management consultants &
project managers

npc

27 March 2015

Liverpool City Council
Locked Bag 7064
Liverpool BC, NSW 1871

Attention: Rajendra Autar

Dear Sir,

Re Georges Cove Marina – New development application

Benedict Industries proposes to submit a new development application for the Georges Cove Marina. The proposal is exactly identical, in flooding terms, to the one considered and approved by the JRPP in August 2014.

The flood modelling work undertaken for the original approved marina proposal therefore remains contemporary and applicable to this new application for the marina.

The attached flood reports to support the new application for the marina therefore comprise the following:-

- Attachment 1: Assessment of the Flood Impact of the Proposed Bridge on Flooding in the Vicinity of the Georges Cove Marina (Cardno, May 2014)
- Attachment 2: Flood Risk Management Report (npc, November 2013)
- Attachment 3: Flood Impact Assessment for the Proposed Georges Cove Marina, Moorebank (Cardno, January 2013).

The flood impacts are unchanged from the approved marina and will remain negligible.

Yours faithfully,

Mark Tooker

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ATTACHMENT 1

Assessment of the Impact of the Proposed Bridge on Flooding in the Vicinity of the Georges Cove Marina, Moorebank (Cardno, May 2014)

Our Ref: NA49913037:BCP/bcp
Contact: Dr Brett C. Phillips

23rd May 2014

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The Manager
npc
PO Box 1060
CROWS NEST NSW 1585

Attention: Mr Mark Tooker

Dear Mark,

ASSESSMENT OF THE IMPACT OF THE PROPOSED BRIDGE ON FLOODING IN THE VICINITY OF THE GEORGES COVE MARINA, MOOREBANK

In 2012 Cardno was commissioned by npc to prepare a flood model to undertake a flood impact assessment of the proposed Georges Cove Marina development in Moorebank, within the Liverpool City Council Local Government Area (LGA).

Cardno has been requested to present the flood impact detailed for the proposed road bridge crossing located to the north of the Georges Cove Marina site. The bridge is proposed to connect Brickmakers Drive to the Benedict site and crossing over the access road to the Moorebank Recyclers site.

A previous concept design of the bridge with four 18m spans (total span of 72m) was approved by Council. The updated design modelled within this assessment is a clear 32m span covering the access road reserve and adjacent open channel.

1. ASSESSMENT SCENARIOS

The proposed location and design layout of the road bridge is shown in **Figure 1**.

The bridge crossing has been modelled in accordance with the concept design (Drawing no. 101015-00561-ci-fig3, Worley Parsons). The following details were adopted for the purpose of the hydraulic modelling assessment:

- The bridge has a clear span with the underside of the bridge higher than the 100 yr ARI flood level (5.52m AHD) so that the waterway opening is not pressurised during a 100 yr ARI flood and the bridge deck can be omitted from the hydraulic model. Consequently the hydraulic roughness of the bridge waterway remained unchanged from existing conditions; and
- The footprint of the proposed embankment for the bridge extends as in the above design plans and as shown schematically in **Figure 1**.

The following scenarios were assessed under developed conditions without and with the bridge crossing:

- A 100 yr ARI flood in the Georges River;
- The 100yr ARI local storm event in combination with two Georges River flooding scenarios:
  - a 20 yr ARI Georges River flood; and,
  - a Georges River base flow of 200 m^3/s.

No blockage has been adopted within the hydraulic modelling for the bridge as the clear span is 32m, which is significantly greater than the 18m spans within the previous bridge design. This approach is in accordance with blockage assessment techniques set-out in AR&R Project 11 Stage 2 Report (Engineers Australia, 2013).

2. FLOOD IMPACT ASSESSMENT

The peak flows under each scenario are summarised in Table 1 while Table 2 summarises the flood level and peak flow velocity at two reference locations. These are located just upstream of the proposed bridge crossing (Location 1) and downstream of the stormwater outfall south of Newbridge Road (Location 2).

Table 1 Peak Flows (m^3/s)

Scenario	Georges River	Local Catchment
1	2,081	0*
2	1,567	35.8
3	200	35.8

* In a 36 hour 100 yr ARI storm the estimated peak runoff from the local catchment was only around 5 m^3/s consequently this local inflow was not included in Scenario 1

Under Scenario 2 the runoff from the local catchment in a 100 yr ARI storm equates to 2.3% of the 20 yr ARI peak flow in the Georges River while under Scenario 3 the runoff from the local catchment in a 100 yr ARI storm equates to 18% of the 200 m^3/s base flow in the Georges River.

Table 2 Peak Water Level (m AHD)

Scenario	Location 1			Location 2		
	Without Bridge	With Bridge	Difference	Without Bridge	With Bridge	Difference
Peak Water Level (m AHD)						
1	5.52	5.52	0.00	5.52	5.52	0.00
2	4.60	4.60	0.00	4.60	4.60	0.00
3	3.33	3.39	0.06	3.56	3.59	0.03

It is noted that under Scenario 3 the peak water level is 1.9 m to 2.2 m lower than the 100 yr ARI flood level.

2.1 Flood Impacts during a 100 yr ARI Georges River Flood

The peak water level differences during a 100 yr ARI flood in the Georges River (Scenario 1) resulting from the proposed bridge are shown in **Figure 2**. It can be seen from Figure 2 and Table 2 that the impact of the proposed bridge crossing on the 100 yr ARI flood level is negligible (ie. <0.01 m). This is because the 100 yr ARI flood level is governed by backwater flooding from the Georges River.

The peak flow velocity differences during a 100 yr ARI flood in the Georges River resulting from the proposed bridge are shown in **Figure 3**. There are minor peak velocity increases (<0.04 m/s) in the vicinity of the bridge span, with minor decreases in velocity (0.04 m/s) for an area south of the bridge.

2.2 Flood Impacts during a Local Catchment 100 yr ARI Storm

In response to preliminary comments received from Liverpool City Council dated 13 May 2014, local catchment flooding has been assessed in accordance with the methodology outlined in the Moorebank Recyclers Flood Impact Assessment (WMA Water, 2013).

A hydrological model of the local catchment was prepared using **xprafts** based on the details given in Section 4.2 of the Moorebank Recyclers Flood Impact Assessment report (WMA Water, 2013). The hydrological model was run and the 100yr ARI flows from the catchment were found to match the peak flow of 35.8 m^3/s reported in the 2013 study.

The flow hydrograph for the local catchment was input in the hydraulic model at the stormwater outfall location identified in **Figure 4** (immediately south of Newbridge Road).

The 100yr ARI local storm event was assessed in combination with two Georges River flooding scenarios, namely in combination with:

- a 20yr ARI Georges River flood (where the peak flows from the local catchment was delayed so that it coincided with the peak flow in the Georges River) (Scenario 2); and,
- a constant Georges River base flow of 200 m^3/s (Scenario 3)

Under Scenario 2 the peak water level differences are shown in **Figure 4** while the peak velocity differences are shown in **Figure 5**.

These results show negligible water level impacts (<0.01m) resulting from the bridge structure as the runoff in a local 100 yr ARI storm has negligible impact on the floodplain compared to the flooding caused by the 20 year ARI flood in the Georges River. It was also found that there are minor peak velocity increases (<0.04 m/s) in the vicinity of the bridge span, with significant decreases in velocity (0.15 m/s) occurring in an area south of the bridge embankment.

Under Scenario 3 the peak water level differences are shown in **Figure 6** while the peak velocity differences are shown in **Figure 7**.

It is noted that the water level increases locally upstream of the bridge by up to 0.1 m in the floodplain, with minor increases (<0.02 metres) further upstream within the Newbridge Road reserve to the north. There are minor peak velocity increases (<0.05 m/s) in the vicinity of the bridge crossing with significant decreases in velocity (0.8 m/s) for an area south of the bridge embankment.

It is noted that under Scenario 3 the peak water level is 1.9 m to 2.2 m lower than the 100 yr ARI flood level.

The water level increases of 0.1 metres for local catchment flooding are considered minor as:

- They do not represent a significant alteration of flow regime when considering the negligible velocity impacts for the area; and,

- They do not have any impact on compliance with Council's development controls because the 100 yr ARI is governed by flooding from the Georges River and the bridge crossing has negligible impacts in this event.

2.3 Flood Storage

The estimated loss of flood storage in a 100 yr ARI Georges River flood due to the construction of the road embankment is estimated to be around 4,780 m3 (in comparison with an indicative flood volume of 12.8 million m3) ie. the loss of flood storage equates to 0.0037% of the 100 yr ARI flood volume.

Note that the previously approved bridge design resulted in a flood storage loss of approximately 1,960m3, therefore the updated bridge design results in an increase in flood storage loss of approximately 2,820m3 over the previous approved design. i.e. the impact of the new design is 0022% of the 100 yr ARI flood volume.

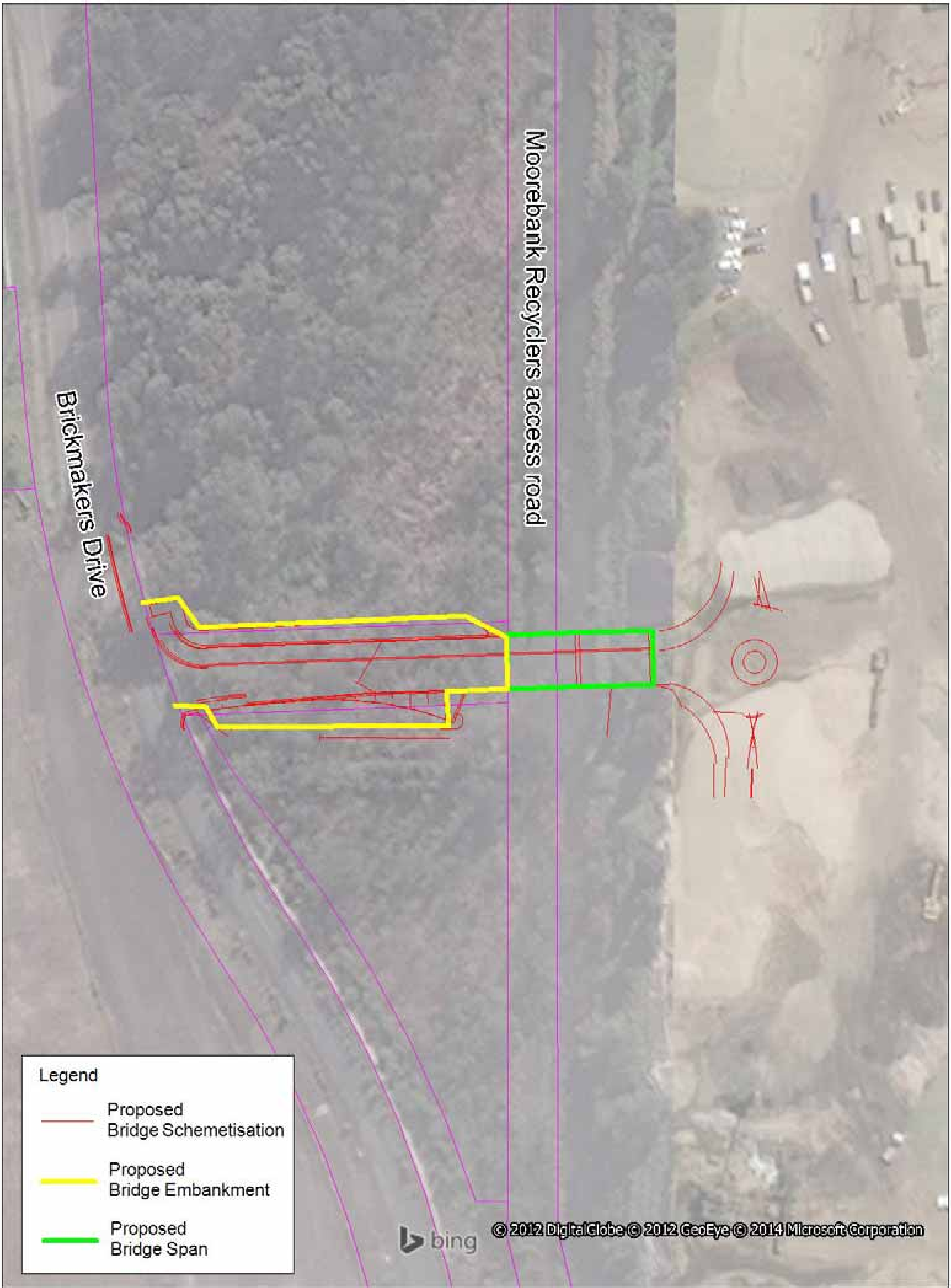
We note from previous correspondence that Council's default position in relation to applications which have some impact on flood storage but do not carry out a detailed Flood Impact Assessment is to require compensatory earthworks or the like to compensate for any loss of storage. The point of undertaking a Flood Impact Assessment is to determine if any loss in floodplain storage has any impact. In this instance, the Flood Impact assessment has clearly shown that the impact of the loss of such a small amount of flood storage has no impact and in our view there is no justification to require works to balance these storage losses.

Yours faithfully

Brett C. Phillips

………………………………

Dr Brett C. Phillips
Director, Water Engineering
for **Cardno**



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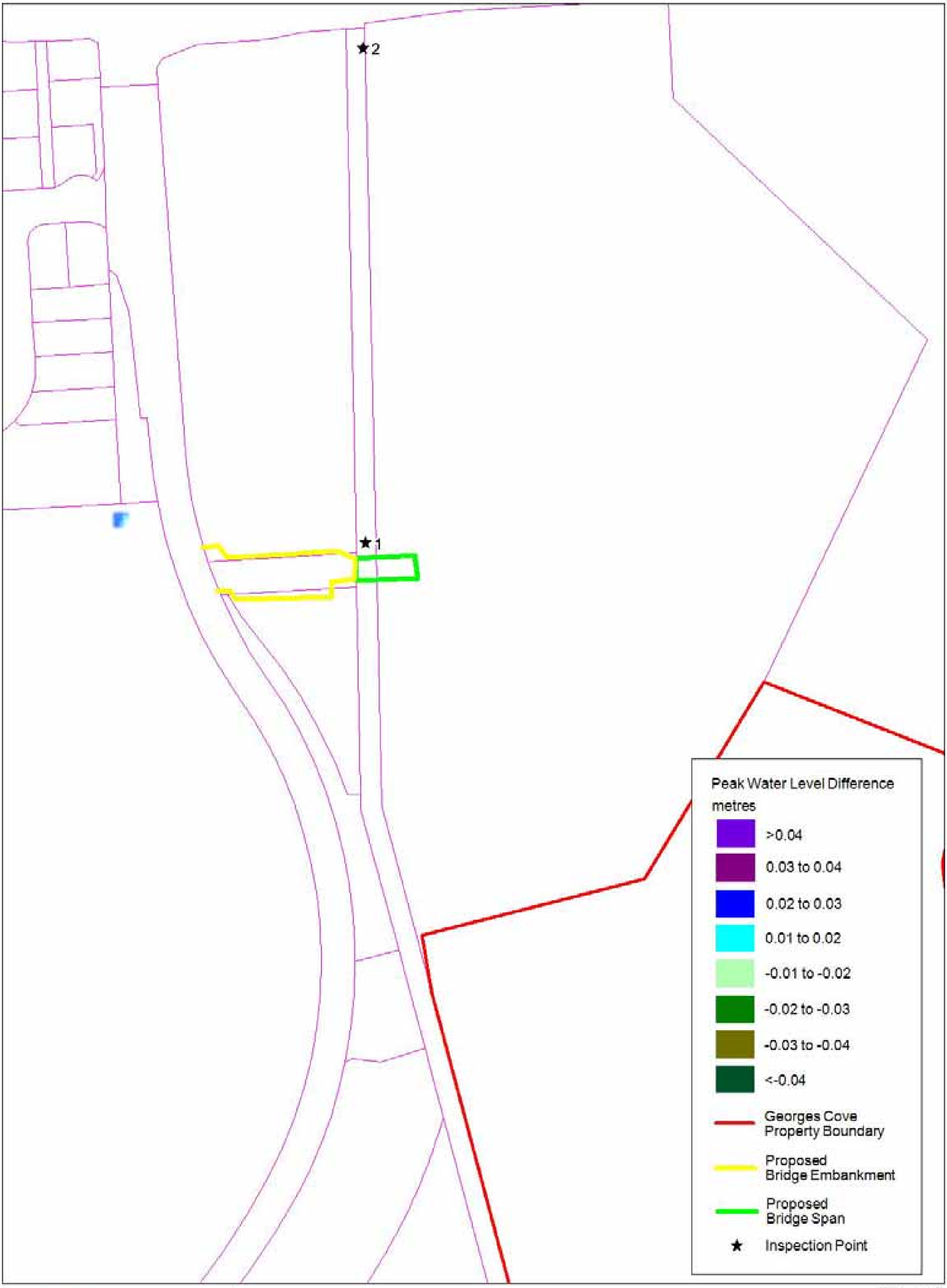
Georges Cove
Flood Impact Assessment

Figure 1
Proposed Road Bridge



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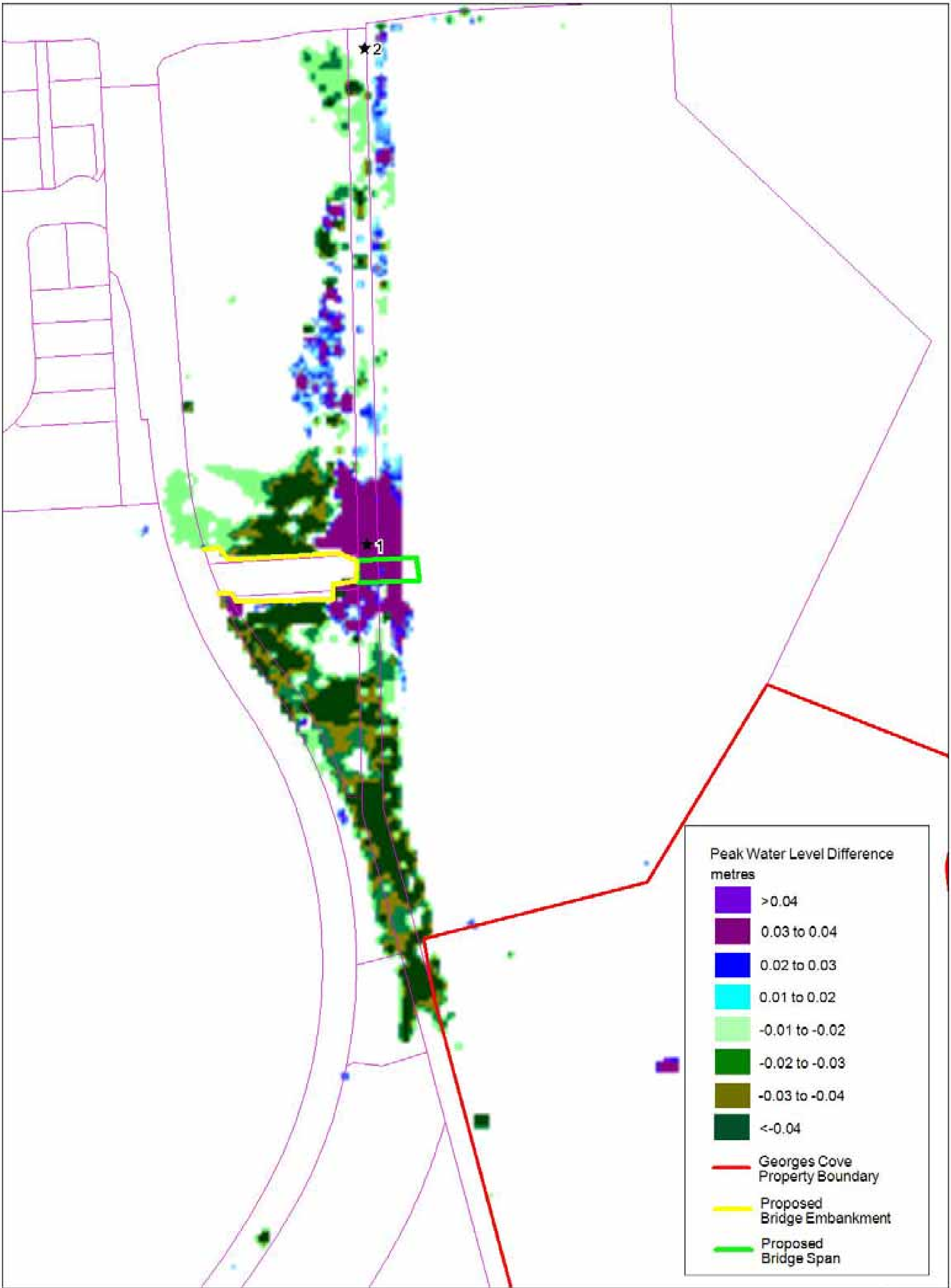
NA49913037
May 2014

Georges Cove
Flood Impact Assessment

Figure 2
100 year ARI Georges River Flooding
Peak Water Level Differences
Post-Development - Road Bridge



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Georges Cove
Flood Impact Assessment

Figure 3
100 year ARI
Peak Velocity Differences
Post-Development - Road Bridge

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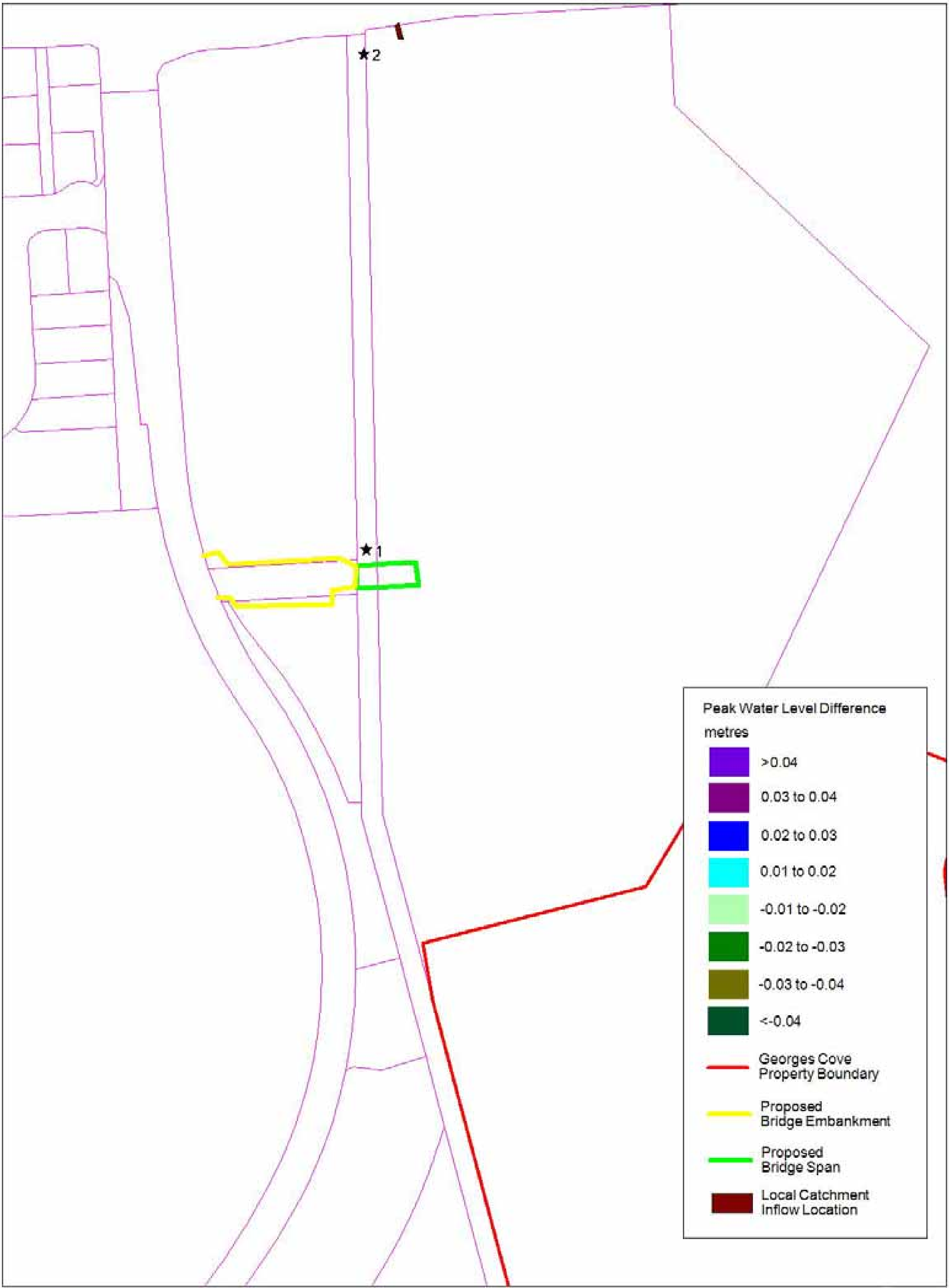

