LUCAS DEVELOPMENT GROUP

SUSSEX INLET RESIDENTIAL & MIXED USE DEVELOPMENT

FINAL REPORT

MAY 2009

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Project Sussex Inlet Residential and Mixed Use Development	**Project Number** 29013
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SUSSEX INLET RESIDENTIAL AND MIXED USE DEVELOPMENT

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1. INTRODUCTION

1.1. Background

Lucas Property Group is proposing to undertake residential and mixed development including a golf course at Badgee Lagoon in Sussex Inlet (Figure 1). Also proposed is the filling of various development areas and roads as shown on Figure 2.

As part of the Director General's Environmental Assessment Requirement, Section 75F of the Environmental Planning and Assessment Act 1979, Key Issue 5.7 requires that:

> *"The [flood risk] assessment must also consider increased in rainfall intensity associated with sea level rise"*

In addition, Key Issue 5.8 refers to the requirement that the assessment:

> *"Consider the potential impacts of any filling on the flood regime of the site and adjacent lands."*

The present report titled "Sussex Inlet Residential and Mixed Use Development" provides a response to these two requirements.

1.2. Climate Change

The 2005 Floodplain Development Manual requires that Flood Studies and Floodplain Risk Management Studies consider the impacts of climate change on flood behaviour. In accordance with the Department of Environment and Climate Change (DECC) – Floodplain Risk Management Guideline 2007, the following climate change scenarios (rainfall by the year 2070 and ocean level rise by the year 2100) are to be considered in this climate change assessment:

- **ocean level rise:**
  - low level ocean rise = 0.18m,
  - medium level ocean rise = 0.55m,
  - high level ocean rise = 0.91m.
- **increase in peak rainfall and storm volume:**
  - low level rainfall increase = 10%,
  - medium level rainfall increase = 20%,
  - high level rainfall increase = 30%.

A high level rainfall increase of up to 30% is recommended for consideration due to the uncertainties associated with this aspect of climate change. It is understood that work currently being undertaken by CSIRO and the Sydney Catchment Authority should provide better direction on the possible impacts on rainfall.

These scenarios were not undertaken as part of the St Georges Basin Flood Study as it was completed in September 2001 prior to publication of the above documents. This present study provides the climate change assessment in accordance with the DECC 2007 guideline.

1.3. Hydraulic Assessment of Filling

Filling is proposed to be undertaken in order to raise the development above the 1% AEP design flood level of 2.3 m AHD (St Georges Basin Flood Study – 2001). By filling sections of the development, there is a potential that flood levels will be raised due to loss of temporary floodplain storage or the loss of flow paths. The potential impacts of filling at the locations shown on Figure 2 have been determined in this study.

2. APPROACH

2.1. Existing Design Conditions

The design flood conditions for Sussex Inlet were evaluated in the St Georges Basin Flood Study (September 2001) and considered:

- the design inflows calculated using a rainfall-runoff hydrologic model,
- design ocean hydrographs,
- a range of critical rainfall durations evaluated for the locations shown on Figure 1.

The existing design flood levels for the area of interest are shown in Table 1.

Table 1: Design Flood Levels (mAHD)

	Flood (AEP)		
Location	**1%**	**2%**	**5%**
Basin	2.4	2.1	1.8
Badgee Lagoon Junction	2.3	2.0	1.7
Jacobs Dr	2.3	2.0	1.7
Cater Canal	2.2	1.9	1.7
Coastal Patrol	2.1	1.8	1.6
The Haven	2.0	1.9	1.7
D/S Sussex Inlet Rd Br	2.3	2.0	1.7
U/S Badgee Br	2.3	2.0	1.7
Jacobs Dr Br	2.3	2.0	1.7
U/S Cater Br	2.3	2.0	1.7

Refer Figure 1 for site locations
AEP = Annual Exceedance Probability

2.2. Climate Change Assumptions

The effect of climate change (ocean level rise or rainfall increase) can be analysed by varying the boundary conditions of the hydraulic model established for the St George Basin Flood Study. From the St Georges Basin Flood Study it was found that the maximum flood levels at the locations of interest are from a 48 hour critical duration rainfall event. Therefore this duration has been used to determine climate change impacts. It should be noted that the results provided are therefore only valid for areas around Sussex Inlet which have a 48 hour critical duration.

