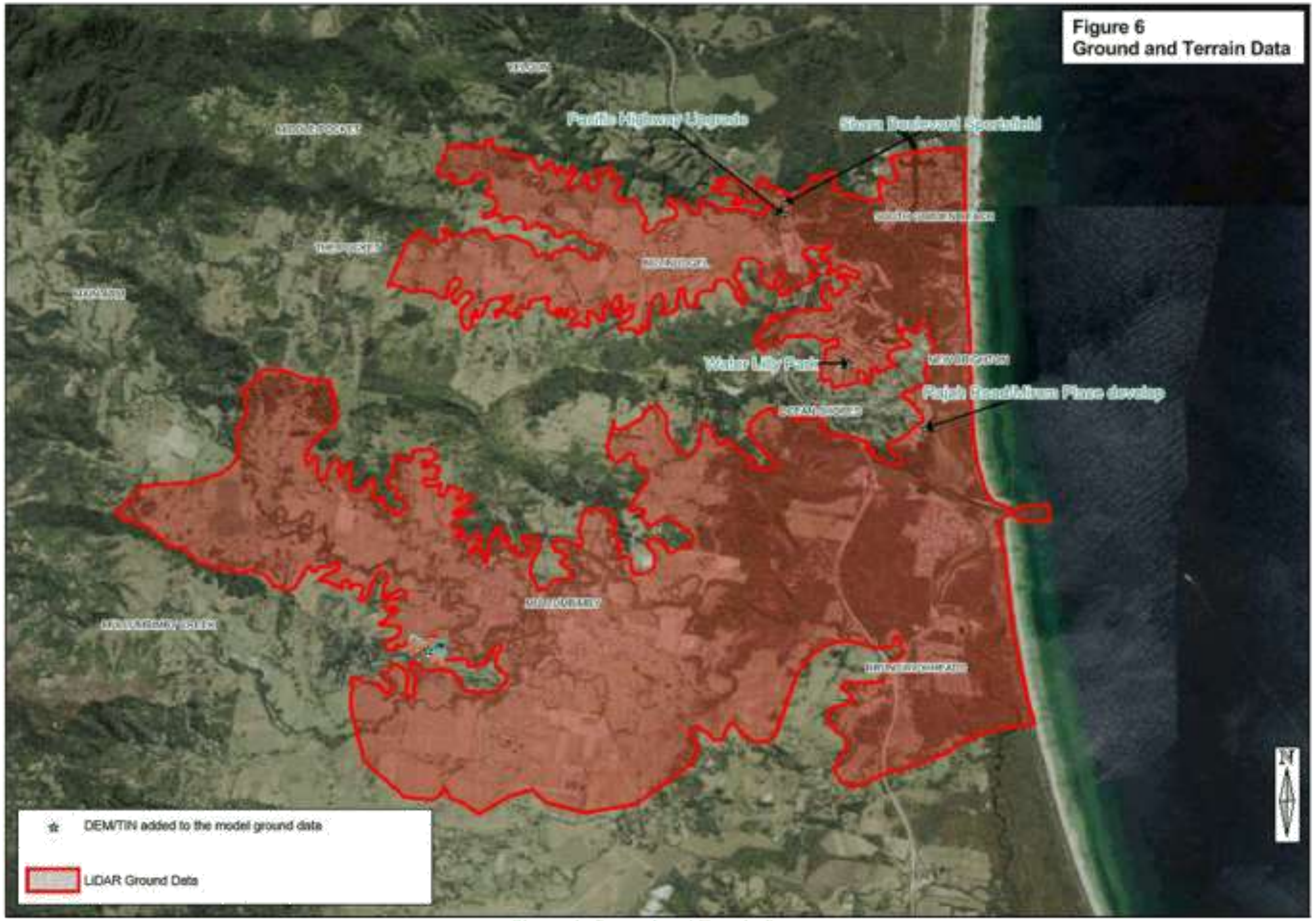

Figure 6: Ground and Terrain Data