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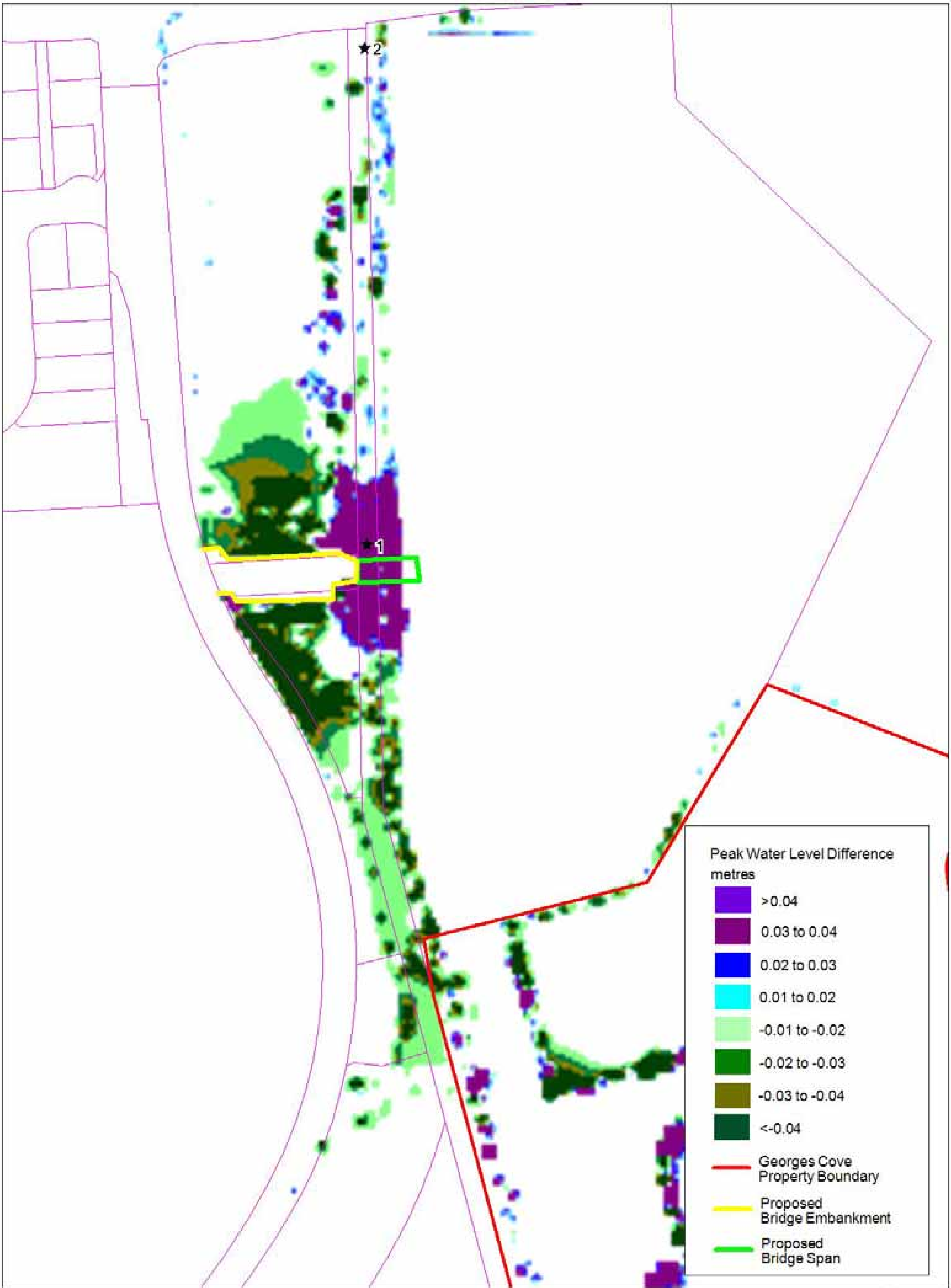
Georges Cove
Flood Impact Assessment

Figure 4
20 year ARI Georges River Flooding
100 year ARI Local Flooding
Peak Water Level Differences
Post-Development - Road Bridge



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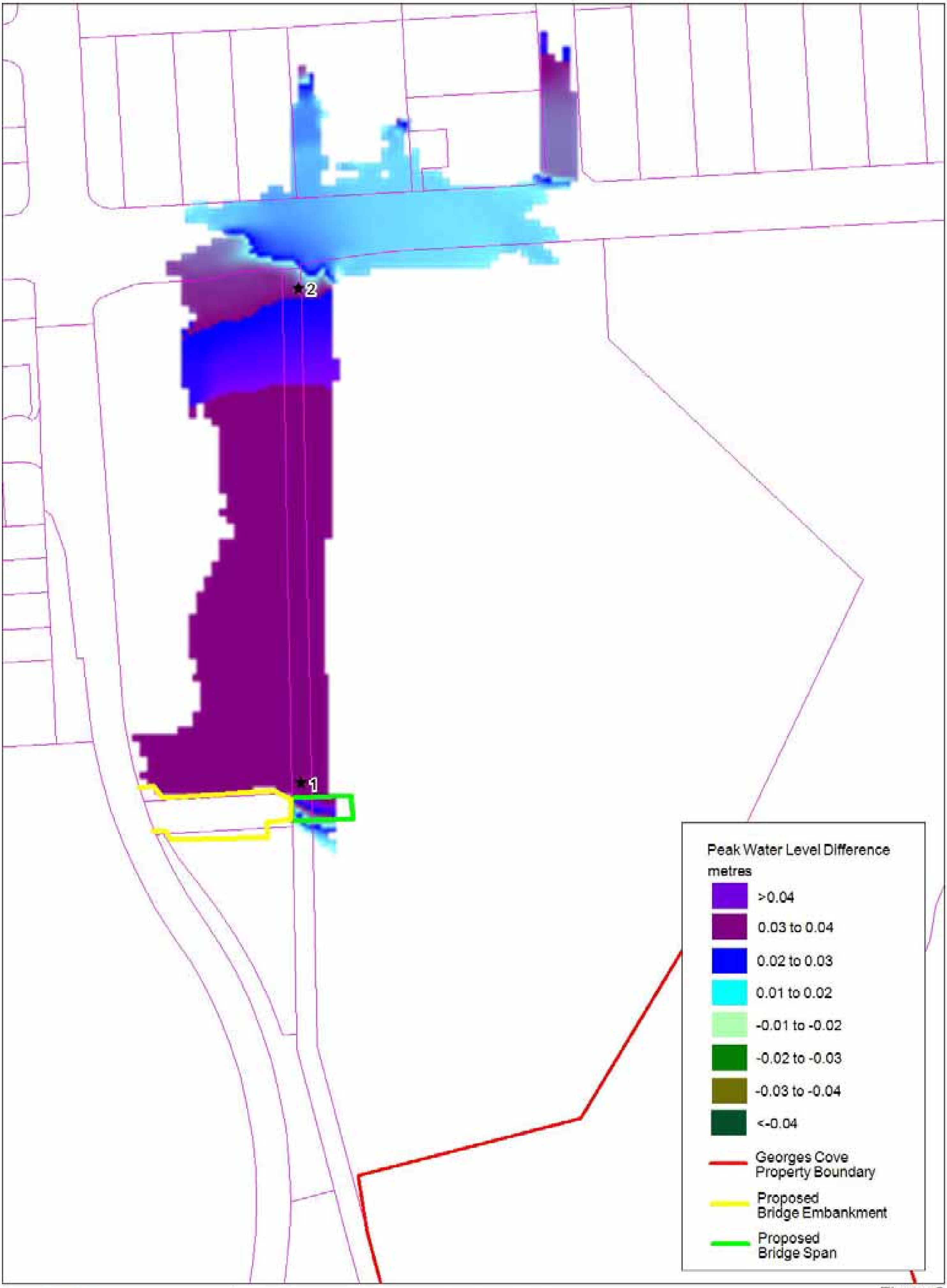
Georges Cove
Flood Impact Assessment

Figure 5
20 year ARI Georges River Flooding
100 year ARI Local Flooding
Peak Velocity Differences
Post-Development - Road Bridge



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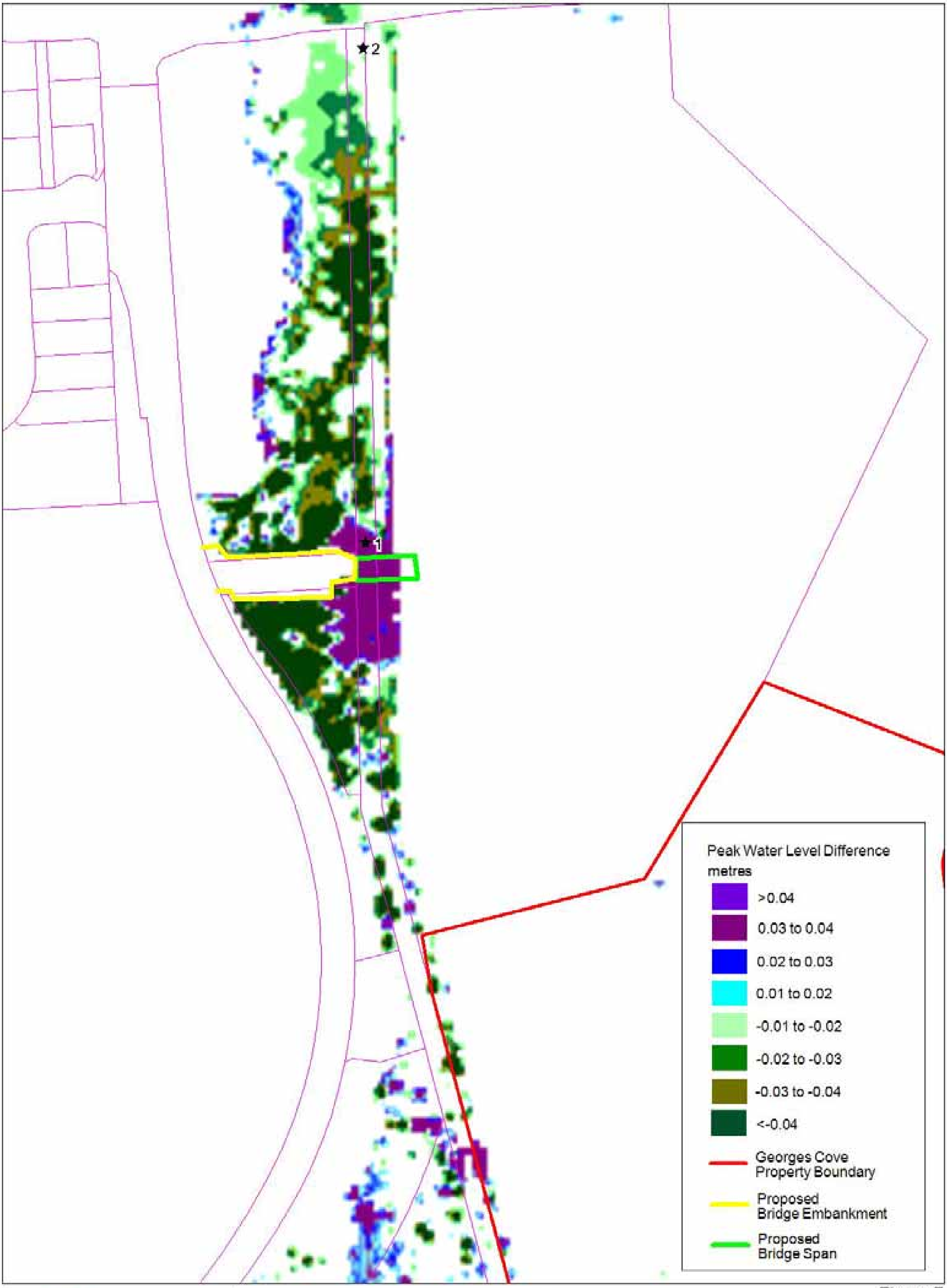
Georges Cove
Flood Impact Assessment

Figure 6
100 year ARI Local Flooding
Peak Water Level Differences
Post-Development - Road Bridge



Cardno

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May 2014

Georges Cove
Flood Impact Assessment

Figure 7
100 year ARI Local Flooding
Peak Velocity Differences
Post-Development - Road Bridge

ATTACHMENT 2

Flood Risk Management Report (npc, November 2013)

Georges Cove Marina
Flood Risk Management

November 2013

1. Flood Levels

The predicted flood levels for the marina site are:-

20 yr ARI	– RL 4.6 to 4.7m AHD
100 yr ARI	– RL 5.6m AHD
Probable Maximum Flood (PMF)	– RL 10.2m AHD

The flood planning level (FPL) is RL 6.1m AHD (100 yr ARI + 0.5m freeboard).

2. Proposed Marina Development

The marina buildings have been designed to minimize their impact on flood behavior and the impact of flooding on the buildings. The main buildings housing the boat storage and amenities has the amenity facilities located above the PMF flood level at a minimum level of RL 10.525m AHD. The upper floor of the amenity facilities will be at RL 14.71m AHD. The first level of boat storage in this building will be at RL 7.3m AHD at least 1.7m above the 100 yr ARI flood level. The building below RL 7.3m AHD will be an open structure to allow flow through during floods. Parking under this main building will be at RL 4.6m AHD which is the 20 yr ARI flood level.

The small building will be the Private Marina Club house with a minimum floor level at the flood planning level of RL 6.1m AHD.

The southern carpark will be at a level of RL 1.65m AHD. This is equivalent to a 5 yr ARI flood level.

The marina development has been designed to ensure there is no loss of flood storage to minimize the impact on flood behavior.

3. Flood Behaviour

The proposed marina is located westwards of the main river flood flow paths and protected from these flows by the high lands immediately north and south of the site. The detailed 2D flood modeling of the proposed development by Cardno reaffirmed this behavior with low peak flow velocities in the 100 yr ARI flood of mainly 0 to 0.3 m/s with some isolated areas of higher velocity up to 0.5m/s. The floodway was located in the main river with velocities around 0.5 to 2 m/s (refer to Figure 3-18 in Cardno report).

The proposed marina and the area to the south west is a flood storage area which also plays an important part in the flood behavior. The proposed marina was designed to minimize any loss of flood storage.

The Cardno report demonstrated that the proposed marina would not have a significant adverse impact on flood levels and velocities. This is shown in the plot of water level and velocity differences between the post and before development scenarios presented in Figures 4-1 to 4-8 in the Cardno Report.

The Cardno flood study established that the preliminary hydraulic hazard in the marina would be rated as high in the 100 yr ARI flood.

4. Government Flood Risk Management Policy

The NSW Government's Flood Prone Land Policy and Floodplain Development Manual support the wise and rational development of flood prone land, the area inundated by the probable maximum flood (PMF). The policy acknowledges that flood prone land is a valuable resource that should not be sterilised by unnecessarily precluding its development and that development should be treated on its merits rather than through the application of rigid and prescriptive criteria.

The Manual specifies a process for appropriate risk management which requires Councils to under a flood study followed by a flood management study which should lead to the formulation of a floodplain management plan.

Liverpool City Council has prepared such a plan and integrated it into its Local Environmental Plan 2008 (Section 7.8) and the Liverpool Development Control Plan 2008 (Section 9 Flooding Risk).

The DCP specifies an industry best practice approach based on a matrix system which provides guidance on allowable development depending on flood risk category, land use risk category and planning controls. Table 4 for Georges River from Section 9 of the DCP applies to the proposed marina development. A copy of Table 4 is contained at Attachment A.

The flood risk category is high and the land use risk category is recreation and non-urban. Development of the marina is permissible subject to the controls listed in Table 4.

In terms of floor level, Table 4 requires non-habitable floor levels to be no lower than the 5 yr ARI level and habitable floors at the FPL. The proposed marina complies with these requirements (refer to Section 2).

For building components, Table 4 requires that all structures have flood compatible building components below the FPL. This can be complied with and is a proposed consent condition (Condition 27).

With structural soundness, Table 4 requires that an Engineer's report be provided to confirm the structure can withstand forces of floodwater, debris and buoyancy up to the FPL. The buildings will be open structures up to the FPL thereby limiting the force on the structures in a flood. The low velocities within the marina will also assist to alleviate the forces on the structures.

The building design would incorporate piles and columns capable of resisting the flood forces. The height of the building to the 100yr ARI flood level from the RL 4.5m and RL 1.65m ground levels would be 1m and 3.95m respectively. This is equivalent to just over a one store building. Also, the buildings will be open structures up to a minimum level of 0.5m above the 100yr ARI flood level.

For the PMF flood, the height to this flood level would be 5.6m and 8.55m respectively. This would represent a 2 to 3 storey building. A well designed building would be able to resist the hydraulic loads from a flood in the proposed conditions. A report from a certified engineer would be obtained to provide this evidence at the construction certificate stage. There is a proposed consent condition requiring this design and report from a certified engineer (Condition 28).

For flood effects, Table 4 requires conformance to three requirements. The first is to provide a report demonstrating no significant impacts on flood behaviour. The Cardno report demonstrates conformance to this requirement.

The second requirement deals with a floodway or major flood conveyance area and the likely adverse impact of structures in this area on flood behaviour. As noted in Section 3, the building structures are not located in a floodway and as such, this is why the Cardno flood study can demonstrate no significant adverse impact on flood behavior.

The third requirement deals with the need for a balanced cut and fill to avoid adverse impacts on flood behavior. This was an important consideration in the formulation of the marina proposal and involved considerable discussions with Council. The proposed marina complies with this requirement. There is a consent condition requiring the balanced cut and fill (Condition 29).

For car parking and driveway access, Table 4 requires conformance to four conditions. The first condition is that open car parking shall be as high as possible. The northern carpark is at the 20 yr ARI flood level at RL 4.6m AHD. The southern carpark is at the lowest level required in floor level conditions in order to balance the cut and fill. As such, this part of the parking conforms to the minimum requirement while being at the maximum level to conform to the balanced cut and fill requirement.

The second condition requires the driveway to be as high as practical and be generally rising. The driveway connects to the two parking areas which are as high as possible. It also generally rises from the southern carpark at RL 1.65m AHD to the northern carpark at RL 4.6m AHD and then to the proposed residential area to the north at RL 6.1m AHD. The driveway therefore conforms to this condition.

The third condition requires parking areas below the 20 yr ARI flood level shall have warning systems, signage and exits. The southern carpark would be fitted with these requirements as part of the Site Emergency Response Flood Plan to be formulated during the detailed design phase. The Site Emergency Response Flood Plan is discussed in Section 7. There is a condition proposed by Council to require a Flood Emergency Response Plan (Condition 115).

The fourth condition requires barriers to be provided in under building carparks to prevent floating vehicles from leaving the site. This condition will be complied with and this condition is proposed by Council (Condition 31).

For evacuation, Table 4 requires conformance with two conditions. The first condition requires that the development is consistent with any relevant flood evacuation strategy or similar plan. The existing strategy is to proceed to higher ground above the PMF level. The proposed evacuation strategy is outlined in Section 7.

The second condition requires that evacuation requirements be considered and an engineer's report would be required where evacuation might not be achieved within the effective warning time. The evacuation requirements have been considered in the provision of a rising route to land above the PMF level. This is discussed more fully in Section 7 along with the 12 hour warning time available which would be readily adequate to evacuate the proposed marina development.

For management and design, Table 4 requires conformance to three conditions. The first condition requires a safe Emergency Response Flood Plan where floor levels are below the design floor level. The Response Plan is outlined in Section 7 and Council has included a Condition requiring such a plan (Condition 115).

The second condition requires that there are areas above the PMF level to store goods. There are areas available in the main building which are above the PMF level which could be used to store goods during a severe flood.

The third condition requires that no materials are to be stored below the FPL which may cause pollution or be potentially hazardous during a flood. This can be readily achieved in the boat storage area which has a minimum storage level of RL 7.3m AHD. This is 1.2m above the FPL. There is a consent condition addressing this issue (Condition 144).

For fencing, Table 4 requires three conditions. These conditions relate to the fences not having an adverse impact on flood behavior by being permeable, allowed to collapse if necessary or not being unsafe during floods. This will be complied with and Council has incorporated a consent condition to address this issue (Condition 25).

The proposed marina development therefore complies with all the flood related requirements in the Liverpool DCP 2008 such that the flood risk management is appropriate and meets the requirements of NSW Government policy and legislation. Confirmation of this is required by the consent conditions throughout the project approval and development phases.

5. Liverpool Local Environmental Plan 2008

Section 7.8 (3) in the Liverpool LEP 2008 specifies the Flood Planning requirements for the proposed marina development. These requirements are addressed below.

5.1 Flood Behaviour and Adjacent Property

a) *will not adversely affect flood behaviour and increase the potential for flooding to detrimentally affect other development or properties*

The detailed flood impact assessment undertaken by Cardno established that the proposed development would not adversely impact flood behavior and would not adversely impact on the flood behaviour on adjacent properties (refer to Figures 4-1 to 4-8 in Cardno report).

5.2 Flow Distributions and Velocities

b) *will not significantly alter flow distributions and velocities to the detriment of other properties or the environment*

The proposed marina structures are located outside the main flood flow areas and is located in a flood storage area with low velocities. As such, there is no adverse impact on flood flow distributions and velocities (refer to Figures 3-8 and 3-18 in the Cardno report and in the responses in Section 5.1).

5.3 Safe Occupation and Evacuation

c) *will enable the safe occupation and evacuation of the land*

The proposed marina will have an approved safe emergency response flood plan as described in Section 7. It meets all the Government requirements for floor and car parking levels, rising evacuation routes, more than adequate warning times, dedicated and trained staff to manage the evacuation plan and a fallback option of vertical evacuation in the main building to levels significantly above the PMF level. The proposed development meets all the requirements of the NSW Government's Floodplain Development Manual and the Council's LEP and DCP for flooding. As such it is considered to enable safe occupation and evacuation.

5.4 Adverse Environmental Impacts

d) *Will not have a significant detrimental effect on the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of any riverbank or watercourse*

The proposed marina development will incorporate rock walls around the marina basin perimeter and on the outer walls along the river. This will stabilise the banks and prevent erosion. As the flood velocities are low, any erosion potential would be low.

As the development does not cause any significant change to the flow distribution and velocities as discussed in Sections 5.1 and 5.2, the development would not induce any new instability in the riverbank.

There will be a low rate of siltation in the marina basin due to sediment ladened flood flow. This is addressed in Section 3.10 of the Worley Parsons report supporting the application. The estimated rate of siltation in the marina basin is approximately 120mm over 100yrs. This will not cause any significant problems as a siltation allowance of 300mm has been incorporated into the selection of the design depth of the basin.