To assess the effects of ocean level rise each ordinate of the design ocean level hydrographs at the Sussex Inlet entrance was increased by the nominated DECC 2007 value (+0.18m, +0.55m +0.91m). A comparison of the adopted peak ocean levels is provided in Table 2.

Table 2: Comparison of Peak Ocean Levels (mAHD)

	Flood (AEP)		
Scenario	**1%**	**2%**	**5%**
Existing	2.00	1.90	1.80
+0.18m Ocean Level Rise	2.18	2.08	1.98
+0.55m Ocean Level Rise	2.55	2.45	2.35
+0.91m Ocean Level Rise	2.91	2.81	2.71

To assess the effects of an increase in peak rainfall and storm volume each ordinate of the design rainfalls was increased by the nominated DECC 2007 value (+10%, +20%, +30%). An example of the change in peak inflows to St Georges Basin is given in Table 3. The inflows are for Wandandian Creek taken at the location named Princes Highway D/S in Figure 1.

Table 3: Comparison of Peak Inflows (m^3/s) at Princes Hwy D/S on Wandandian Creek

	Flood (AEP)		
Scenario	**1%**	**2%**	**5%**
Existing	1167	1018	886
+10% Increase	1304	1140	995
+20% Increase	1427	1249	1093
+30% Increase	1563	1371	1201

In the St Georges Basin Flood Study it was found that wave setup due to wind stresses and barometric pressures had a large impact on tidal levels. It is uncertain what effect climate change would have on storm conditions and therefore wave setup during a rainfall event.

Whilst it is generally regarded that ocean levels will rise by the year 2100 (the amount of the rise is as yet not definitive), the effect of climate change on design rainfalls is less understood. For example, it is possible that design rainfall intensities may decrease in some parts of NSW and for many parts there will only be a 10% increase.

It should be noted that the increase in the existing peak flow from a 5% to a 2% AEP event is approximately 15% and from a 5% to the 1% AEP event is approximately 30%. Thus a 15% increase in flow would mean that the existing 2% AEP flood level would be reached or exceeded on average once in 20 years as opposed to once in 50 years.

3. RESULTS – CLIMATE CHANGE

3.1. Results

The boundary conditions of the hydraulic model adopted in the St George Basin Flood Study to determine design flood levels were adjusted to reflect the adopted ocean level rise and increase in rainfall climate change scenarios given in Section 2.2 for the 48 hour critical rainfall duration. The results at key locations along the Sussex Inlet are provided in Table 4.

Table 4: Results – Increase in Peak Flood Level (m) due to Climate Change

Flood AEP	1%	2%	5%	1%	2%	5%	1%	2%	5%
Scenario	**0.18m ocean level rise**			**0.55m ocean level rise**			**0.91m ocean level rise**		
Basin	0.1	0.1	0.1	0.4	0.4	0.5	0.7	0.8	0.8
Badgee Lagoon Junction	0.1	0.1	0.1	0.4	0.4	0.5	0.8	0.8	0.8
Jacobs Dr	0.1	0.1	0.1	0.4	0.5	0.5	0.8	0.8	0.8
Cater Canal	0.1	0.1	0.1	0.5	0.5	0.5	0.7	0.8	0.8
Coastal Patrol	0.1	0.1	0.1	0.5	0.5	0.5	0.8	0.8	0.8
The Haven	0.2	0.2	0.2	0.5	0.5	0.5	0.9	0.9	0.9
D/S Sussex Inlet Rd Br	0.1	0.1	0.1	0.4	0.4	0.5	0.8	0.8	0.8
U/S Badgee Br	0.1	0.1	0.1	0.4	0.4	0.5	0.8	0.8	0.8
Jacobs Dr Br	0.1	0.1	0.1	0.4	0.4	0.5	0.8	0.8	0.8
U/S Cater Br	0.1	0.1	0.1	0.4	0.4	0.5	0.7	0.7	0.8