The existing riparian vegetation along the river foreshore at the marina site is limited and will be maintained.

5.5 Sustainable Flood Related Social and Economic Costs

e) will not be likely to result in unsustainable social and economic costs to the flood affected community or general community as a consequence of flooding

The proposed marina has been designed to minimize the potential flood related damages in terms of the building form, materials selection and adopted floor levels. Also, flood safety has been an important design principle. The proposed development is in accord with the NSW Government Floodplain Development Manual and thus, along with the above design approach, ensures that the development offers a sustainable approach to the social and economic costs of the local and general community. Importantly, it does not require significant additional flood related infrastructure or resources to support the proposed development.

5.6 Compatible with Flood Flow and Hazard

f) if located in the floodway, will be compatible with the flow of flood waters and with any flood hazard on that floodway

The development is not located within a floodway however it still is compatible with the flood flow and hazard. The buildings have been specifically located west of the main flood flows and designed to comply with its flood hazard and the associated requirements of Council's LEP and DCP as discussed in Section 4.

6. NSW Government Flood Related Legislation

The NSW Government's Floodplain Development Manual 2005 sets out the Government's Flood Prone Land Policy. Section 117 of the Environmental Planning and Assessment Act 1979 (EPA Act) allows the Minister for Planning to give directions to Councils regarding principles, aims, objectives or policies to be achieved in the preparation of draft local environmental plans (LEP).

The Minister released new directions on 1 July 2009 under Section 117(2) of the EPA Act. For directions related to Flood Prone Land, they were the same as Direction 15 issued on 31 January 2007.

The Directions for Flood Prone Land relate to the preparation of a Planning Proposal or draft LEP and as such are not relevant to the Georges Cove Marina DA.

Also, these Directions permit inconsistency with the Directions if the inconsistency was in accordance with the principles and guidelines of the Floodplain Development Manual 2005. Liverpool City Council has conformed with the Floodplain Development Manual 2005 in the undertaking and preparation of the Georges River flood study, floodplain management study and plan, the Liverpool LEP and DCP. In this way, the Section 117(2) Directions relating the Flood Prone Land are not applicable to the subject development as the development complies with the Liverpool LEP and DCP.

7. Site Emergency Response Flood Plan

The site emergency response flood plan would be formulated in detail as required in Council's consent conditions (Conditions 115-119). The approach and structure of this plan is discussed in the following sections.

The plan would be managed on site by the manager of the marina development. The leases for the onsite activities would identify the manager of the plan and provide the manager with the authority to order various activities under the plan such as training drills and evacuations.

Flooding in the Georges River has a 12 hour warning time issued by the Bureau of Meteorology for severe flooding. This warning can be issued electronically direct to the marina manager and other dedicated staff in the marina facility. In addition to this warning, there would be water level readers located at the waters edge which issue an electronic warning and sound an audible alarm when the river level reaches RL 1.3m AHD. The marina manager would then assess the flood risk and decide on the appropriate actions.

In considering the appropriate actions, the manager would review whether advice had been received from SES.

The first action would be to clear any cars parked in the southern carpark to areas offsite above the PMF level.

If the flooding was considered to be severe then the manager would instigate an orderly evacuation of the site. The evacuation would involve:-

- locking down the moored boats;
- storing any hazardous materials into designated areas above the FPL;
- requiring all persons to evacuate by the designated route and remove cars from the northern carpark.

The marina pontoons and pile supports would be designed to cater for flood levels, flood flows and debris imposed by the 100 yr ARI flood. A back up anchor pile and chain system would hold in place the marina pontoons. All craft could be readily tied to the chain system with quick lock fixtures when a severe flood warning was received.

The marina manager would act as the flood warden and he would have a number of designated assistant flood wardens. It would be the responsibility of the assistant flood wardens to ensure all people and cars in the facility have been evacuated.

The designated evacuation route would be east along the rising marina access road to the proposed bridge to Governor Macquarie Drive and up to Nuwarra Road. Nuwarra Road is above the PMF flood level and provides opportunities for refuge.

Flood warning signs would be provided in the carparks indicating that evacuation may be required and providing directions as to the evacuation route.

Each lease provided in the marina would include a flood management package alerting lessees of the potential flood risk, the evacuation plan and the need to follow the directions of the flood warden.

The flood warden would be responsible for providing flood training at the beginning of each new lease and organizing flood evacuation training for all employees on site at least once a year.

The flood risk management onsite is relatively straight forward as the people on site will be either employees or visitors to the site all under the control and management of the marina manager. There is also considerable flood warning time allowing for an orderly evacuation. Importantly, there is a fail safe back up evacuation plan which should not need to be used but if for some reason, a person does not evacuate the site in time, there is refuge available in the upper floors of the main building in areas above the PMF flood level.

8. JRPP Flood Related Issues

Liverpool City Council has conformed to the requirements of the NSW Government Flood Prone Land Policy and Floodplain Development Manual for the Georges River floodplain by undertaking a flood study, floodplain management study and floodplain management plan. Council has devised an appropriate means of achieving an acceptable flood risk management in the development of the floodplain in the formulation of a flood risk management matrix in its Liverpool DCP 2008 and the flood planning requirements in its LEP 2008.

The proposed marina conforms with the flood risk management guidelines thereby balancing the issues of risk management with the social and economic benefits of development. The specific aspects raised by the JRPP and the compliance of the marina development is summarised in the following sections.

8.1 Compliance with LEP

The compliance with Section 7.8 (3) of the Liverpool LEP 2008 is discussed in Section 5. This compliance is supported by the detailed flood impact assessment by Cardno and the discussion in Section 4 of the marina compliance with the flood risk management matrix in the Liverpool DCP 2008.

8.2 Compliance with NSW Legislation and Floodplain Development Manual

NSW Government policy requires a merit based approach to flood risk management based on a specified process of defining the flood behavior (flood study) and formulating a strategy for how best to deal with the flood risks (flood management plan, LEP and DCP requirements). This process has been followed by Council and the discussion in Sections 4, 5, 6 and 7 demonstrates how the proposed marina conforms to the requirements.

8.3 Building Adequacy

The proposed buildings are not located within the floodway. The Cardno detailed flood study demonstrates that the flow velocities are low in the area of the proposed buildings and the buildings are located in a flood storage area. Nonertheless, the building has been designed as an open structure below the FPL to minimize the flood loads. The low flow velocities will assist to minimize the flood forces on the building.

The structural adequacy issue is discussed in Section 4 and would be verified by a report from a certified engineer.

8.4 Site Evacuation

A site emergency response flood plan is discussed in Section 7 and outlines how this plan would provide a “trigger point” for critical flood events and an evacuation strategy for practical and safe passage of vehicles and patrons from the site.

ATTACHMENT A

Table 4

Section 9 Liverpool DCP 2008

Flooding Risk

Table 4 Georges River Floodplain (Includes Harris Ck and Williams Ck, lower parts of Anzac Ck, but not Cabramatta Creek)

Flood Risk Category	Land Use Risk Category	Planning Controls							
		Floor Level	Building Components	Structural Soundness	Flood Effects	Car Parking & Driveway Access	Evacuation	Management & Design	Fencing
Low Flood Risk	Critical Uses & Facilities								
	Sensitive Uses & Facilities	13	4	4	2, 4, 5	2, 3, 6, 7, 8	6, 6, 9	2, 4	
	Subdivision				2, 4, 5			1	
	Residential (++)	2, 6	2	3	2, 4, 5	2, 3, 6, 7, 8	6, 9		
	Commercial & Industrial	4, 8, 15	2	3	2, 4, 5	2, 3, 6, 7, 8	(4 or 9), 6	2, 3, 5	
	Tourist Related Development	2, 6, 15	2	3	2, 4, 5	2, 3, 6, 7, 8	6, 9	2, 3, 5	
	Recreation & Non-Urban	2, 7	2	3	2, 4, 5	1, 5, 7, 8	6, 8	2, 3, 5	
	Concessional Development	14, 15	2	3	2, 4, 5	1, 7, 8, 9	6, 9	2, 3, 5	
Medium Flood Risk	Critical Uses & Facilities								
	Sensitive Uses & Facilities								
	Subdivision				1, 4, 5			1	1, 2, 3
	Residential	2, 6, 15	2	2	2, 4, 5	2, 3, 6, 7, 8	6, 9		1, 2, 3
	Commercial & Industrial	8, 4, 15	2	2	2, 4, 5	2, 3, 6, 7, 8	4, 6	2, 3, 5	1, 2, 3
	Tourist Related Development	2, 6, 15	2	2	2, 4, 5	2, 3, 6, 7, 8	6, 9	2, 3, 5	1, 2, 3
	Recreation & Non-Urban	2, 7	2	2	2, 4, 5	1, 5, 7, 8	6, 8	2, 3, 5	1, 2, 3
	Concessional Development	14, 15	2	2	2, 4, 5	1, 7, 8, 9	8, 9	2, 3, 5	1, 2, 3
High Flood Risk	Critical Uses & Facilities								
	Sensitive Uses & Facilities								
	Subdivision								
	Residential								
	Commercial & Industrial								
	Tourist Related Development								
	Recreation & Non-Urban	2, 7	2	2	1, 4, 5	1, 5, 7, 8	6, 8	2, 3, 5	1, 2, 3
	Concessional Development	14, 15	2	2	1, 4, 5	1, 7, 8, 9	6, 9	2, 3, 5	1, 2, 3

Key:

(green)	Not Relevant
(pink)	Unsuitable Land Use
1, 2, 3	Control reference number relevant to the particular planning consideration. (see Table 6)
(++)	Attached dwellings, Dwelling houses, dual occupancies, multi unit dwelling housing, residential flat buildings (not including development for the purpose of group homes or seniors housing), Secondary dwellings and Semi-detached dwellings are exempt from these controls.

Table 5 Local Overland Flooding

Flood Risk Category	Land Use Risk Category	Planning Controls							
		Floor Level	Building Components	Structural Soundness	Flood Effects	Car Parking & Driveway Access	Evacuation	Management & Design	Fencing
Local Overland Flood Risk	Critical Uses & Facilities	13	4	5	3	4, 7, 8	7	3, 5	2, 4
	Sensitive Uses & Facilities	13	4	5	3	4, 7, 8	7	3, 5	2, 4
	Subdivision				3		5	1	2, 4
	Residential	3, 5	1	6	3	4, 7, 8	5		2, 4
	Commercial & Industrial	10	1	6	3	4, 7, 8	5	3, 5	2, 4
	Tourist Related Development	3, 5	1	6	3	4, 7, 8	5	3, 5	2, 4
	Recreation & Non-Urban	3, 5	1	6	3	4, 7, 8	5	3, 5	2, 4
	Concessional Development	14	1	6	3	4, 7, 8	5	3, 5	2, 4

Key:

(shaded)	Not Relevant
1, 2, 3	Control reference number relevant to the particular planning consideration.

Table 6 Explanation of Development Controls

Ref No	Controls
Floor level	
1	All floor levels to be as high as practical but not less that the 20% AEP flood level.
2	Non habitable floor levels to be as high as practical but no less than the 5% AEP flood level.
3	Non-habitable floor levels to be not less than the 1% AEP flood.
4	The level of Non-habitable and general Industrial floor areas to be as high as practical but not less that the 2% AEP flood. Where this is impractical for single lot developments within an existing developed area, the floor shall be as high as practical but no less than the 5% AEP flood.
5	Habitable floor levels to be equal to or greater than the 1% AEP flood level plus 300mm freeboard.
6	Habitable floor levels to be equal to or greater than the 1% AEP flood level plus 500mm freeboard.
7	Habitable floor levels to be no lower than the 1% AEP flood plus 500mm freeboard unless justified by site specific assessment.
8	Habitable and general commercial floor levels to be as high as practical but no lower than the 1% AEP flood plus 500mm freeboard unless justified by site specific assessment.
9	The level of habitable floor areas to be equal to or greater than the 1% AEP flood level plus 500mm freeboard. If this level is impractical a lower floor level may be considered provided the floor level is as high as possible but no less than the 5% AEP flood level.
10	All floor levels to be equal to or greater than the 1% AEP flood level plus 300mm freeboard. Freeboard may be reduced if justified by site specific assessment.
11	All floor levels to be no lower than the 1% AEP flood plus 500mm freeboard. Freeboard may be reduced if justified by site specific assessment.
12	All floor levels to be equal to or greater than the PMF level. If this level is impractical a lower floor level may be considered provided the floor level is as high as possible but no less than the 1% AEP flood level plus 500mm freeboard.

Ref No	Controls
13	Floor levels to be no lower than the PMF level unless justified by a site specific assessment.
14	Floor levels to be equal to or greater than the minimum requirements normally applicable to this type of development. Where this is not practical due to compatibility with the height of adjacent buildings, or compatibility with the floor level of existing buildings, or the need for access for persons with disabilities, a lower floor level may be considered. In these circumstances, the floor level is to be as high as practical, and, when undertaking alterations or additions no lower than the existing floor level.
15	A restriction is to be placed on the title of the land, pursuant to S.88B of the *Conveyancing Act*, where the lowest habitable floor area is elevated more than 1.5m above finished ground level, confirming that the undercroft area is not to be enclosed.
Building Components & Method	
1	All structures to have flood compatible building components below the 1% AEP flood level plus 300mm freeboard.
2	All structures to have flood compatible building components below the 1% AEP flood level plus 500mm freeboard.
3	All structures to have flood compatible building components below the 1% AEP flood level plus 500mm freeboard or a PMF if required to satisfy evacuation criteria (see below).
4	All structures to have flood compatible building components below the PMF level.
Structural Soundness	
1	Applicant to demonstrate that the structure can withstand the forces of floodwater, debris and buoyancy up to and including a 1% AEP flood plus 500mm freeboard or a PMF if required to satisfy evacuation criteria (see below). An engineers report may be required.
2	Engineer's report to certify that the structure can withstand the forces of floodwater, debris and buoyancy up to and including a 1% AEP flood plus 500mm freeboard.
3	Applicant to demonstrate that the structure can withstand the forces of floodwater, debris and buoyancy up to and including a 1% AEP flood plus 500mm freeboard.
4	Applicant to demonstrate that any structure can withstand the forces of floodwater, debris and buoyancy up to and including a PMF. An engineers report may be required.
5	Applicant to demonstrate that any structure can withstand the forces of floodwater, debris and buoyancy up to and including a PMF.
6	Applicant to demonstrate that the structure can withstand the forces of floodwater, debris and buoyancy up to and including a 1% AEP flood plus 300mm freeboard.
Flood Effects	
1	Engineers report required to certify that the development will not increase flood effects elsewhere, having regard to: (I) loss of flood storage; (ii) changes in flood levels, flows and velocities caused by alterations to flood flows; and (iii) the cumulative impact of multiple similar developments in the floodplain.
2	The flood impact of the development to be considered to ensure that the development will not increase flood effects elsewhere, having regard to: (i) loss of flood storage; (ii) changes in flood levels and velocities caused by alterations to the flood conveyance; and (iii) the cumulative impact of multiple potential developments in the floodplain. An engineer's report may be required.
3	The flood impact of the development to be considered to ensure that the development will not increase flood affectation elsewhere having regard to changes in flood levels and velocities caused by

Ref No	Controls
	alteration of conveyance of flood waters. An engineers report may be required if Council considers a significant affectation is likely. The unmitigated obstruction, concentration or diversion of overland flow paths to adjacent property shall not be permitted.
4	A floodway or boundary of significant flow may have been identified in this catchment. This area is the major conveyance area for floodwaters through the floodplain and any structures placed within it are likely to have a significant impact on flood behaviour. Within this area no structures other than concessional development, open type structures or small non habitable structures (not more than 30sqm) to support agricultural uses will normally be permitted. Development outside the Boundary of Significant flow may still increase flood effects elsewhere and therefore be unacceptable
5	Any filling within the 1% AEP flood will normally be considered unacceptable unless compensatory excavation is provided to ensure that there is no net loss of floodplain storage volume below the 1% AEP flood.
Car Parking and Driveway Access	
1	The minimum surface level of open car parking spaces, carports or garages, shall be as high as practical.
2	The minimum surface level of a car parking space, which is not enclosed (e.g. open car parking space or carport) shall be as high as practical, but no lower than the 5% AEP flood level or the level of the crest of the road at the highest point were the site can be accessed. In the case of garages, the minimum surface level shall be as high as practical, but no lower than the 5% AEP flood.
3	Garages capable of accommodating more than 3 vehicles on land zoned for urban purposes, or basement car parking, must be protected from inundation by floods equal to or greater than the 1% AEP flood plus 0.1m freeboard.
4	Basement car parking shall be protected from inundation by the 1% AEP flood.
5	The driveway providing access between the road and car parking space shall be as high as practical and generally rising in the egress direction.
6	The level of the driveway providing access between the road and car parking space shall be no lower than 0.3mbelow the 1% AEP flood or such that depth of inundation during a 1% AEP flood is not greater than either the depth at the road or the depth at the car parking space. A lesser standard may be accepted for single detached dwelling houses where it can be demonstrated that risk to human life would not be compromised.
7	Basement car parking or car parking areas accommodating more than 3 vehicles (other than on Rural zoned land) with a floor level below the 5% AEP flood or more than 0.8m below the 1% AEP flood level; shall have adequate warning systems, signage and exits.
8	Barriers to be provided to prevent floating vehicles leaving a site during a 1% AEP flood.
9	Driveway and car parking space levels shall be no lower than the minimum requirements normally applicable to this type of development. Where this is not practical, a lower level may be considered. In these circumstances, the level is to be as high as practical and, when undertaking alterations or additions no lower than the existing level.
Evacuation	
1	Reliable access for pedestrians required during a 1% AEP flood.
2	Reliable access for pedestrians or vehicles is required from the building, commencing at a minimum level equal to the lowest habitable floor level to an area of refuge above the PMF level, or a minimum of 20% of the habitable floor area is above the PMF.
3	Reliable access for pedestrians or vehicles is required from the building to an area of refuge above the PMF level, or a minimum of 20% of the habitable floor area is above the PMF

Ref No	Controls
4	Reliable access for pedestrians or vehicles required during a 1% AEP flood to a publicly accessible location above the PMF.
5	The evacuation requirements of the development during flooding shall be considered.
6	The development is to be consistent with any relevant flood evacuation strategy or similar plan.
7	The evacuation requirements of the development are to be considered up to the PMF level.
8	The evacuation requirements of the development are to be considered. An engineers report will be required if circumstances are possible where the evacuation of persons might not be achieved within the effective warning time.
9	Adequate flood warning is available to allow safe and orderly evacuation without increased reliance upon the SES or other authorised emergency services personnel.
Management and Design	
1	Applicant to demonstrate that potential development as a consequence of a subdivision proposal can be undertaken in accordance with this DCP.
2	Site Emergency Response Flood Plan required where floor levels are below the design floor level, (except for single dwelling-houses).
3	Applicant to demonstrate that area is available to store goods above the 1% AEP flood level plus 500mmfreeboard.
4	Applicant to demonstrate that area is available to store goods above the PMF level.
5	No storage of materials below the design floor level which may cause pollution or be potentially hazardous during any flood.
6	Finished land levels in new release areas shall be not less than the 1% AEP flood unless justified by site specific assessment. A surveyor's certificate will be required upon completion certifying that the final levels are not less that the required level.
Fencing	
1	Fencing within a High Flood Risk area, Boundary of Significant Flow or floodway will not be permitted except for permeable open type fences.
2	Fencing is to be constructed in a manner that does not obstruct the flow of floodwaters so as to have an adverse impact on flooding.
3	Fencing shall be constructed to withstand the forces of floodwaters or collapse in a controlled manner so as not to obstruct the flow of water, become unsafe during times of flood or become moving debris.
4	Fencing shall be constructed to withstand the forces of floodwaters.

ATTACHMENT 3

Flood Impact Assessment for the Proposed Georges Cove Marina, Moorebank (Cardno, January 2013)

Our Ref: NA49913037-L02:BCP/bcp
Contact: Dr Brett C. Phillips

29th January 2013

The Manager
npc
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Dear Mark,

FLOOD IMPACT ASSESSMENT FOR THE PROPOSED GEORGES COVE MARINA, MOOREBANK

Cardno was commissioned by npc to conduct a Flood Impact Assessment for the proposed Georges Cove Marina development in Moorebank, within the Liverpool City Council Local Government Area (LGA).

The objective of the study was to determine the flooding behaviour for the proposed Georges Cove Marina site during major flood events and to assess the impact if any of proposed development on flooding of adjacent properties.

At the request of Liverpool City Council flooding in the 20 year and 100 year Average Recurrence Interval (ARI) events has been assessed. Council was particularly concerned about the proposed marina impacting on flows during the 20 yr ARI flood into the flood storage area immediately southwest of the site and the potential increase in flood levels on adjacent properties.

1. BACKGROUND

1.1 Study Area

The Georges Cove Marina site is located on the western bank of the Georges River between Newbridge Road and the M5 motorway in the suburb of Moorebank, in south-west Sydney. The site location is shown in **Figure 1-1**.

The site covers an area of approximately 12.3 ha and is part of the Benedict Sand & Gravel (BS&G) landholding. Sand extraction activities are undertaken on the site. There are large expanses of undeveloped vegetated floodplain south of the site.

1.2 Flooding in the Georges River at Moorebank

The 2004 Georges River Floodplain Risk Management Study by Bewsher Consulting modelled the flooding behaviour for the Georges River from the upper Georges River upstream of Liverpool to Botany Bay downstream. The Study used the 1D hydraulic modelling program MIKE-11 as the basis for its flood analysis.

The following overview has been extracted from the Georges River Floodplain Risk Management Study (Bewsher Consulting, 2004) detailing various flood studies that had occurred prior to 2004:

> *Design flood levels on the Georges River are available from the Georges River Flood Study [PWD, 1991]. This study used a physical scale model of the Georges River to simulate flood conditions between Picnic Point and Liverpool.*
>
> *A number of other studies have also been undertaken to define flood conditions upstream of Liverpool and for the main tributary creeks of the Georges River. These studies include:*
>
> - *Upper Georges River Flood Study [DLWC, 1999];*
> - *Draft Cabramatta Creek Floodplain Management Study [Bewsher Consulting,1999];*
> - *Lower Prospect Creek Floodplain Management Study [Willing & Partners, 1990];*
> - *Milperra Industrial Area Hydraulic Study [Willing & Partners, 1990];*
> - *Little Salt Pan Creek Flood Study [Manly Hydraulics Laboratory, 1995];*
> - *Salt Pan Creek Flood Study [PWD, 1991];*
> - *Deadmans Creek Flood Study [DLWC, 1997].*
>
> *A single computer model of the Georges River study area was developed by Bewsher Consulting for Liverpool Council. This model has been used as part of further flood investigations for the 2004 floodplain management study.*
>
> *The Georges River MIKE-11 model was developed from various sources. The origin of the model was a MIKE-11 in-bank tidal model, which was first developed by the Public Works Department to study tidal behaviour between Liverpool and Botany Bay [PWD, 1992]. The tidal model was subsequently extended by Bewsher Consulting to incorporate the floodplain, by extending model cross sections and inserting additional overbank flow paths. A separate MIKE-11 model, developed as part of the Upper Georges River Flood Study [DLWC, 1998], was also added to the main model to extend it upstream of Liverpool (Bewsher, 2004)*

Council requested that a flood impact assessment be undertaken of the proposed development using a 2D floodplain model of the site and adjoin lands upstream and downstream of the site. Council provided a copy of the MIKE-11 model to assist in the assembly of the 2D floodplain model.

1.3 Proposed Development

The proposed development has been described in the following terms.

The proposed development of a marina is located on land zoned private and public recreation located on the western bank of the Georges River and is around 600 m due south of Newbridge Road.

The site is presently a sand extraction area located immediately south of a proposed residential area (ground level above the 100yr ARI), immediately east of the residential development in the former Boral quarry site and immediately north of a large elevated former landfill site (levels near and above the 100yr ARI). The Flower Power site also immediately to the north has been recently approved for development by Council. The residential area immediately to the north includes a high level bridge connection to the former Boral quarry site residential development which provides access to high ground above the PMF level. The marina development will have access to this bridge.

The flood levels at the site estimated from the 2004 Georges River Floodplain Risk Management Study are as follows:

20 yr ARI	RL 4.6 m AHD
100 yr ARI	RL 5.6m AHD
PMF	RL 10.2m AHD

The flood planning level is RL 6.1m AHD (100 yr ARI plus 0.5m).

The proposed marina development consists of floating berths, a dry storage facility incorporating amenities at the upper levels and a private marina club house. Importantly the buildings are located on the western edge of the site and are open structures below the flood planning level. The formation of the marina basin creates additional flood storage.

The lowest level of boat storage is above the FPL at RL 7.3 m AHD. The lowest amenities area in the boat storage building is at a level above the PMF level at RL 10.525 m AHD. The private marina club level is at the FPL of RL 6.1 m AHD. It is stated that these buildings provide minimum disruption to any flood conveyance because:

1. They are open structures below the FPL;
2. They do not extend eastwards of the major flood flow controllers either upstream or downstream of the site which are the residential area (and Flower Power) to the north and the former landfill site to the south.

A key issue is that stated presence of high ground immediately north of the proposed development (higher than the 100 yr ARI flood level) and a large elevated former landfill site (levels near and above the 100yr ARI) located immediately south of the proposed development. If this is the case then it would be expected that flooding of the proposed development in events up to the 100 yr ARI event would be primarily by the lateral discharge of floodwaters from the river into the site rather than longitudinal flood flows spilling into the site across its northern boundary and discharging through the southern boundary of the site. The lateral interchange of flow with the river would be then primarily controlled by the ground levels on the bank of the river (eastern side of the site) and the waterway opening through the river bank.

It is expected that in a PMF the site would be subject initially to lateral flows which would then become longitudinal flood flows as the flood level continues to rise above the 100 yr ARI flood level.

The development site is located between high ground upstream and downstream and it is expected that in events less than a 100 yr ARI event that the proposed development would have only local impacts on design flood levels and it is likely that these impacts would be minimal and would not have any significant impacts upstream of the site.

The proposed development has been detailed on an architectural plan view, included as **Figure 1-2**, and section views of the proposed site included as **Figure 1-3**, prepared by Michael Fountain Architects on 11th November 2010.

2. HYDRAULICS

Hydrological modelling was not required to support this assessment (with the exception of the Newbridge culverts, refer to **Section 2.2.1**) due to the availability of routed hydrographs that were obtained from Council's existing MIKE-11 models which were prepared as part of the 2004 Georges River Flood Risk Management Study.

In order to assess the spatial impact of the proposed development on flooding it was proposed to assemble a local 2D floodplain model of the development and a reach upstream and downstream of the site. The hydraulic study area is identified in **Figure 2-1**.

2.1 2D Floodplain Model

The TUFLOW 2D hydraulic model covers an area of about 744 ha. The model extends from upstream of Newbridge Road in the north to just downstream of the M5 Motorway to the south.

Digital Elevation Model

The Digital Elevation Model (DEM), which assigns elevation values to the 2D grid cells, has been mostly based on Aerial Laser Survey (ALS) data provided by Liverpool City Council on the 14th September 2012.

Generally, the accuracy of the ALS data is +/- 0.15m for vertical elevations on hard surfaces, but provides less reliable records in densely vegetated areas. ALS is unable to penetrate surface of water bodies and therefore provides no data on the bed geometry of the Georges River. Hence the Georges River bed geometry was represented in the DEM based on the 1D cross sections extracted from Council's existing MIKE-11 model. The bed and bank geometry were interpolated between cross sections to create a 2D DEM of the river bed and banks.

The base DEM is shown in **Figure 2-2**.

For assessment purposes a 2m x 2 m grid size was adopted in the TUFLOW 2D floodplain model.

Surface Roughness

Hydraulic surface roughness have been modelled in the 2D TUFLOW model using spatially distributed Manning roughness ("n") values based on aerial photography (NearMap, recorded 23/10/11). Areas of the floodplain were assigned a land-use category, with an associated roughness value as shown in **Table 2-1**.

The land-use breakdown for the study area is shown in **Figure 2-3**.

Boundary Conditions

Inflows to the local 2D floodplain model were based on routed hydrographs that were obtained from Council's existing MIKE-11 models which were prepared as part of the 2004 Georges River Flood Risk Management Study.

Table 2-1 Roughness Values for Different Landuse Categories

Land-Use Type	Manning Roughness Value
Water Body	0.040 – 0.045
Open Space	0.04
Floodplain	0.09
Environmental / Special Use	0.09
Road	0.02
Residential	0.12
Commercial	0.20
Industrial	0.20
Rockwall	0.10

There were three main inflows considered in this study:

- *Georges River:* The critical duration storm for the Georges River catchment is the 36 hour storm for both the 20 year and 100 year ARI events and is estimated to generate peak flows of approximately 1,570 m^3/s and 2,080 m^3/s respectively in the vicinity opposite Bankstown Airport (refer MIKE-11 Cross Section Chainage 10121 m).

- *Milperra Drain:* The Milperra Drain collects runoff from the suburbs of Georges Hall and Milperra and from Bankstown Airport. It flows in a westerly direction along the northern boundary of Bankstown Golf Course before turning south and flowing along the western boundary of the Bankstown Golf Course before then turning west and flowing under Henry Lawson Drive and eventually discharging into the Georges River. The peak flow for the 20 year and 100 year ARI 36 hour duration storms was calculated to be approximately 54 m^3/s and 66 m^3/s respectively (refer MIKE-11 Cross Section MD8470 m). The inflows from Milperra Drain were input in the 2D floodplain model in the vicinity of the northwestern corner of the Bankstown Golf Course.

- *Newbridge Road Drain:* There is a major stormwater outfall located on the southern side of Newbridge Road to the west of the BS&G site. The outfall comprises 4 x 0.65 m (H) x 1.75 m (W) box culverts. This is the outfall of a drainage network with unknown extents in the suburb of Chipping Norton to the north of the site. The potential peak discharge of the culverts in a 36 hour storm was estimated by assembling a broadscale DRAINS model for the estimated local catchment area. The peak discharges at the outfall in the 20 year and 100 year ARI 36 hour storms were estimated to be approximately 4 m^3/s and 5 m^3/s respectively. These minor inflows were considered negligible in comparison with the flows in the Georges River and Milperra Drain and therefore the discharge from the Newbridge Road outfall was not included in the TUFLOW hydraulic model.

The hydrograph inflow locations are shown in **Figure 2-2**.

The adopted downstream boundary conditions were the 20 and 100 year ARI water level time series obtained from Council's existing MIKE-11 model at a cross section located immediately downstream of the M5 Motorway (Chainage 14180 m).

2.1 Model Calibration

The calibration of the TUFLOW floodplain model was conducted iteratively by comparing the 100 yr ARI and 20 yr ARI flood levels predicted by the TUFLOW and 2004 MIKE-11 models by progressively adjusting the roughness values within acceptable ranges to achieve an acceptable fit to the design flood levels estimated in 2004.

A comparison of the design flood levels predicted by the 2004 MIKE-11 model and TUFLOW floodplain model is given in **Table 2-2**. Approximate locations of the MIKE-11 cross section locations are shown in **Figure 2-2**. Cross sections from chainages 11960 m to 12890 m are within the vicinity of the Georges Cove site with cross sections chainages 12330 m, 12500 m, and 12620 m are adjacent to the Georges Cove site.

It is concluded that the TUFLOW base model gives an acceptable representation of the MIKE-11 design flood with the level of agreement for the predicted 100 yr ARI flood levels being between – 0.02 m to +0.15 m and for the 20 yr ARI flood levels being between – 0.02 m to +0.15 m. In the vicinity of the proposed development the level of agreement for the predicted 100 yr ARI flood levels being between – 0.02 m to +0.02 m and for the 20 yr ARI flood levels being between – 0.01 m to +0.03 m.

Table 2-2 Comparison of Predicted Design Flood Levels (m AHD)

Cross Section Chainage (m)	MIKE-11 Peak WL Results (m AHD)		TUFLOW Peak WL Results (m AHD)		WL Difference (m) (TUFLOW Less MIKE-11)	
	20 year ARI	100 year ARI	20 year ARI	100 year ARI	20 year ARI	100 year ARI
10120	5.15	5.94	5.18	6.01	0.03	0.06
10290	5.05	5.85	5.11	5.94	0.06	0.09
10410	5.01	5.81	5.08	5.91	0.07	0.10
10590	4.96	5.78	5.05	5.89	0.09	0.11
10740	4.91	5.74	5.02	5.87	0.11	0.13
10890	4.86	5.70	4.99	5.85	0.13	0.15
10930	4.84	5.68	4.97	5.83	0.13	0.15
10970	4.78	5.65	4.93	5.80	0.15	0.15
11050	4.78	5.66	4.93	5.79	0.15	0.13
11140	4.79	5.67	4.94	5.80	0.15	0.14
11350	4.76	5.65	4.83	5.73	0.07	0.08
11650	4.76	5.65	4.79	5.69	0.04	0.05
11780	4.75	5.65	4.77	5.66	0.02	0.02
11960	4.74	5.64	4.74	5.63	-0.01	-0.01
12140	4.72	5.63	4.71	5.61	-0.01	-0.02
12330	4.70	5.60	4.70	5.59	0.00	-0.01
12500	4.64	5.54	4.67	5.57	0.03	0.02
12620	4.65	5.56	4.64	5.54	-0.01	-0.02
12890	4.59	5.50	4.58	5.49	-0.01	-0.01
13030	4.56	5.47	4.56	5.46	0.00	-0.01
13200	4.54	5.44	4.53	5.44	0.00	-0.01
13520	4.48	5.37	4.49	5.39	0.02	0.02
13820	4.39	5.29	4.39	5.30	-0.01	0.01
13960	4.35	5.25	4.33	5.24	-0.02	-0.01
14150	4.28	5.19	4.29	5.19	0.00	0.00
14180	4.28	5.18	4.28	5.18	0.00	0.00

The main differences between the predicted flood levels are attributed to the differences in floodplain storage associated with a 1D representation of the floodplain in comparison with a 2D representation of the floodplain at a far finer scale than the 1D model. It is expected that the 2D model provides a better definition of the floodplain topography and floodplain storage.

2.6 Benchmark (Pre-Development) Scenario

The calibrated benchmark pre-development model was adjusted to represent approved levels on a number of sites located within the study area as follows:

- There are a number of current developments near the Georges Cove site which have the potential to impact on the hydraulics of the study area. Liverpool City Council advised npc that the future finished levels of the Flower Power site, and northern portion of the BS&G site would be 6.3 m AHD. These two sites were raised to these levels in the benchmark scenario.

- There is also a residential development proposed to the west of the Georges Cove site which was flood affected in the initial TUFLOW model (refer to **Figure 2-4**). It was assumed that the landform would be modified such that there will be is no inundation on the development in either the 20 year or the 100 year ARI events.

- Following discussion with Liverpool City Council it was agreed that the levels of the Georges Cove site in the benchmark model should represent the likely rehabilitated site topography following works to remove the existing lakes and material stockpiles from the site.

  The pre-development site includes an environmental protection zone on the eastern side of the site incorporated within a 40 m riparian zone along the bank of the Georges River. The pre-development level of this area is around 1.9 m AHD and was assumed to be represented by a hydraulic roughness of 0.04. The remainder of the site is subject to a rehabilitation consent condition that requires finished levels of between 1.6 m AHD – 1.7m AHD. This area was treated as cleared land with a hydraulic roughness of 0.04.

The changes to the pre-development study area are summarised in **Figure 2-4**, the pre-development DEM is shown in **Figure 2-5**, and the pre-development land-use / roughness map is shown in **Figure 2-6**.

2.7 Post-Development Scenario

The benchmark floodplain model was subsequently modified to represent planned development site as detailed on an architectural plan view, included as **Figure 1-2**, and section views of the proposed site included as **Figure 1-3**, prepared by Michael Fountain Architects on 11th November 2010.

The main features of the proposed development are as follows:

- A marina basin located in the middle of the site with an assumed an invert level of -3.5m AHD for the marina and a hydraulic roughness of 0.04;
- A series of wetlands with a finished level of 0.6m AHD, and vegetated areas with a finished level of 1.9 m AHD located along the eastern side of the site located within the 40 m wide riparian zone of the Georges River, with an adopted hydraulic roughness of 0.09;
- A car park in the north-west corner of the site raised to 4.7 m AHD with an adopted hydraulic roughness of 0.02;

- A proposed 6 storey building on the western side of the site with car parking on the ground floor at 4.7 m AHD which is suspended above a 1.65 m AHD finished ground level at the southern end of the building, with a hydraulic roughness of 0.12; and
- A lower car park located on the southern side of the site with a ground level of at 1.65 m AHD and a hydraulic roughness of 0.02.

The post-development DEM is shown in **Figure 2-7**, the post-development land-use / roughness map included as **Figure 2-8**, and a comparison of the levels adopted in the pre-development and post-development DEMs has been included in **Figure 2-9**.

A post-development building blockage sensitivity analysis was also assessed. The sensitivity analysis was based on the assumption that the area under the southern side of the building will be 50% blocked during a rainfall event by debris and other objects. The blockage scenario sensitivity analysis DEM is shown in **Figure 2-10**. A comparison of the levels adopted in the pre-development and post-development DEMs for this option has been included in **Figure 2-11.**

3. FLOOD IMPACT ASSESSMENT

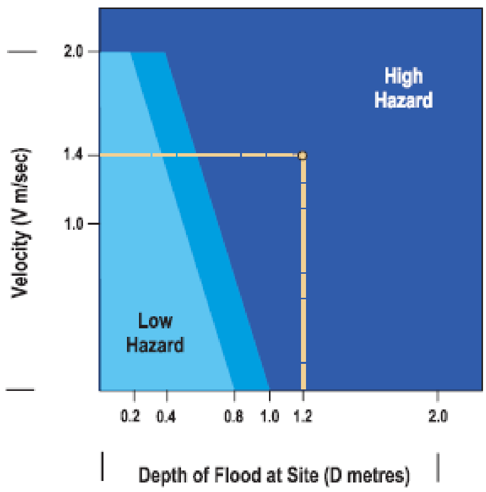
3.1 Pedestrian and Vehicular Stability

When considering pedestrian and vehicular stability, three velocity x depth criteria were identified as follows:

Velocity x Depth	Comment
≤ 0.4 m^2/s	This is typically adopted by Councils as a limit of stability for pedestrians
0.4 – 0.6 m^2/s	Unsafe for pedestrians but safe for vehicles if overland flood depths do not exceed around 0.3 m
> 0.6 m^2/s	This is typically adopted by Councils as a limit of stability for vehicles

3.2 Flood Hazards

Experience from studies of floods throughout NSW and elsewhere has allowed authorities to develop methods of assessing the hazard to life and property on floodplains. This experience has been used in developing the NSW Floodplain Development Manual to provide guidelines for managing this hazard. These guidelines are shown schematically below.



Provisional Hazard Categories
(after Figure L2, NSW Government, 2005)

To use the diagram, it is necessary to know the average depth and velocity of floodwaters at a given location. If the product of depth and velocity exceeds a critical value (as shown below), the flood flow will create a **high hazard** to life and property. There will probably be danger to persons caught in the floodwaters, and possible structural damage. Evacuation of persons would be difficult. By contrast, in **low hazard** areas people and their possessions can be evacuated safely by trucks. Between the two categories a transition zone is defined in which the degree of hazard is dependent on site conditions and the nature of the proposed development. This calculation leads to a provisional hazard rating. The provisional hazard rating may be modified by consideration of effective flood warning times, the rate of rise of floodwaters, duration of flooding and ease or otherwise of evacuation in times of flood.

3.3 Benchmark Conditions

The estimated 20 yr ARI flood levels, depths, velocities, velocity x depth and hazards under benchmark conditions are plotted in **Figures 3-1, 3-2, 3-3, 3-4** and **3-5** respectively.

The estimated 100 yr ARI flood levels, depths, velocities, velocity x depth and hazards under benchmark conditions are plotted in **Figures 3-6, 3-7, 3-8, 3-9** and **3-10** respectively.

It was concluded that:

- Peak flow velocities across the site are low;
- Velocities in the floodplain southwest of the site are even lower; and that
- The floodplain southwest of the site is flood storage in floods up to the 100 yr ARI event.

3.4 Post-Development Conditions

Two development scenarios were assessed as follows:

- Development of the Georges Cove site as given in **Figure 2-7** with no blockage factor applied under Marina building
- Development of the Georges Cove site as given in **Figure 2-10** with a 50% blockage factor applied under Marina building

The estimated 20 yr ARI flood levels, depths, velocities, velocity x depth and hazards under the Post-development conditions are plotted in **Figures 3-11, 3-12, 3-13, 3-14** and **3-15** respectively.

The estimated 100 yr ARI flood levels, depths, velocities, velocity x depth and hazards under the Post-development conditions are plotted in **Figures 3-16, 3-17, 3-18, 3-19** and **3-20** respectively.

The estimated 20 yr ARI flood levels, depths, velocities, velocity x depth and hazards under Post-development – blockage conditions are plotted in **Figures 3-21, 3-22, 3-23, 3-24** and **3-25** respectively.

The estimated 100 yr ARI flood levels, depths, velocities, velocity x depth and hazards under Post-development – blockage conditions are plotted in **Figures 3-26, 3-27, 3-28, 3-29** and **3-30** respectively.

4. FLOOD IMPACT ASSESSMENT

4.1 Post-development Condition

The post-development condition represents the marina as proposed in the applicant's Development Application.

The flood level differences in a 20 Yr ARI and 100 yr ARI events for Post-development Conditions are plotted in **Figures 4-1** and **4-2** respectively. The flood velocity differences in a 20 Yr ARI and 100 yr ARI events for Post-development Conditions are plotted in **Figures 4-5** and **4-6** respectively.

In a 20 yr ARI flood it was assessed that the planned development would locally reduce the 20 yr ARI flood levels west of the site by up to 0.03 m while a small local increase would occur in the entry channel to the marina. This local increase is confined to the waterway and does not impact on any other property. Similarly in the 100 yr ARI flood it was assessed that the planned development would locally reduce the 100 yr ARI flood levels southwest of the site by up to 0.03 m while a small local increase would occur in the entry channel to the marina and within the site. These local increases do not impact on any other property.

In the 20 yr ARI flood the peak velocity within the site of up to around 0.9 m/s occurs locally in the southern car park (Car Park B in Figure 1-2) while in the 100 yr ARI flood the peak velocity in this area increase to around 1.0 m/s.

In the 20 yr ARI flood and the 100 yr ARI flood the planned development reduces peak velocities within the site waterways and adjoining areas by greater than 0.04 m/s while in the south-west corner of the site the peak velocity is increased by up to 0.04 m/s. The peak velocity in the Newbridge Road drainage corridor increases by up to 0.04 m/s in the 20 yr ARI flood and the 100 yr ARI flood. The peak velocity in the majority of the land south-west of the site decreases by up to 0.04 m/s or more in the 20 yr ARI flood and the 100 yr ARI flood.

In a 20 yr ARI flood and the 100 yr ARI flood the impact of the planned development on peak velocity x depth is negligible except where the local raising of the ground levels to 4.7 m AHD eliminates the velocity x depth in comparison with pre-development conditions.

On the landform raised to 4.7 m AHD the velocity x depth under the building and in the elevated car park (Car Park C in Figure 1-2) is around 0.6 m^2/s in the 100 yr ARI flood (ie. the stability limit for vehicles).

In a 20 yr ARI event the impact of the planned development on flood hazard is negligible except where planned raising of the ground level on the western side of the site eliminates the flood hazard while in the 100 yr ARI flood the impact of the planned development on flood hazard is negligible.

It is concluded that the proposed development has negligible impact on the behaviour of flooding in the flood storage area located southwest of the proposed marina and nil or negligible impacts on any other adjacent properties.

4.2 Post-development – Blockage Scenario

This option blocks around 50% of the undercroft under the marina building further to the south. The flood level differences in a 20 yr ARI and 100 yr ARI events for the blockage scenario are plotted in **Figures 4-3** and **4-4** respectively. The flood velocity differences in a 20 Yr ARI and 100 yr ARI events for Post-development Conditions are plotted in **Figures 4-7** and **4-8** respectively

In a 20 yr ARI flood it was assessed that the partial blockage planned development would locally reduce the 20 yr ARI flood levels west of the site by up to 0.02 m while a small local increase would occur in the entry channel to the marina. This local increase is confined to the waterway and does not impact on any other property. Similarly in the 100 yr ARI flood it was assessed that the planned development would locally reduce the 100 yr ARI flood levels southwest of the site by up to 0.03 m while a small local increase would occur in the entry channel to the marina and within the site. While the local impact within the site is greater than under the nil blockage scenario these local increases do not impact adversely on any other property.

In the 20 yr ARI flood and the 100 yr ARI flood the planned development with partial blockage reduces peak velocities within the site waterways and adjoining areas by greater than 0.04 m/s while in the south-west corner of the site the peak velocity is increased by up to 0.04 m/s. The peak velocity in the Newbridge Road drainage corridor increases by up to 0.04 m/s in the 20 yr ARI flood and the 100 yr ARI flood. The peak velocity in the majority of the land south-west of the site decreases by up to 0.04 m/s or more in the 20 yr ARI flood and the 100 yr ARI flood.

In a 20 yr ARI flood the impact of the planned development and partial blockage on peak velocity x depth is negligible except where the local raising of the ground levels to 4.7 m AHD eliminates peak velocity x depth in comparison with pre-development conditions. In the 100 yr ARI flood planned development and partial blockage creates a zone of higher velocity x depth on the northwestern corner of the site.

In a 20 yr ARI event the impact of the planned development and partial blockage on flood hazard is negligible except where planned raising of the ground level on the western side of the site eliminates the flood hazard while in the 100 yr ARI flood the impact of the planned development and partial blockage on flood hazard is negligible.

5. CONCLUSIONS

The main features of the proposed development are as follows:

- A marina basin located in the middle of the site with an assumed an invert level of -3.5m AHD for the marina and a hydraulic roughness of 0.04;
- A series of wetlands with a finished level of 0.6m AHD, and vegetated areas with a finished level of 1.9 m AHD located along the eastern side of the site located within the 40 m wide riparian zone of the Georges River, with an adopted hydraulic roughness of 0.09;
- A car park in the north-west corner of the site raised to 4.7 m AHD with an adopted hydraulic roughness of 0.02;
- A proposed 6 storey building on the western side of the site with car parking on the ground floor at 4.7 m AHD which is suspended above a 1.65 m AHD finished ground level at the southern end of the building, with a hydraulic roughness of 0.12; and
- A lower car park located on the southern side of the site with a ground level of at 1.65 m AHD and a hydraulic roughness of 0.02.

The post-development DEM is shown in **Figure 2-7** while the post-development land-use / roughness map included as **Figure 2-8**. A post-development with 50% blockage of the undercroft was also assessed.

5.1 Post Development

It was concluded from the assessment of Post Development Conditions that:

(i) In a 20 yr ARI flood the planned development would locally reduce the 20 yr ARI flood levels west of the site by up to 0.03 m while a small local increase would occur in the entry channel to the marina.