Flood AEP	1%	2%	5%	1%	2%	5%	1%	2%	5%
Scenario	**10% increase in rainfall**			**20% increase in rainfall**			**30% increase in rainfall**		
Basin	0.2	0.2	0.2	0.4	0.3	0.3	0.5	0.5	0.5
Badgee Lagoon Junction	0.2	0.2	0.2	0.4	0.3	0.3	0.6	0.5	0.4
Jacobs Dr	0.2	0.2	0.1	0.4	0.3	0.3	0.6	0.5	0.4
Cater Canal	0.2	0.1	0.1	0.3	0.3	0.2	0.5	0.4	0.4
Coastal Patrol	0.1	0.1	0.1	0.3	0.2	0.2	0.4	0.3	0.3
The Haven	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D/S Sussex Inlet Rd Br	0.2	0.2	0.2	0.4	0.3	0.3	0.5	0.5	0.4
U/S Badgee Br	0.2	0.2	0.2	0.4	0.3	0.3	0.5	0.5	0.4
Jacobs Dr Br	0.2	0.2	0.2	0.4	0.3	0.3	0.5	0.5	0.4
U/S Cater Br	0.2	0.2	0.1	0.3	0.3	0.3	0.5	0.5	0.4

Note: Increase in levels are shown relative to existing conditions

Flood AEP	1%	2%	5%	1%	2%	5%	1%	2%	5%
Scenario	0.18m ocean level rise			0.18m ocean level rise			0.18m ocean level rise		
	10% increase in rainfall			20% increase in rainfall			30% increase in rainfall		
Basin	0.3	0.2	0.2	0.4	0.4	0.4	0.6	0.6	0.5
Badgee Lagoon Junction	0.3	0.2	0.2	0.4	0.4	0.4	0.6	0.6	0.5
Jacobs Dr	0.3	0.3	0.2	0.4	0.4	0.3	0.6	0.6	0.5
Cater Canal	0.3	0.2	0.2	0.4	0.4	0.3	0.6	0.5	0.4
Coastal Patrol	0.2	0.2	0.2	0.4	0.3	0.3	0.5	0.4	0.4
The Haven	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
D/S Sussex Inlet Rd Br	0.3	0.2	0.2	0.4	0.4	0.4	0.6	0.6	0.5
U/S Badgee Br	0.3	0.2	0.2	0.4	0.4	0.4	0.6	0.6	0.5
Jacobs Dr Br	0.3	0.2	0.2	0.4	0.4	0.4	0.6	0.6	0.5
U/S Cater Br	0.3	0.2	0.2	0.4	0.4	0.3	0.6	0.5	0.5

Flood AEP	1%	2%	5%	1%	2%	5%	1%	2%	5%
Scenario	0.55m ocean level rise			0.55m ocean level rise			0.55m ocean level rise		
	10% increase in rainfall			20% increase in rainfall			30% increase in rainfall		
Basin	0.6	0.6	0.6	0.8	0.7	0.7	0.9	0.9	0.9
Badgee Lagoon Junction	0.6	0.6	0.6	0.8	0.8	0.7	0.9	0.9	0.9
Jacobs Dr	0.6	0.6	0.6	0.8	0.8	0.7	1.0	0.9	0.8
Cater Canal	0.6	0.6	0.6	0.7	0.7	0.7	0.9	0.8	0.8
Coastal Patrol	0.6	0.6	0.6	0.7	0.7	0.7	0.8	0.8	0.7
The Haven	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
D/S Sussex Inlet Rd Br	0.6	0.6	0.6	0.8	0.7	0.7	0.9	0.9	0.9
US Badgee Br	0.6	0.6	0.6	0.8	0.7	0.7	0.9	0.9	0.9
Jacobs Dr Br	0.6	0.6	0.6	0.8	0.7	0.7	0.9	0.9	0.9
US Cater Br	0.6	0.6	0.6	0.8	0.7	0.7	0.9	0.9	0.8

Flood AEP	1%	2%	5%	1%	2%	5%	1%	2%	5%
Scenario	0.91m ocean level rise			0.91m ocean level rise			0.91m ocean level rise		
	10% increase in rainfall			20% increase in rainfall			30% increase in rainfall		
Basin	0.9	0.9	0.9	1.0	1.0	1.0	1.2	1.2	1.2
Badgee Lagoon Junction	0.9	0.9	0.9	1.1	1.0	1.0	1.2	1.2	1.2
Jacobs Dr	0.9	0.9	0.9	1.1	1.1	1.0	1.2	1.2	1.2
Cater Canal	0.9	0.9	0.9	1.0	1.0	1.0	1.2	1.1	1.1
Coastal Patrol	0.9	0.9	0.9	1.0	1.0	1.0	1.1	1.1	1.0
The Haven	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
D/S Sussex Inlet Rd Br	0.9	0.9	0.9	1.1	1.0	1.0	1.2	1.2	1.2
US Badgee Br	0.9	0.9	0.9	1.1	1.0	1.0	1.2	1.2	1.2
Jacobs Dr Br	0.9	0.9	0.9	1.1	1.0	1.0	1.2	1.2	1.2
U/S Cater Br	0.9	0.9	0.9	1.0	1.0	1.0	1.2	1.2	1.1

Note: Increase in levels are shown relative to existing conditions

3.2. Comment on Results

3.2.1. Ocean Level Rise

Three ocean level rises were considered and the results indicate a corresponding increase in flood level of slightly less that the increase in ocean level. The effect is reasonably consistent throughout Sussex Inlet with all locations showing similar rises in peak flood levels.

3.2.2. Rainfall Increase

A 10% increase in rainfall intensity equates to approximately a 0.1 to 0.2 m increase in flood levels except at The Haven (Figure 1) where the peak flood levels are primarily determined by ocean levels.

A 20% increase in rainfall intensity raises peak levels by 0.2 to 0.4 m. A rainfall intensity increase of 30% raises flood levels by 0.3 to 0.6 m. The levels at The Haven are again determined by ocean levels. The impact of the changed rainfall intensity increases as one travels upstream from The Haven as the ocean effect becomes less dominant.

3.2.3. Combination of Ocean Level and Rainfall Increase

For all scenarios flood levels at the downstream end of Sussex Inlet at The Haven are equivalent to the corresponding ocean level rise. At the Basin (Figure 1) it was found that for a combined sea level rise and increased rainfall intensity scenario, the impact on flooding is approximately the sum of the two individual scenarios.

The greatest impact occurs with a 0.91 m ocean level rise and simultaneous 30% increase in rainfall intensity, giving an increase in flood levels of 1.2 m at the Basin.

3.3. Implications

The DECC flood risk management guideline (2007) recommends that minimum fill and floor levels for new developments include an allowance for high scenario climate change in order to accommodate for the potential changes in rainfall intensities and ocean level rises.

4. HYDRAULIC IMPACTS OF FILLING

4.1. Description

The St Georges Basin Flood Study (2001) determined that the 1% AEP design flood level in the area of interest was 2.3 m AHD. It is assumed that filling will be undertaken for all development areas on land below this level (as shown on Figure 2). As a consequence there is the potential that this filling will increase design flood levels for events up to the 1% AEP.

The area of the Basin is much larger than the area requiring filling and therefore it is expected that the proposed filling will have a relatively insignificant effect on peak flood levels.

4.2. Approach

The areas proposed to be filled are shown on Figure 2. The volume of fill has been estimated using the ground contours provided and it should be noted that these contours were based on photogrammetry (and therefore of unknown accuracy) and not field survey data. The estimated volumes of fill are provided in Table 5.

Table 5: Assumed Areas to be Filled (refer Figure 2)

	Area A	Area B	Area C	Area D
Assumed Volume of Fill (m^3)	413	20520	43145	8690

Note: Lucas Development Group provided an extent of fill (refer Figure 2) and it should be noted that this is indicative only.

The effect of the fill indicated in Table 5 was simulated in the hydraulic model by altering the cross-sections to reflect the change in conveyance and temporary floodplain storage.

4.3. Comment on Results

The results of the hydraulic model indicate that the proposed filling indicated in Table 5 changes flood levels by less than $\pm$ 0.01 m. A change in flood levels of $\pm$ 0.01 m or less is considered to be within the accuracy of the modelling approach and therefore can be ignored.

The reason for the minimal impact on flood levels is due to the significant temporary floodplain storage in the St Georges Basin and surrounds. A rise of water levels from 1 m to 2.3 m AHD would correspond to a temporary storage of approximately 48 million m^3. The volume of filling in Table 5 is equivalent to 0.1% of this storage.