(ii) Similarly in the 100 yr ARI flood the planned development would locally reduce the 100 yr ARI flood levels southwest of the site by up to 0.03 m while a small local increase would occur in the entry channel to the marina and within the site.

(iii) The local increases in 20 yr ARI and 100 yr ARI are in a very limited area only and do not impact on any other property;

(iv) In the 20 yr ARI flood and the 100 yr ARI flood the planned development reduces peak velocities within the site waterways and adjoining areas by greater than 0.04 m/s while in the south-west corner of the site the peak velocity is increased by up to 0.04 m/s;

(v) The peak velocity in the Newbridge Road drainage corridor increases by up to 0.04 m/s in the 20 yr ARI flood and the 100 yr ARI flood while the peak velocity in the majority of the land south-west of the site decreases by up to 0.04 m/s or more in the 20 yr ARI flood and the 100 yr ARI flood;

(vi) In a 20 yr ARI flood the velocity x depth on land southwest of the site is reduced in some areas while in the 100 yr ARI flood the impact of the planned development on peak velocity x depth is negligible except where the local raising of the ground levels to 4.7 m AHD eliminates the velocity x depth in comparison with pre-development conditions;

(vii) On the landform raised to 4.7 m AHD the velocity x depth under the building and in the elevated car park (Car Park C in Figure 1-2) is around 0.6 m2/s in the 100 yr ARI flood (ie. the stability limit for vehicles).

(viii) In a 20 yr ARI event the impact of the planned development on flood hazard is negligible except where planned raising of the ground level on the western side of the site eliminates the flood hazard while in the 100 yr ARI flood the impact of the planned development on flood hazard is negligible; and

(ix) The proposed development has negligible impact on the behaviour of flooding in the flood storage area located southwest of the proposed marina and nil or negligible impacts on any other adjacent properties.

5.2 Post Development with Blockage

It was concluded from the assessment of Post Development conditions with 50% blockage of the undercroft that:

(i) In a 20 yr ARI flood the planned development would locally reduce the 20 yr ARI flood levels west of the site by up to 0.02 m while a small local increase would occur in the entry channel to the marina.

(ii) Similarly in the 100 yr ARI flood the planned development would locally reduce the 100 yr ARI flood levels southwest of the site by up to 0.03 m while a small local increase would occur in the entry channel to the marina and within the site.

(iii) The local increases in 20 yr ARI and 100 yr ARI are in a very limited area only and do not impact on any other property;

(iv) In the 20 yr ARI flood and the 100 yr ARI flood the planned development with partial blockage reduces peak velocities within the site waterways and adjoining areas by greater than 0.04 m/s while in the south-west corner of the site the peak velocity is increased by up to 0.04 m/s;

(v) The peak velocity in the Newbridge Road drainage corridor increases by up to 0.04 m/s in the 20 yr ARI flood and the 100 yr ARI flood while the peak velocity in the majority of the land south-west of the site decreases by up to 0.04 m/s or more in the 20 yr ARI flood and the 100 yr ARI flood;

(vi) In a 20 yr ARI flood the impact of the planned development with partial blockage on peak velocity x depth is minor except where the local raising of the ground levels to 4.7 m AHD eliminates the peak velocity x depth in comparison with pre-development conditions;

(vii) In the 100 yr ARI flood the impact of the planned development with partial blockage on peak velocity x depth is negligible except where the local raising of the ground levels to 4.7 m AHD reduces significantly the peak velocity x depth in comparison with pre-development conditions;

(viii) In a 20 yr ARI event the impact of the planned development with partial blockage on flood hazard is negligible except where planned raising of the ground level on the western side of the site eliminates the flood hazard while in the 100 yr ARI flood the impact of the planned development on flood hazard is negligible.

(ix) The proposed development with partial blockage has negligible impact on the behaviour of flooding in the flood storage area located southwest of the proposed marina and nil or negligible impacts on any other adjacent properties.

Yours faithfully

Brett C. Phillips

………………………………

Dr Brett C. Phillips
Director, Water Engineering
for **Cardno**

Cardno

Georges Cove
Flood Impact Assessment

Figure 1-1
Subject Site

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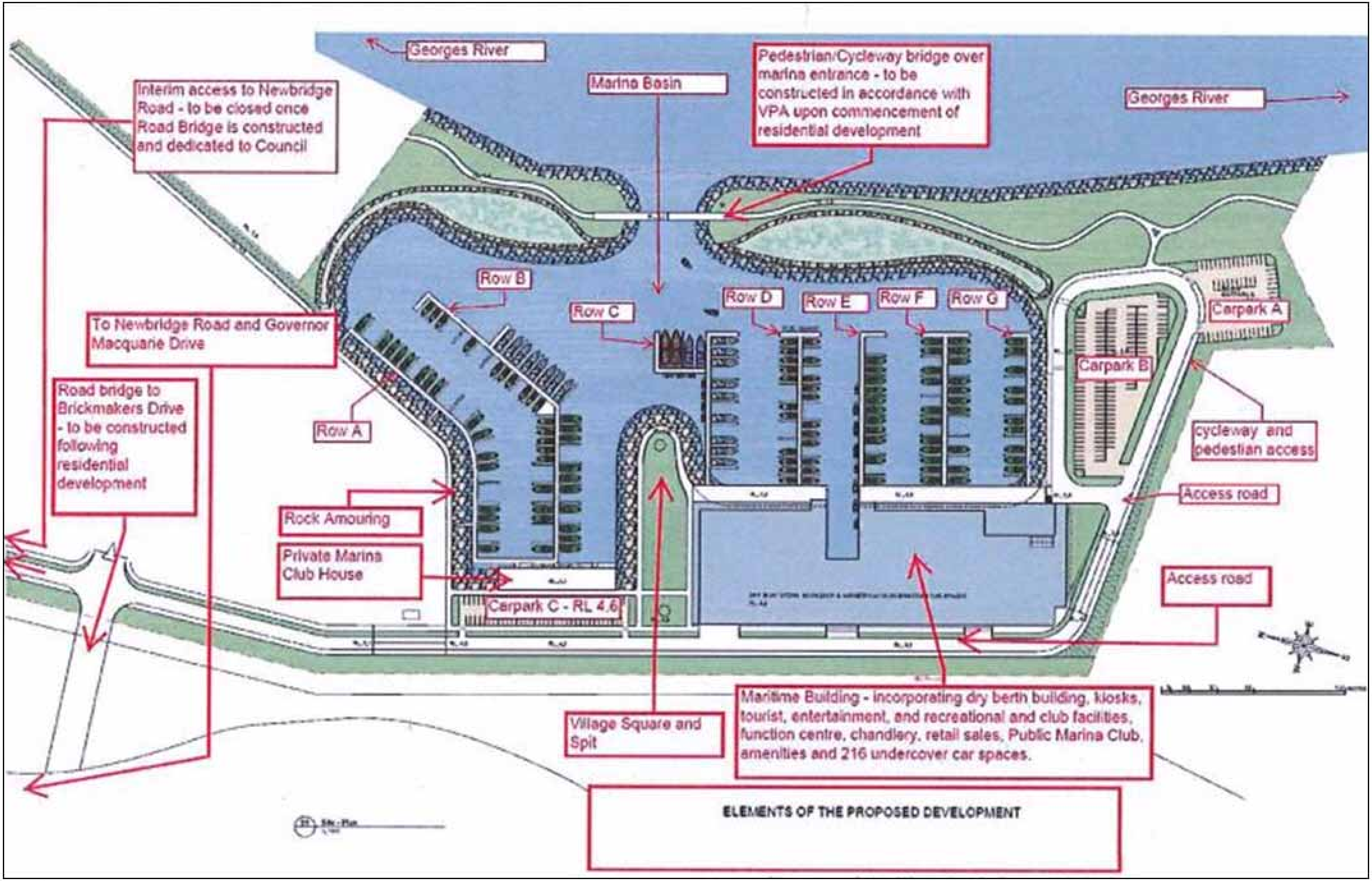
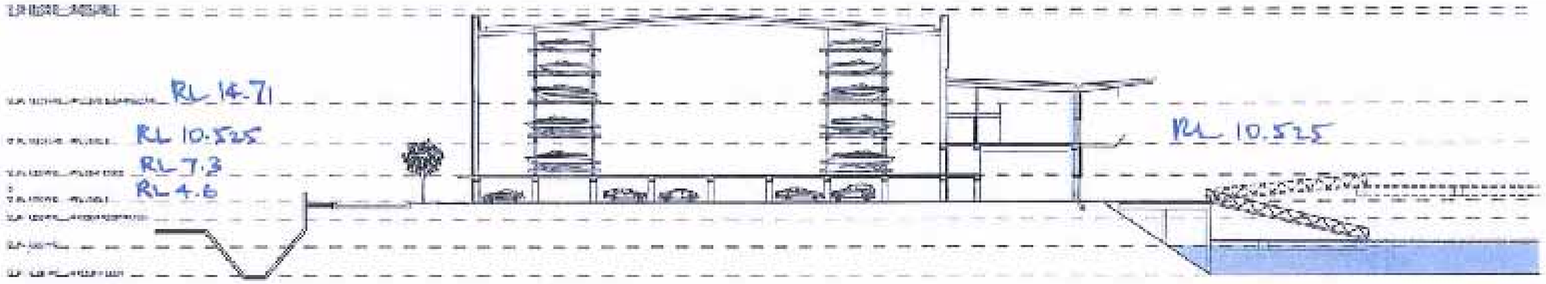


Figure 1-2
Proposed Development
Plan View

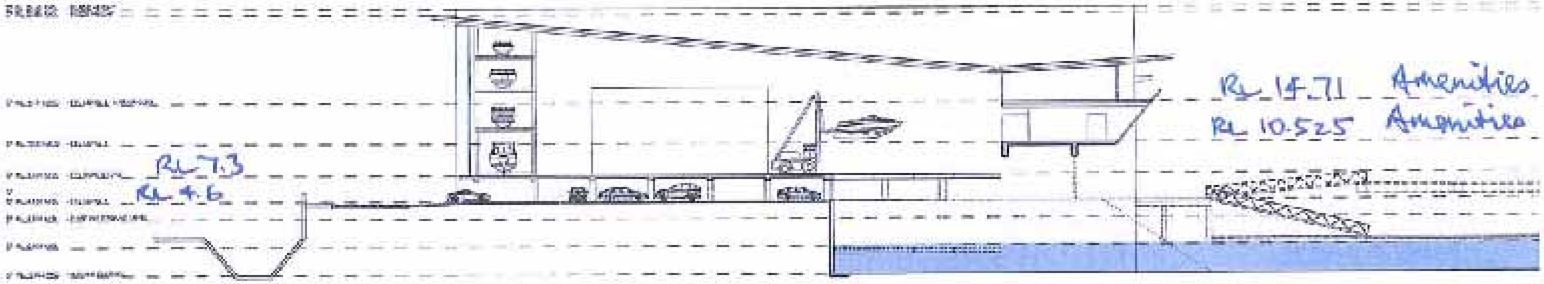
According to Flood Consultant Worley Parsons:
the 1 in 100 year floor level is 5.6 AHD
the flood planning level is 6.1 AHD,
all habitable development should be at or above this level.

We have therefore assumed the following levels.

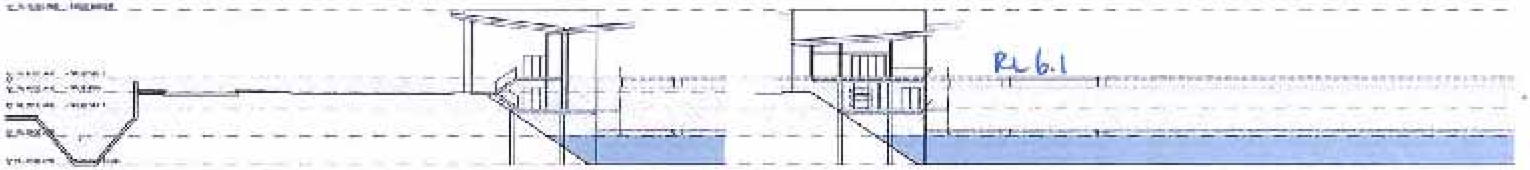
6.10	Commercial spaces, dry berth stores and the hardstand
4.60	Dry store carpark and Northern car park
2.8	Southern car park
0.98	Higher high water springs
	(All levels are AHD)



Section - Dry Berth Store



Section - Dry Berth Store



Sections - Private Marina Clubhouse

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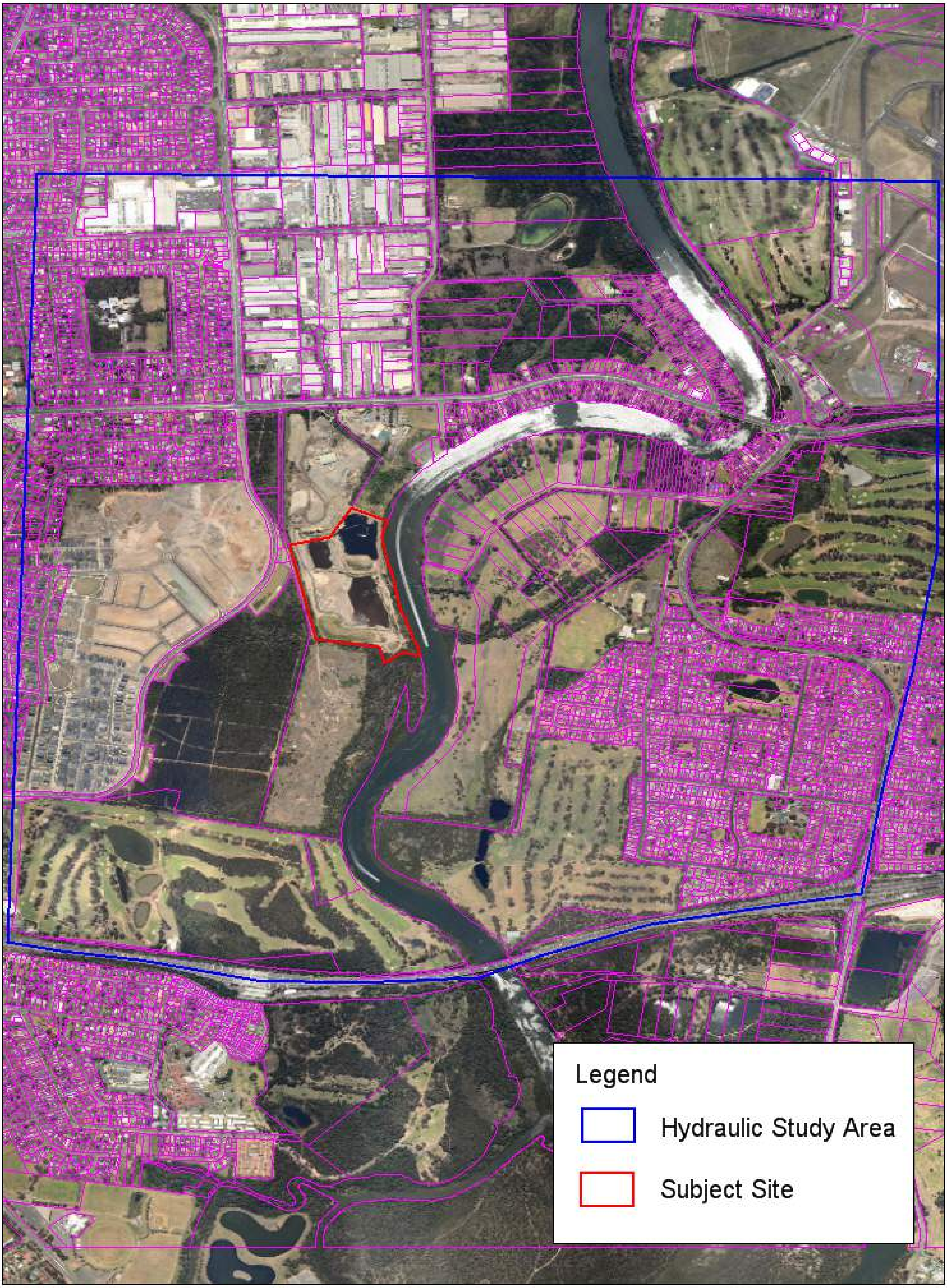
Web: www.mfa.com.au

Issue:
TO CLIENT
Date:
11th November 2010

Project:
GEORGES COVE MARINA
NEWBRIDGE ROAD, MOOREBANK
Client:
BENEDICT INDUSTRIES PTY LTD

georges cove marina



Georges Cove
Flood Impact Assessment

Figure 2-1
Hydraulic Study Area

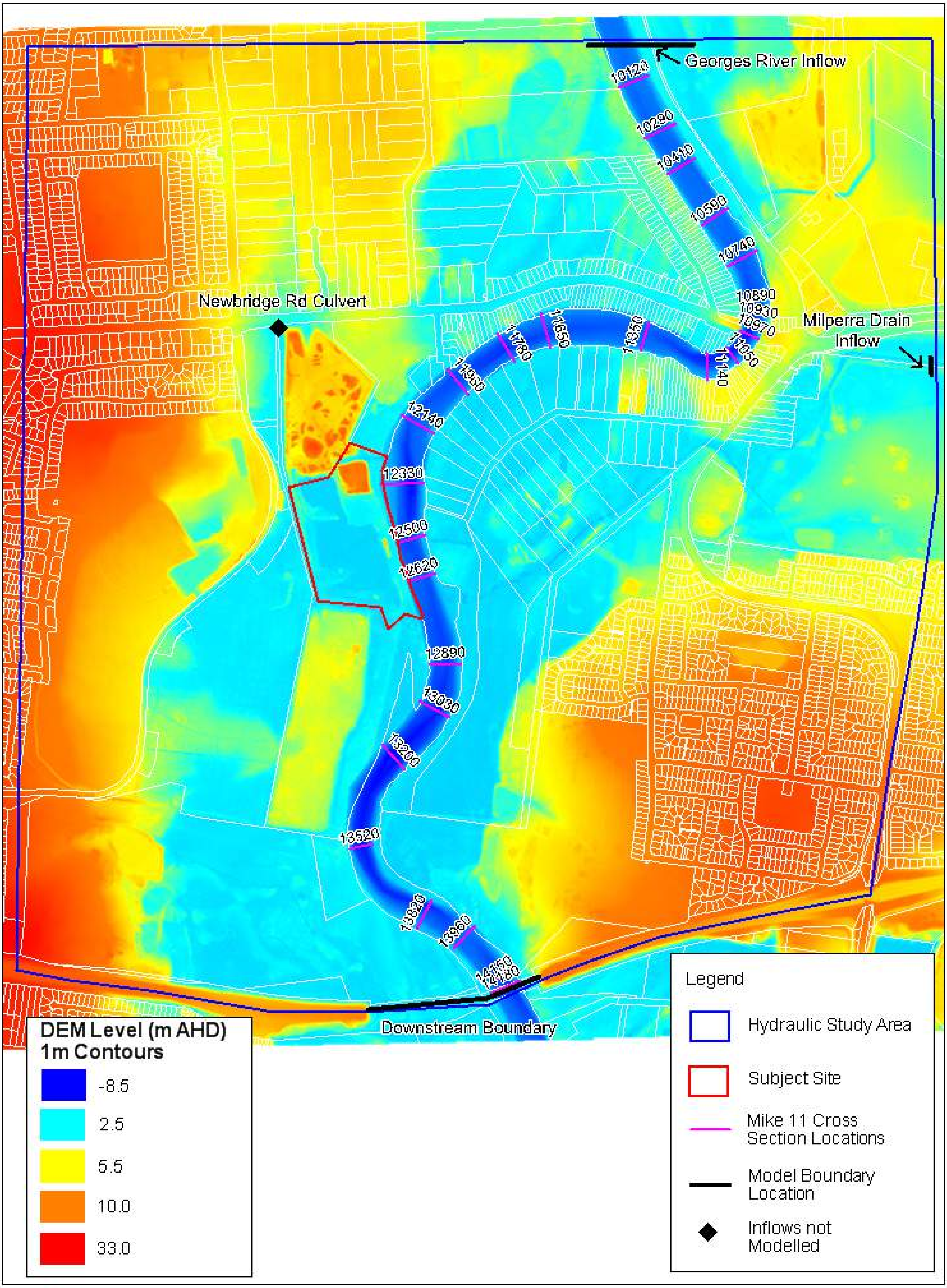


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Figure 2-2
Base Model Set-up

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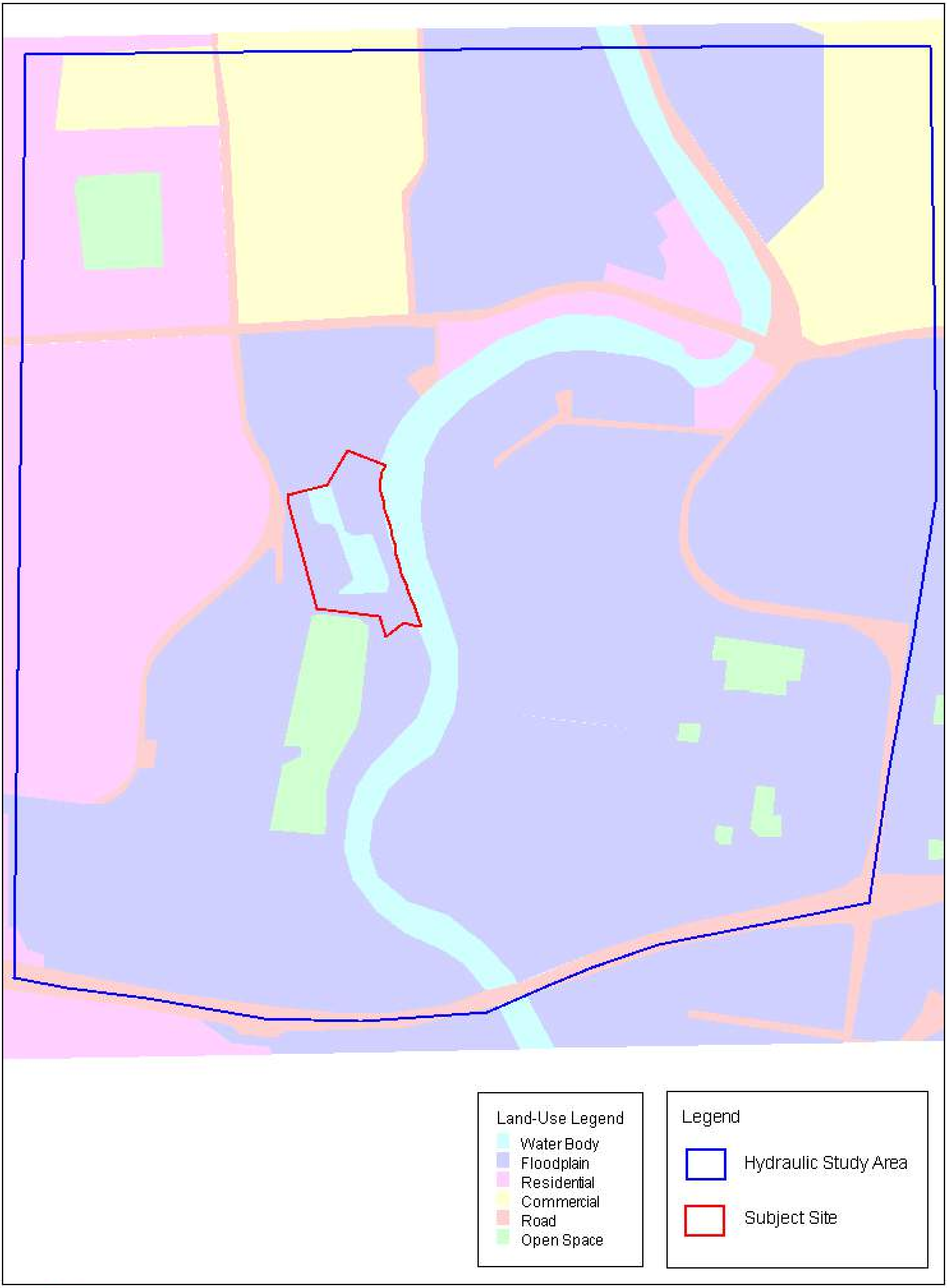