The extent of filling has only been evaluated up to the 1% AEP flood event and the effect of filling on runoff from local catchments has not been considered in this assessment. This assessment is only valid for the extent of fill shown in Table 5 and any significant changes would require a re-evaluation.

Figures

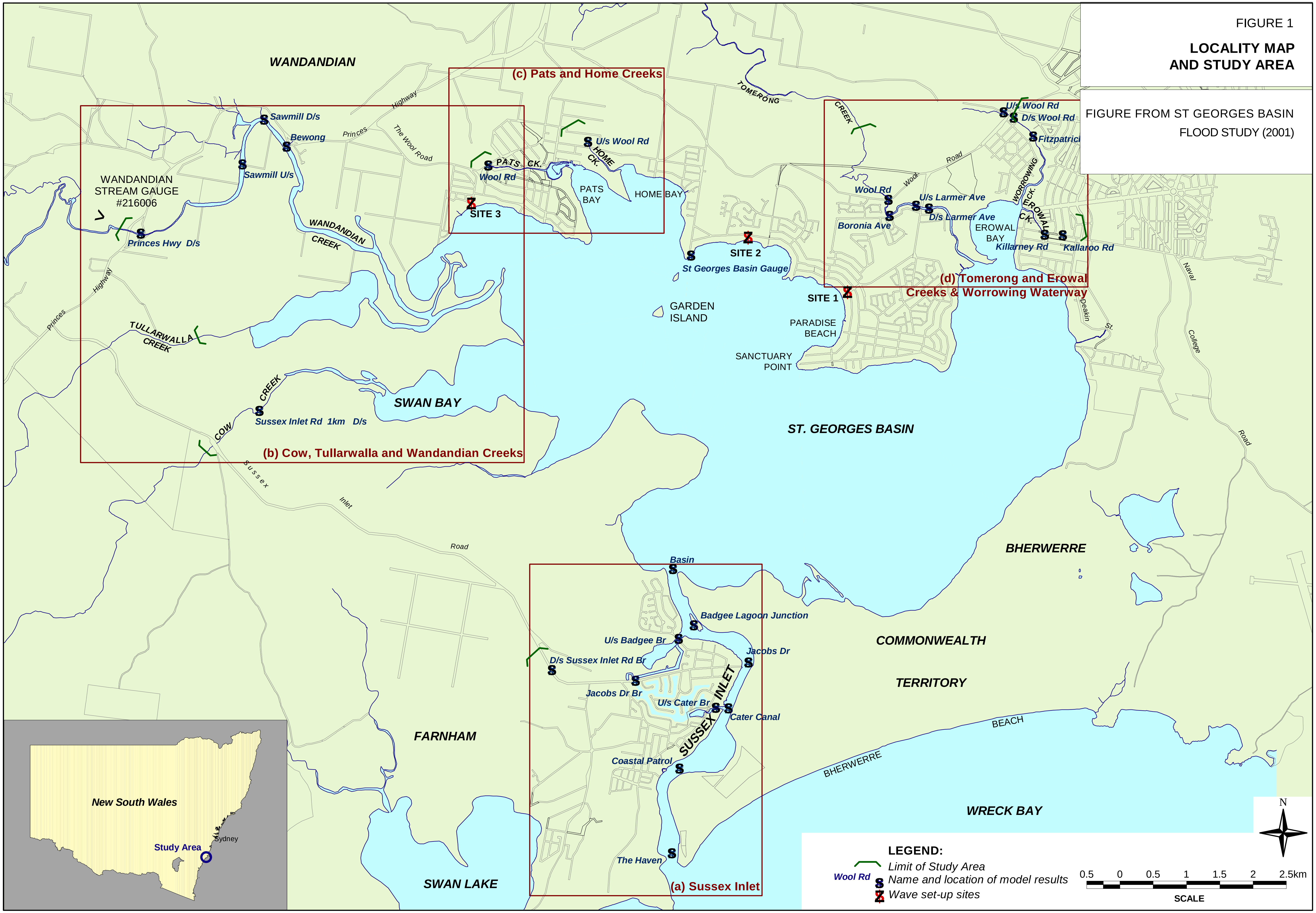

FIGURE 1

LOCALITY MAP AND STUDY AREA

FIGURE FROM ST GEORGES BASIN FLOOD STUDY (2001)

FIGURE 2
LOCATIONS OF FILLING