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Figure 2-3
Land-Use

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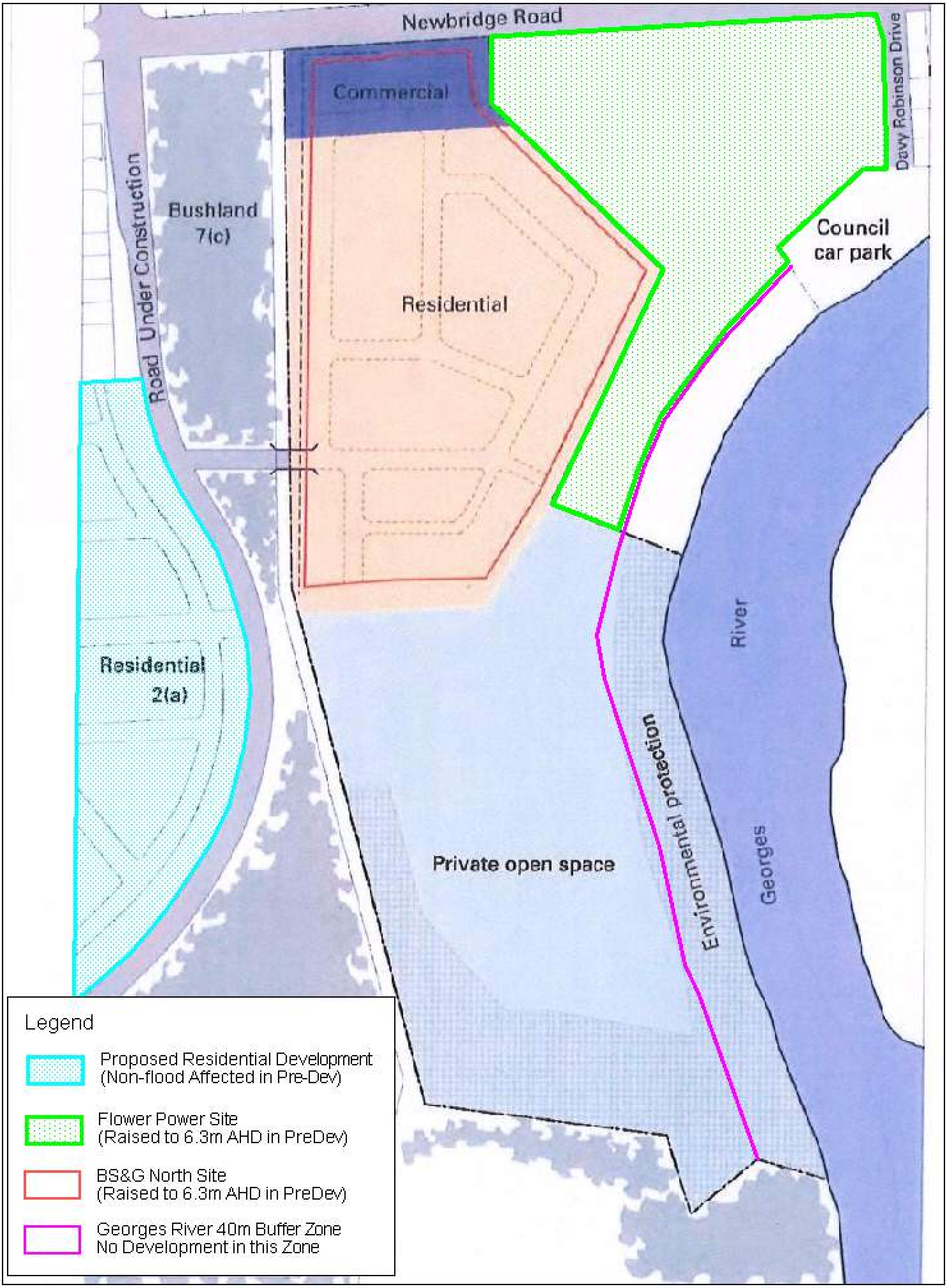

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Figure 2-4
Pre-Development Scenario
Development in the Vicinity
of the Site

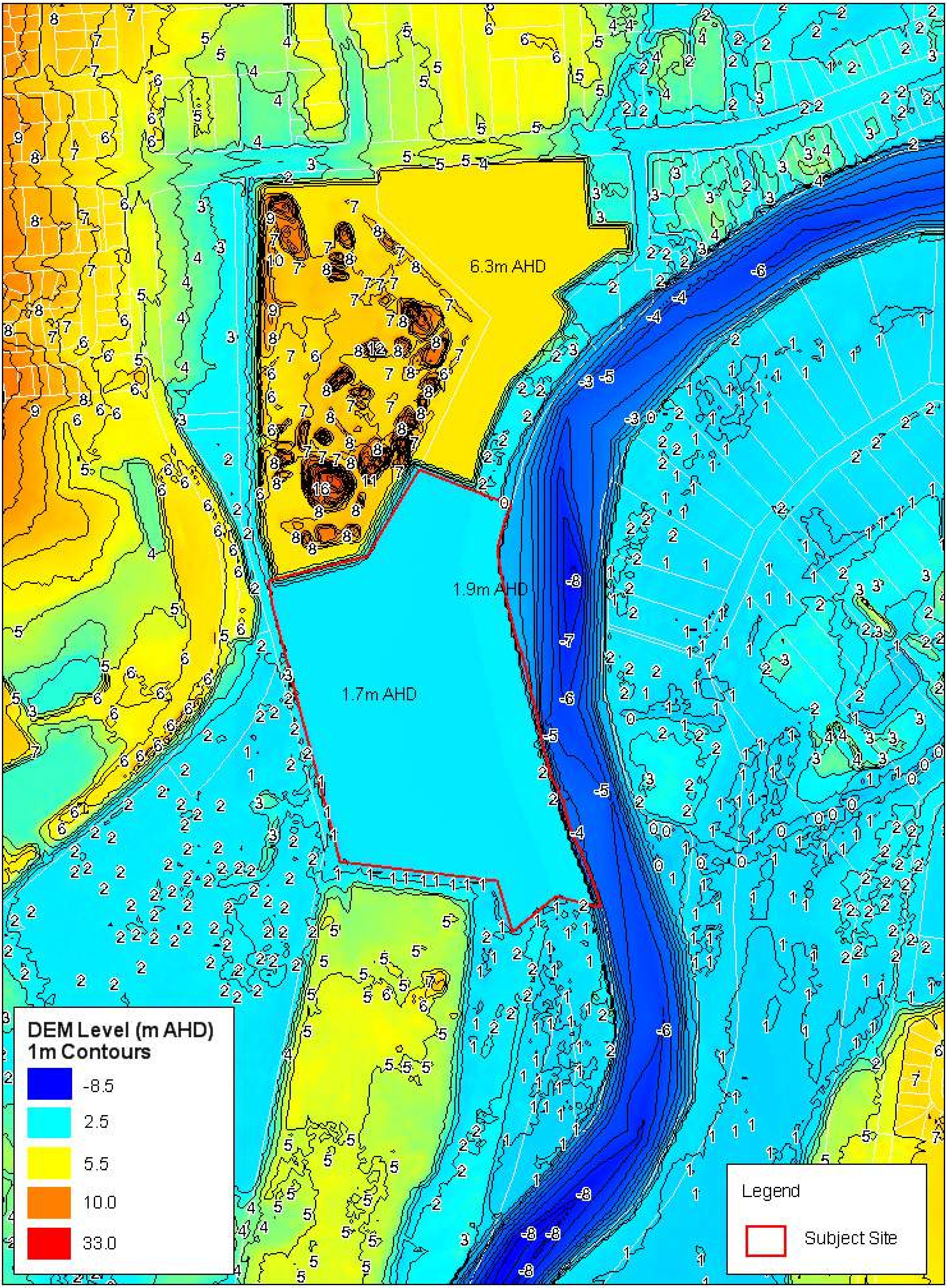

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Figure 2-5
Benchmark (Pre-Development) DEM

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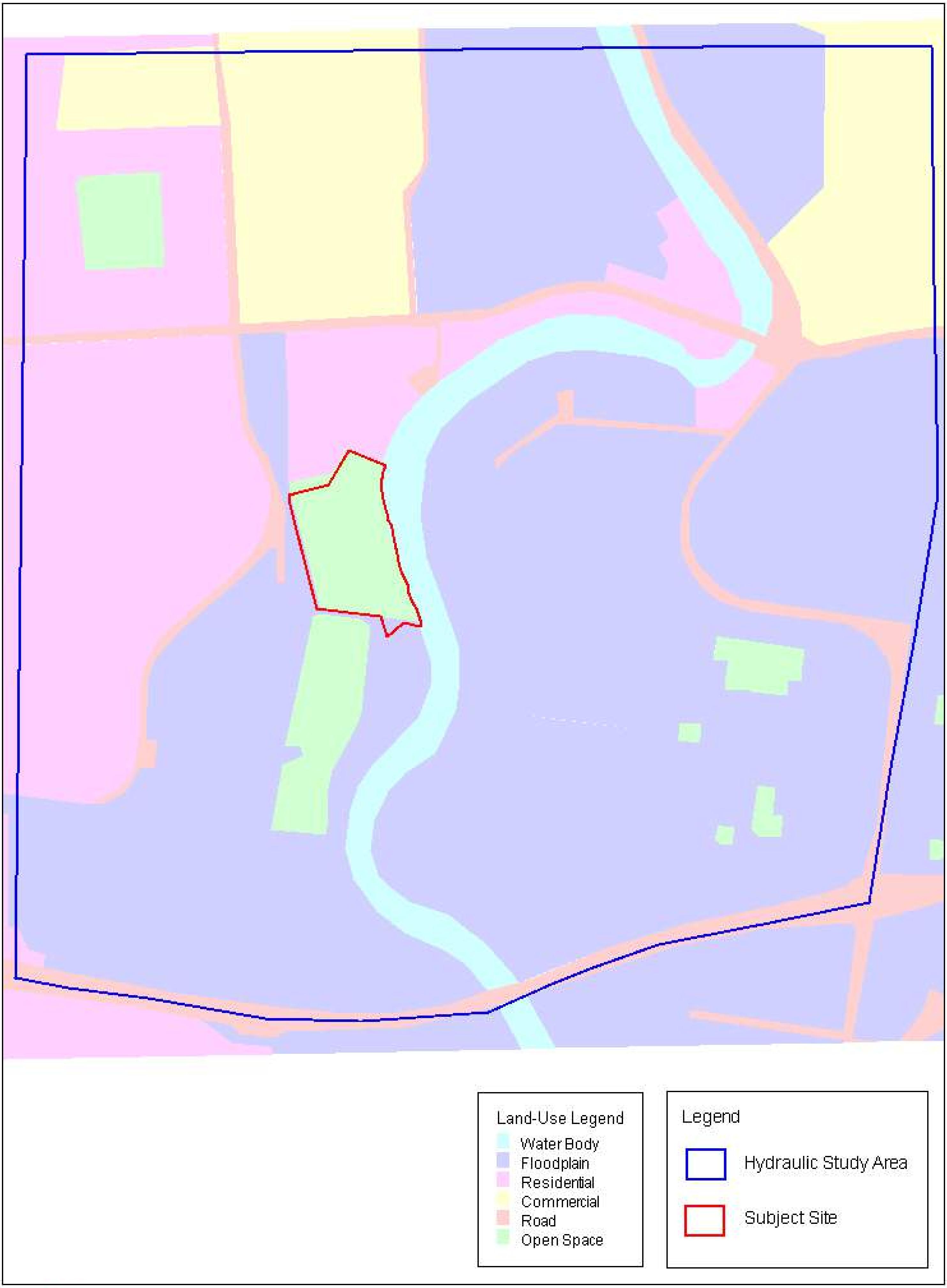

Land-Use Legend
Water Body
Floodplain
Residential
Commercial
Road
Open Space
Legend
Hydraulic Study Area
Subject Site

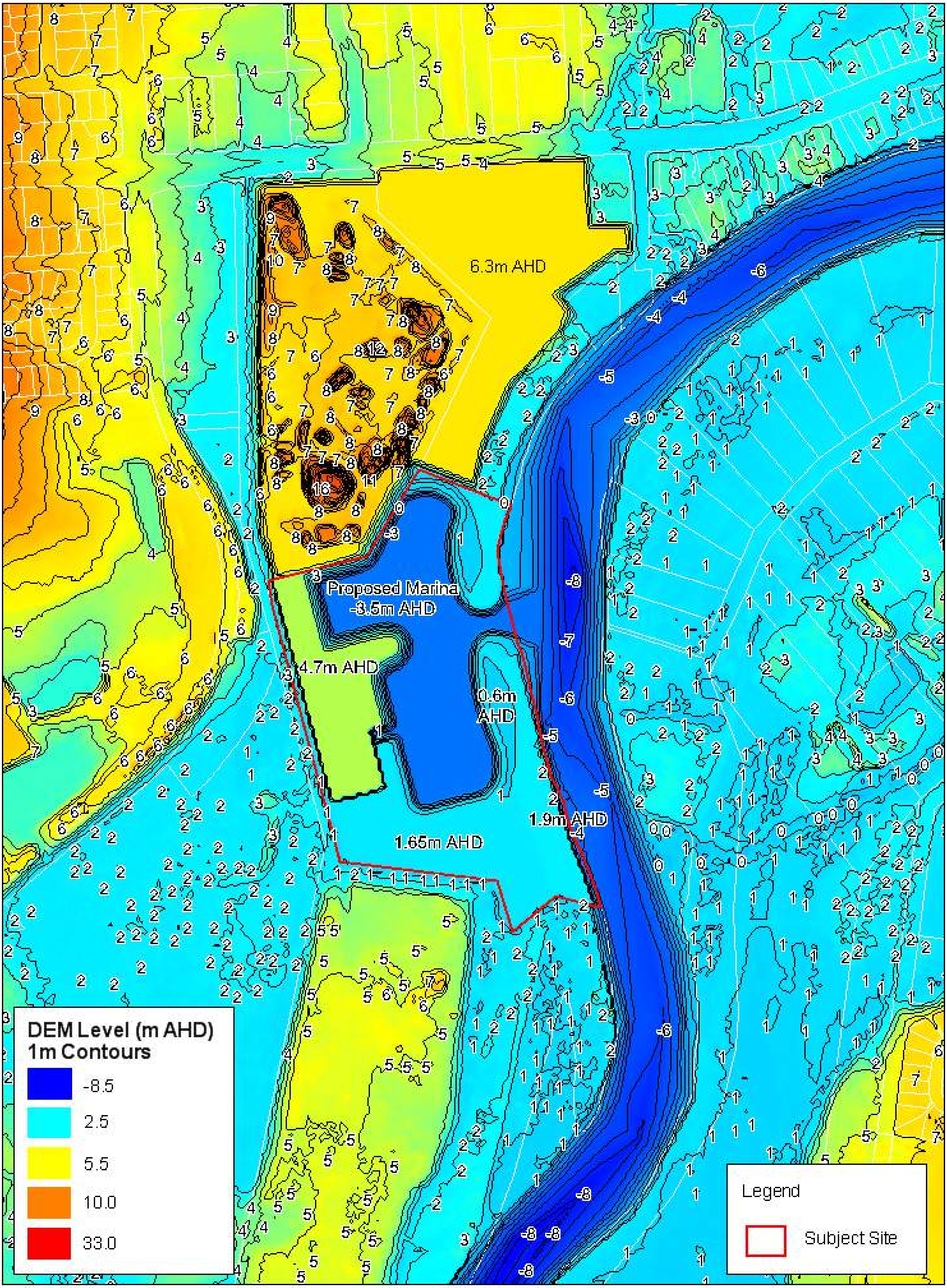

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Figure 2-7
DEM
Post-Development

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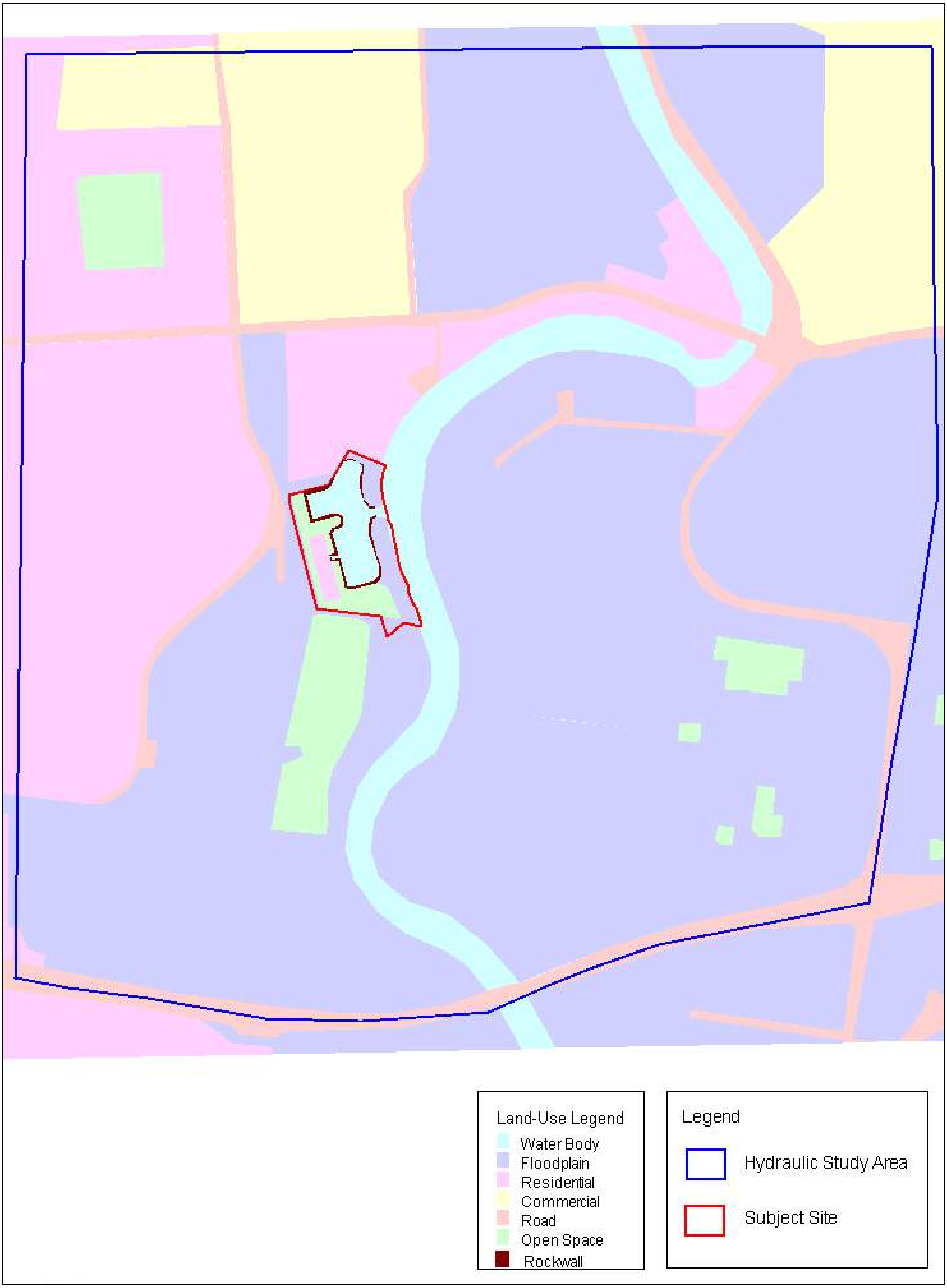

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Figure 2-8
Land-Use
Post-Development

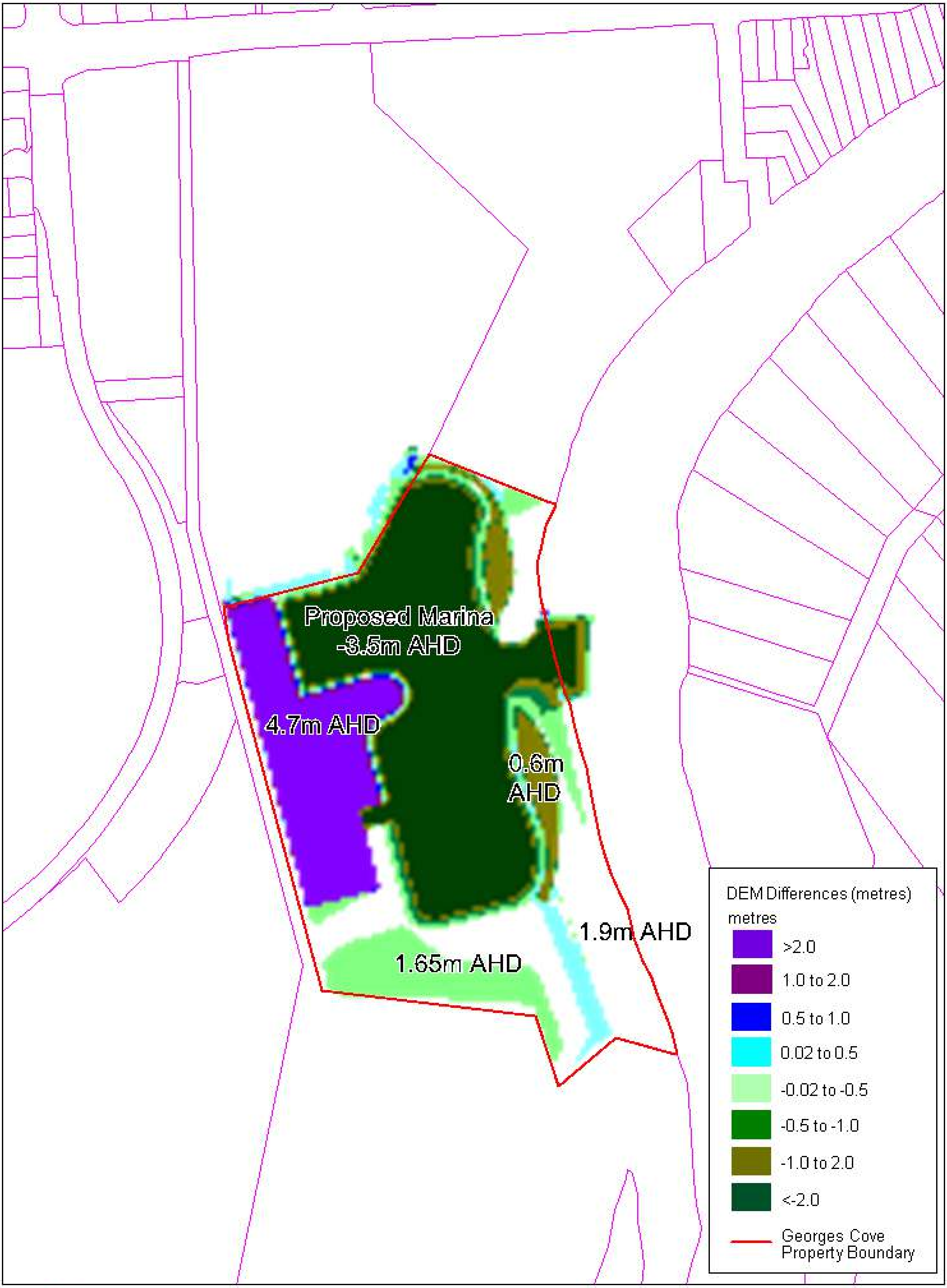

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Figure 2-9
DEM Difference
Post-development Less Predevelopment

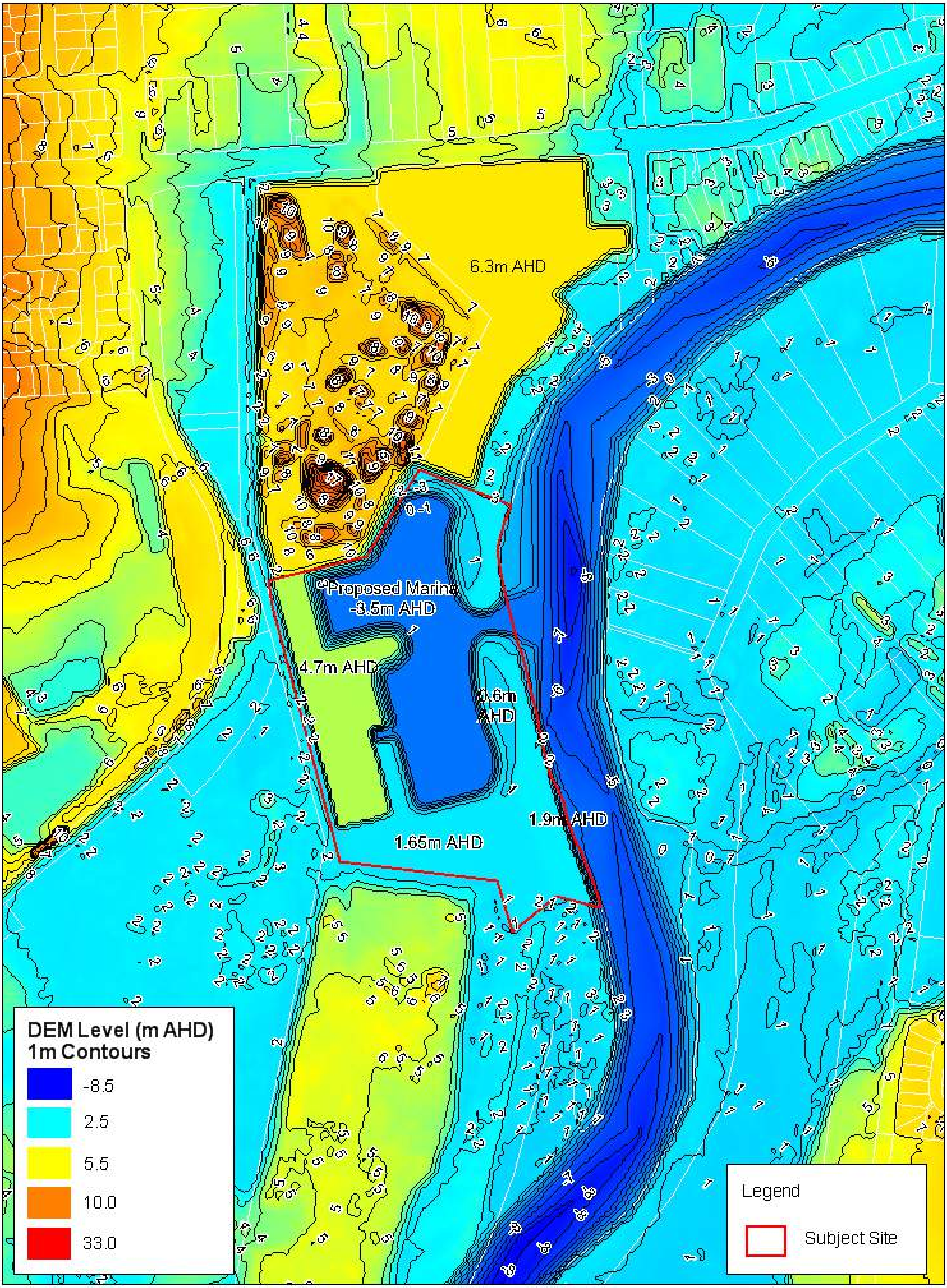

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Figure 2-10
DEM
Post-Development-Blockage

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January 2013

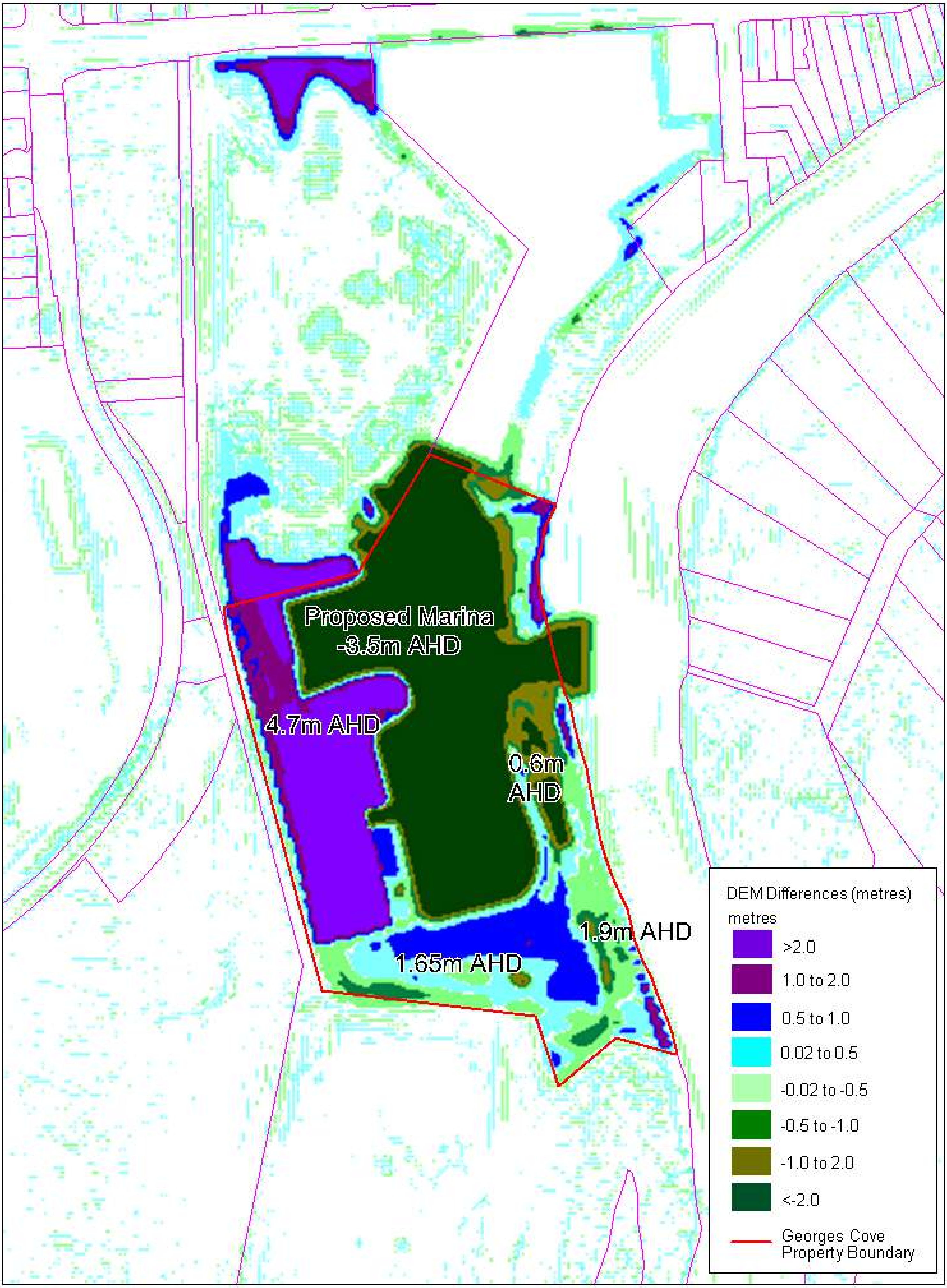

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Figure 2-11
DEM Difference
Post-development-Blockage Less Predevelopment

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January 2013

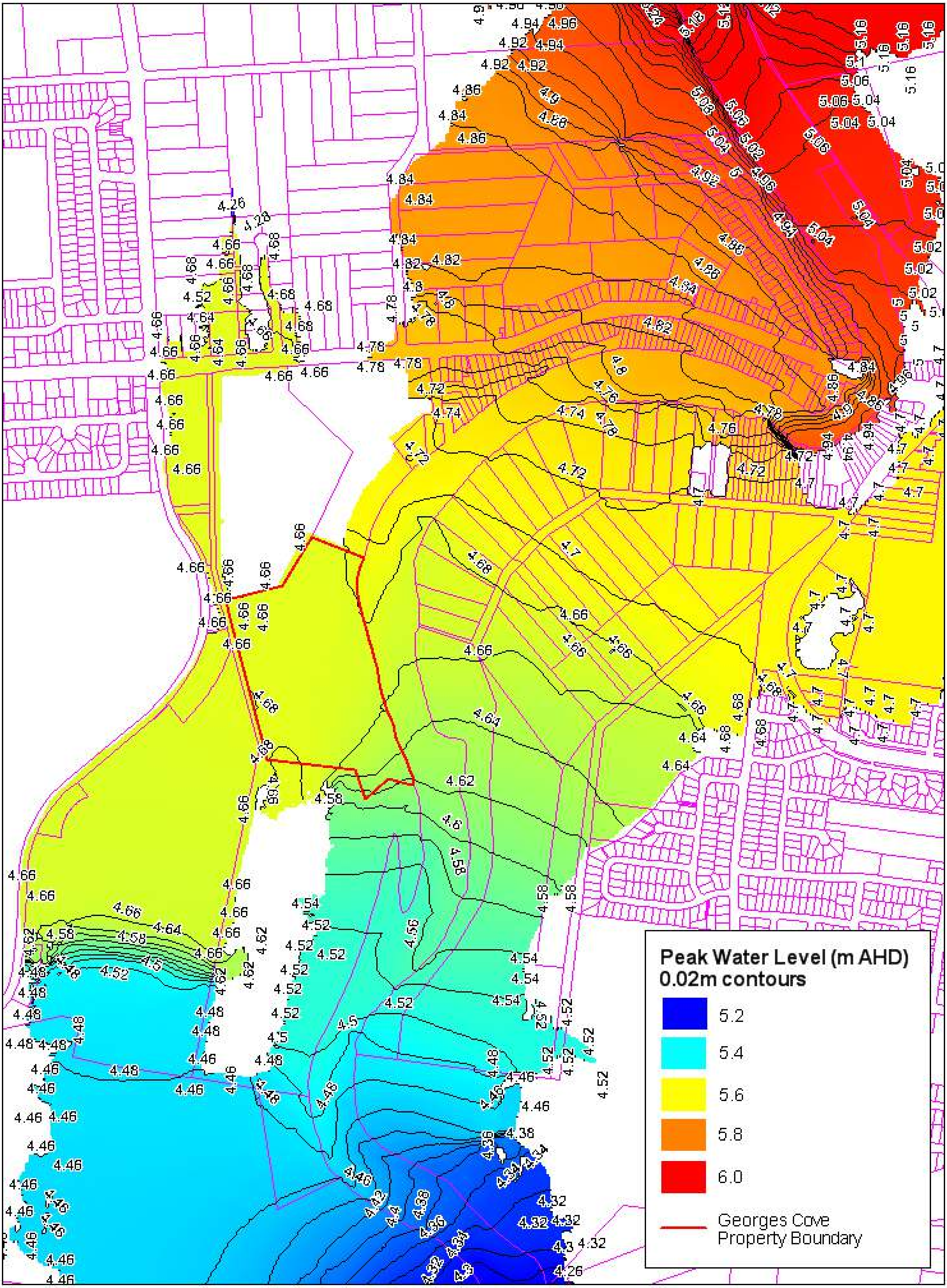

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Figure 3-1
20 year ARI
Peak Water Level
Pre-Development

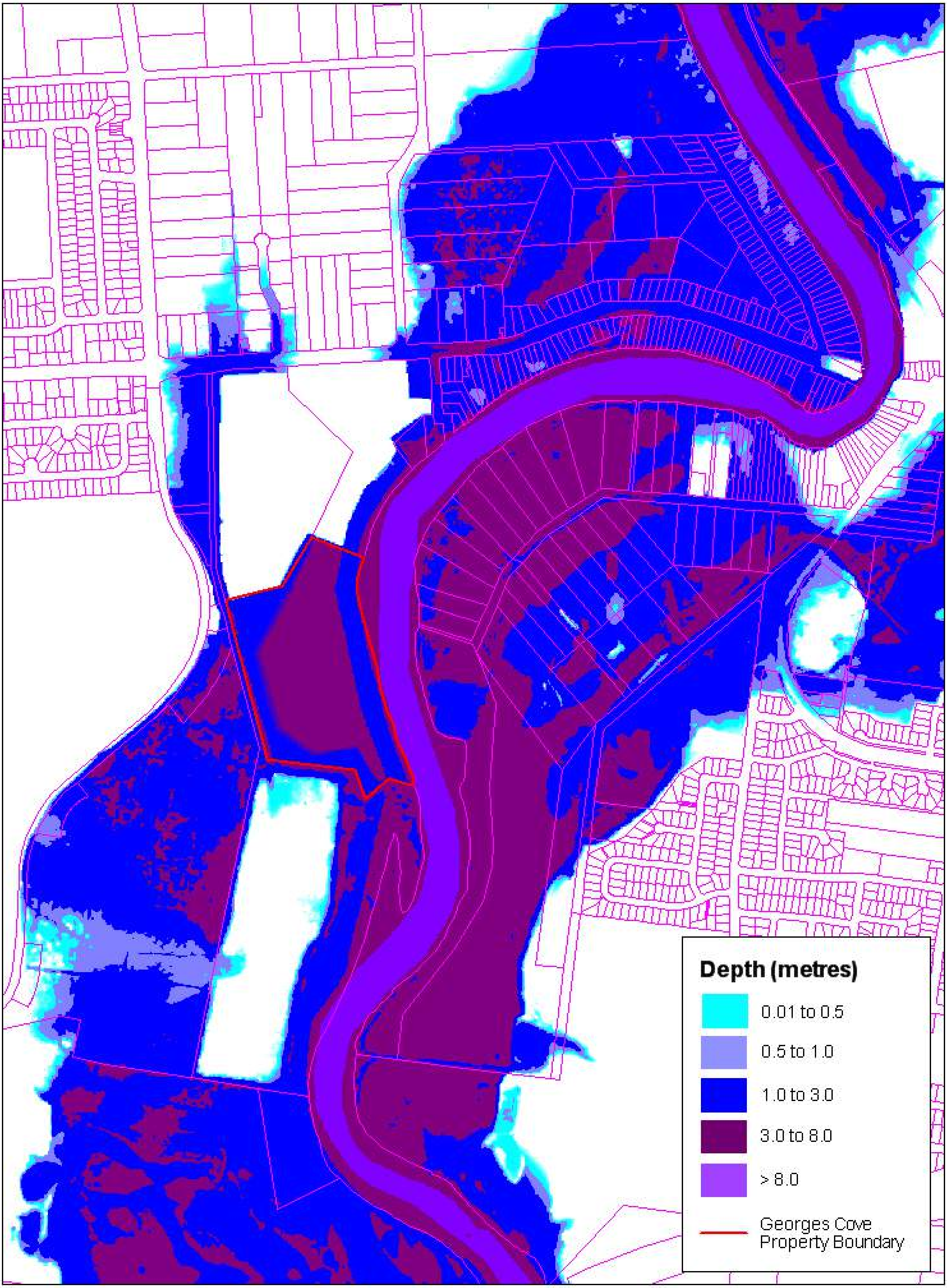

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Figure 3-2
20 year ARI
Peak Depth
Pre-Development

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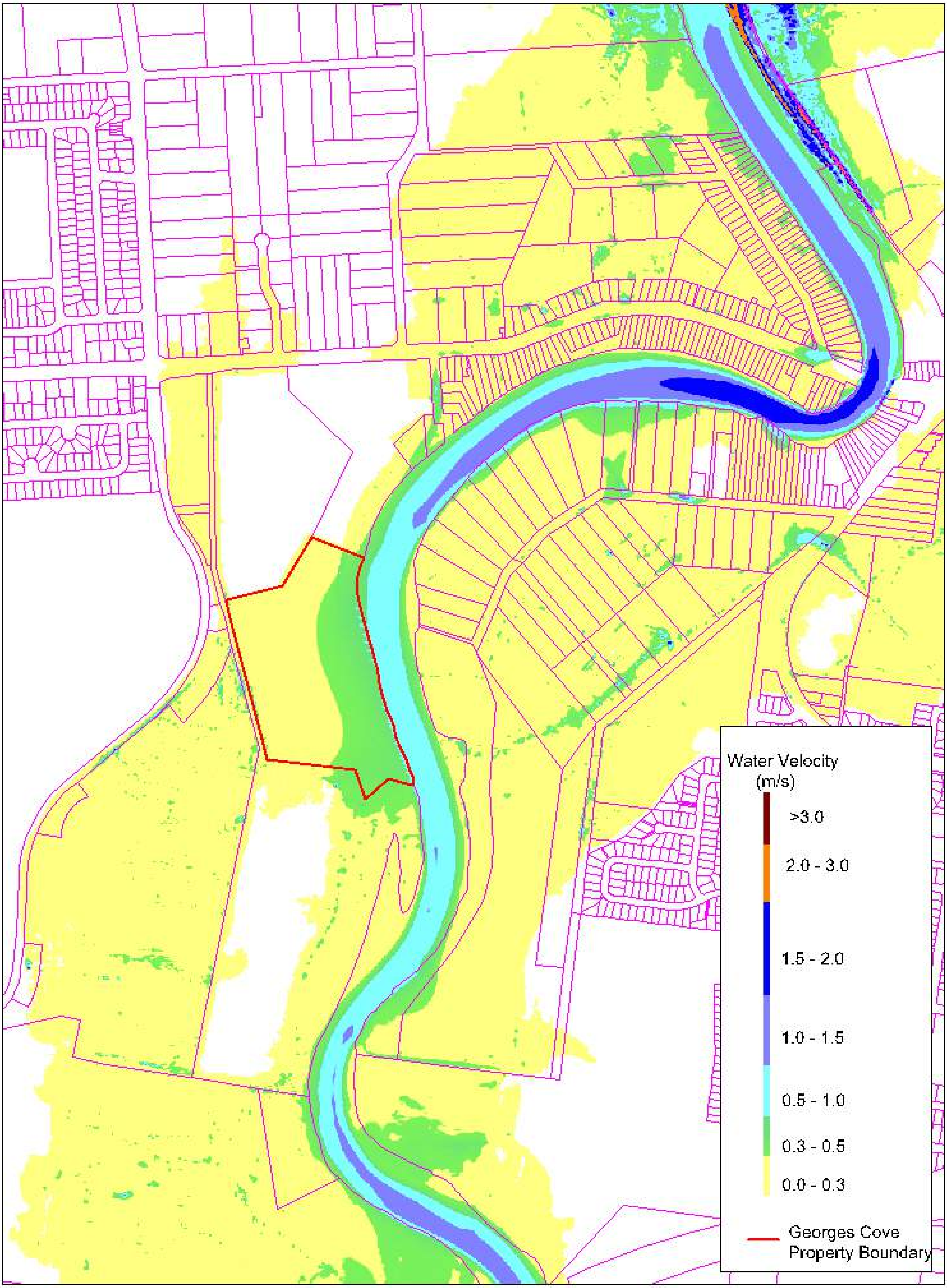
January 2013



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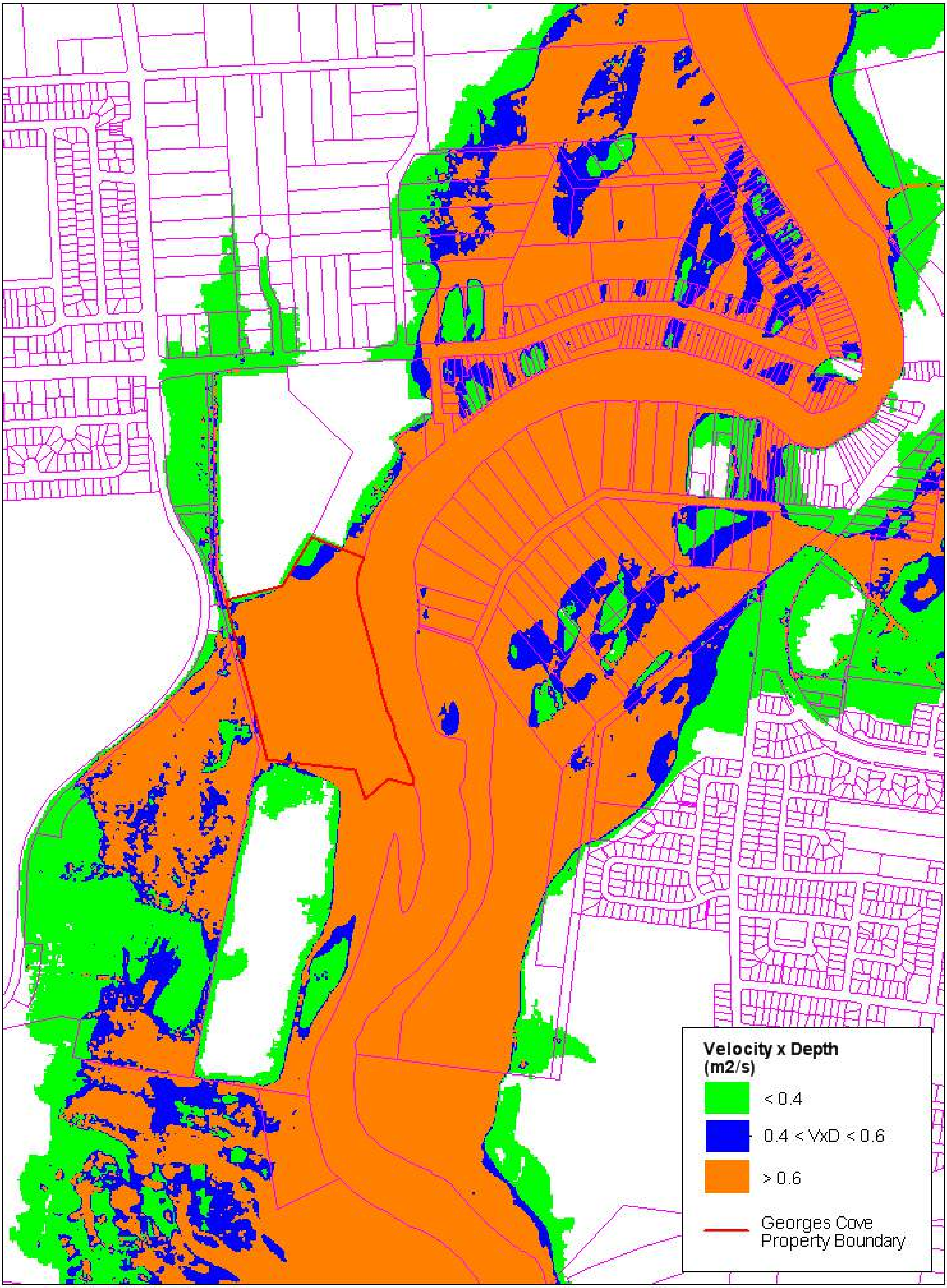
NA49913037
January 2013

Georges Cove
Flood Impact Assessment

Figure 3-3
20 year ARI
Peak Velocity
Pre-Development



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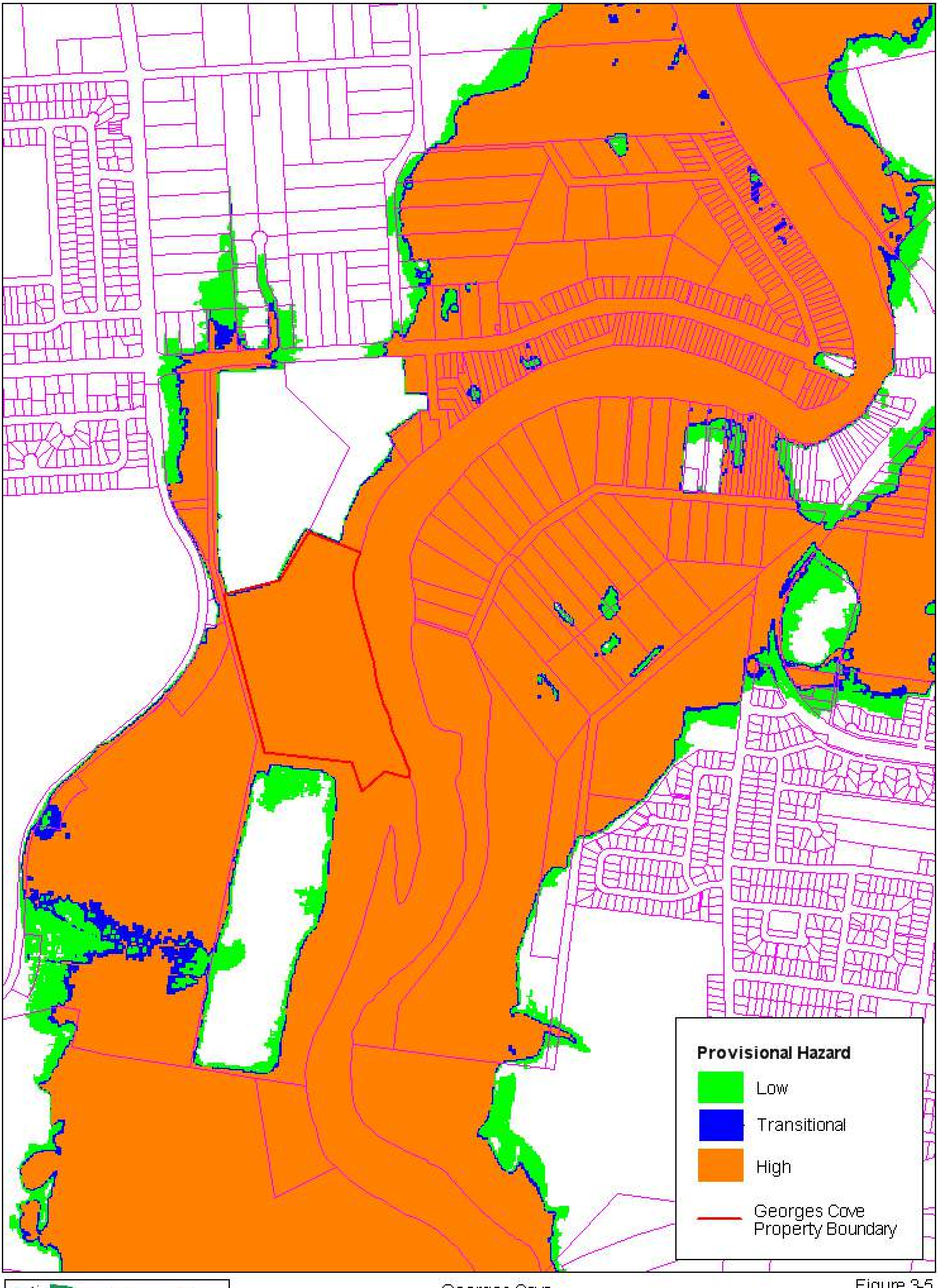
January 2013

Georges Cove
Flood Impact Assessment

Figure 3-4
20 year ARI
Peak Velocity x Depth
Pre-Development



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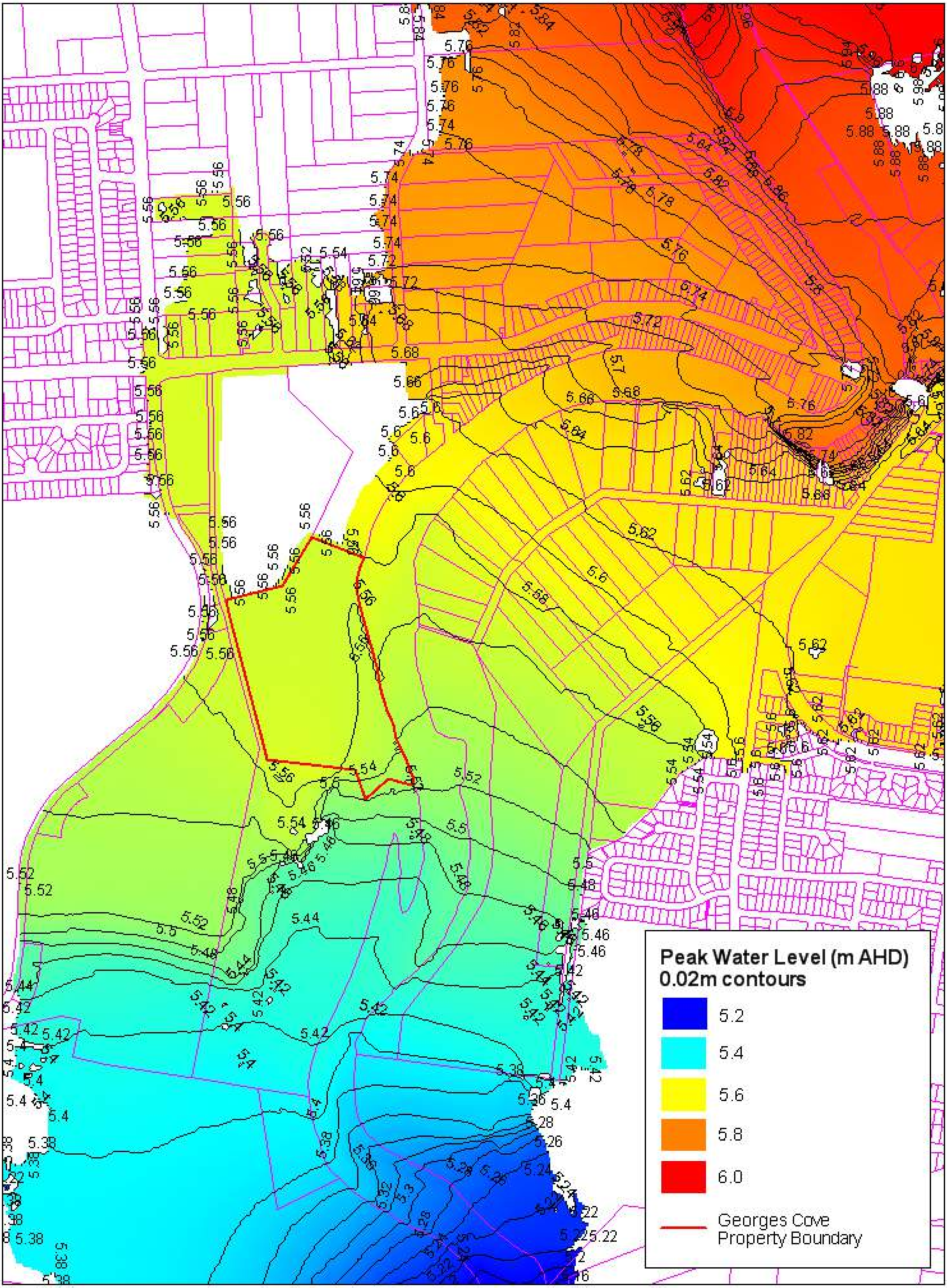
Georges Cove
Flood Impact Assessment

Figure 3-5
20 year ARI
Provisional Hazard
Pre-Development



Georges Cove
Flood Impact Assessment

Figure 3-6
100 year ARI
Peak Water Level
Pre-Development

NA49913037
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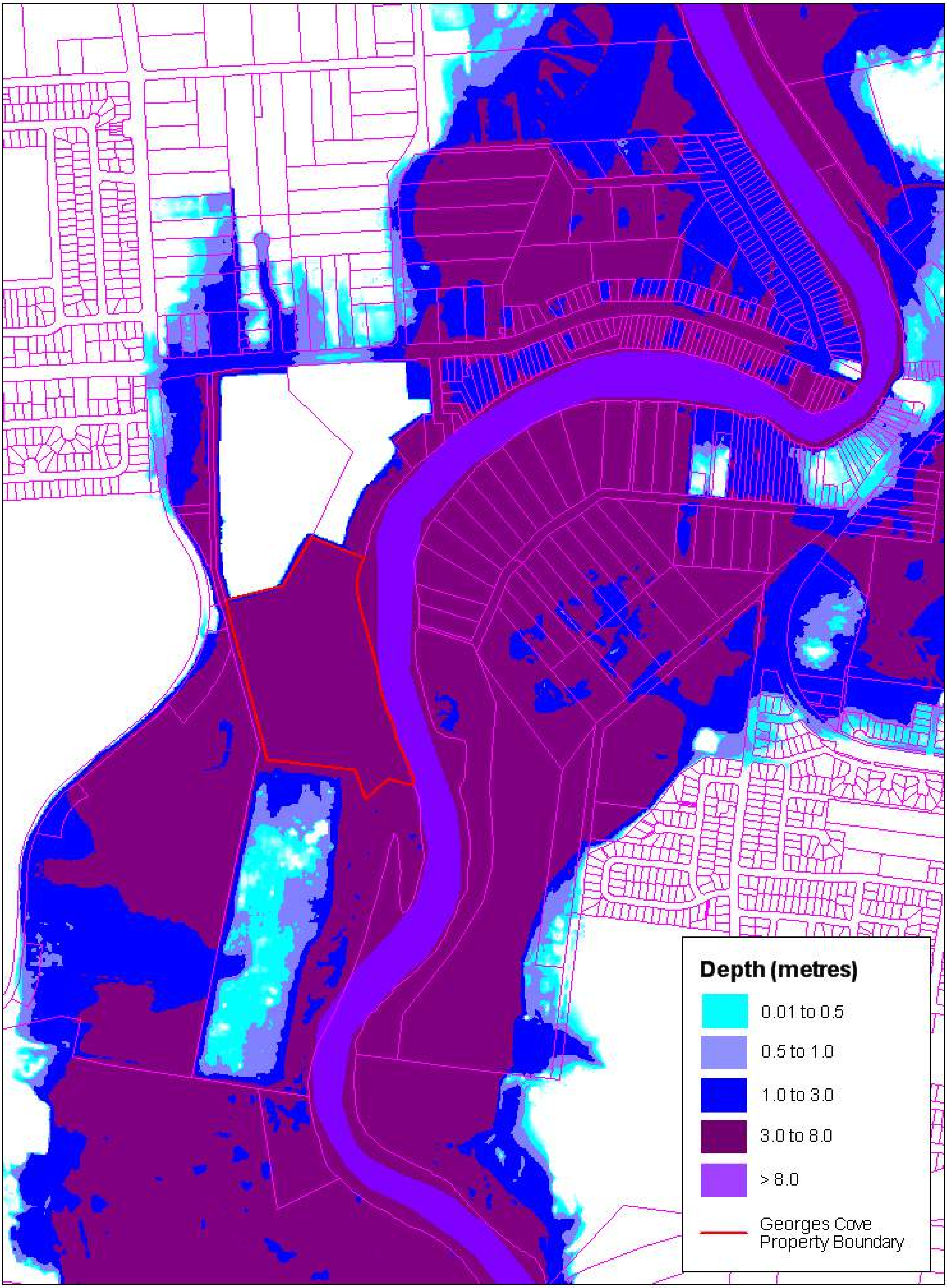

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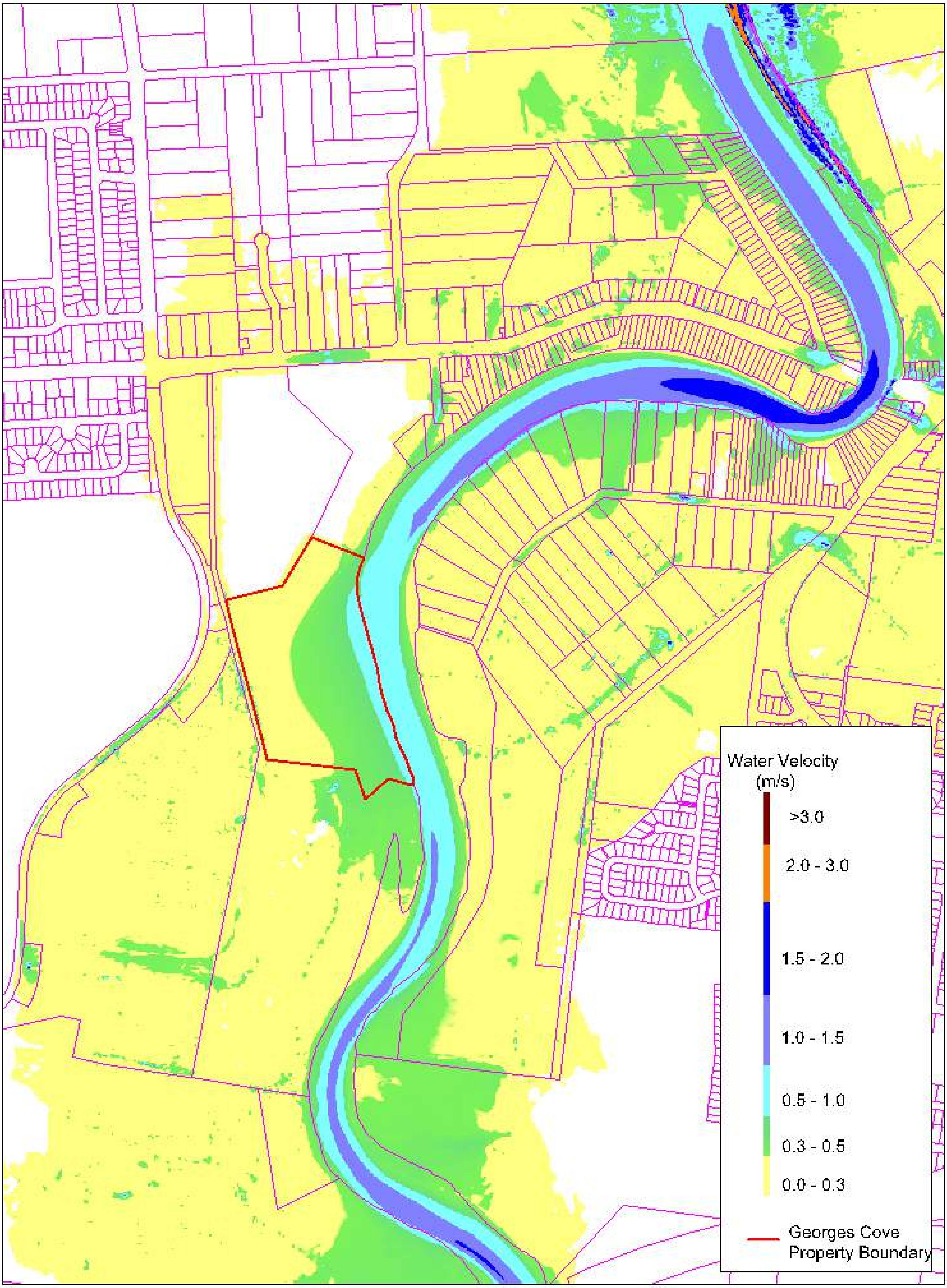
Georges Cove
Flood Impact Assessment

Figure 3-7
100 year ARI
Peak Depth
Pre-Development



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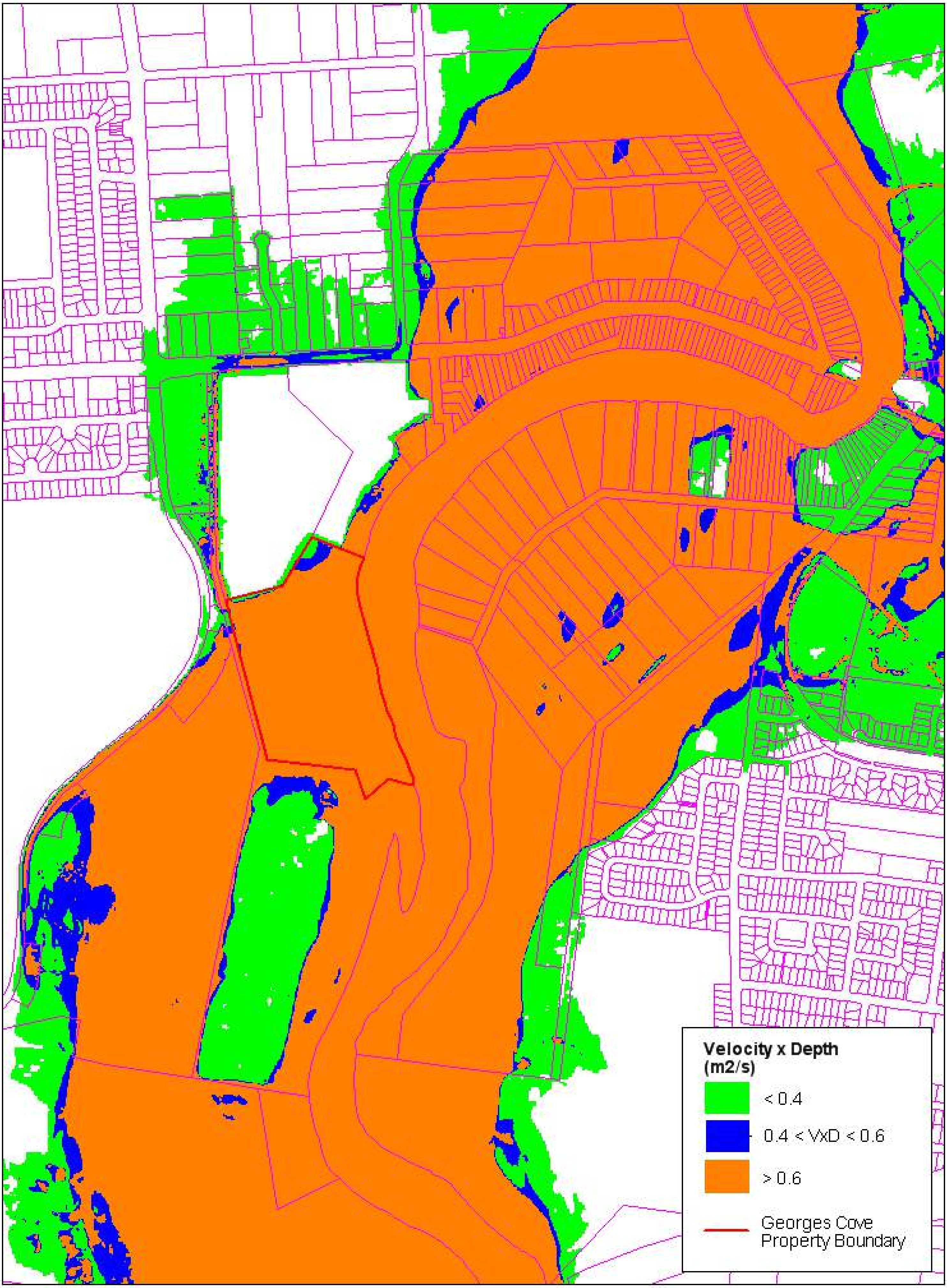
Georges Cove
Flood Impact Assessment

Figure 3-8
100 year ARI
Peak Velocity
Pre-Development



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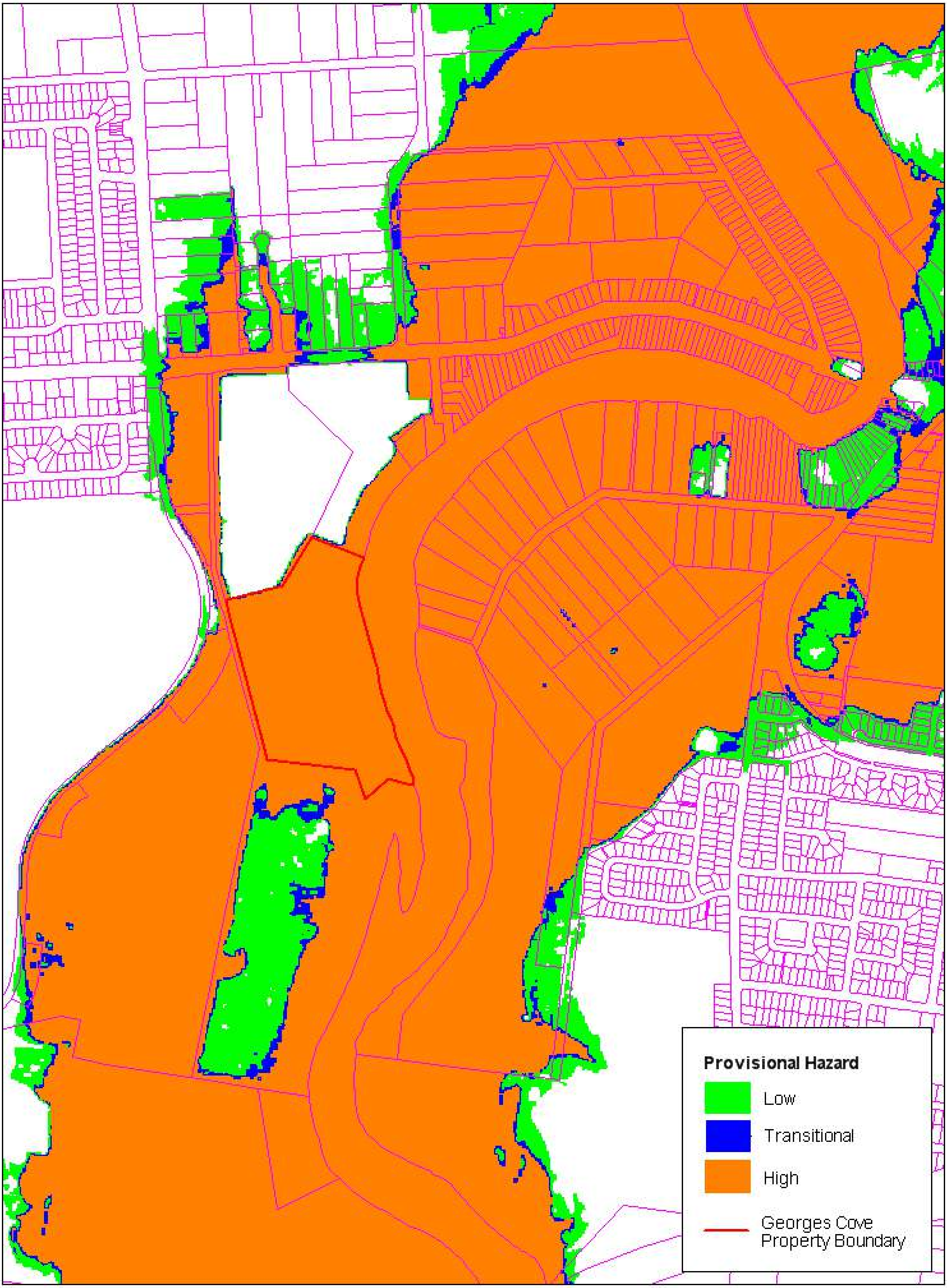
Georges Cove
Flood Impact Assessment

Figure 3-9
100 year ARI
Peak Velocity x Depth
Pre-Development



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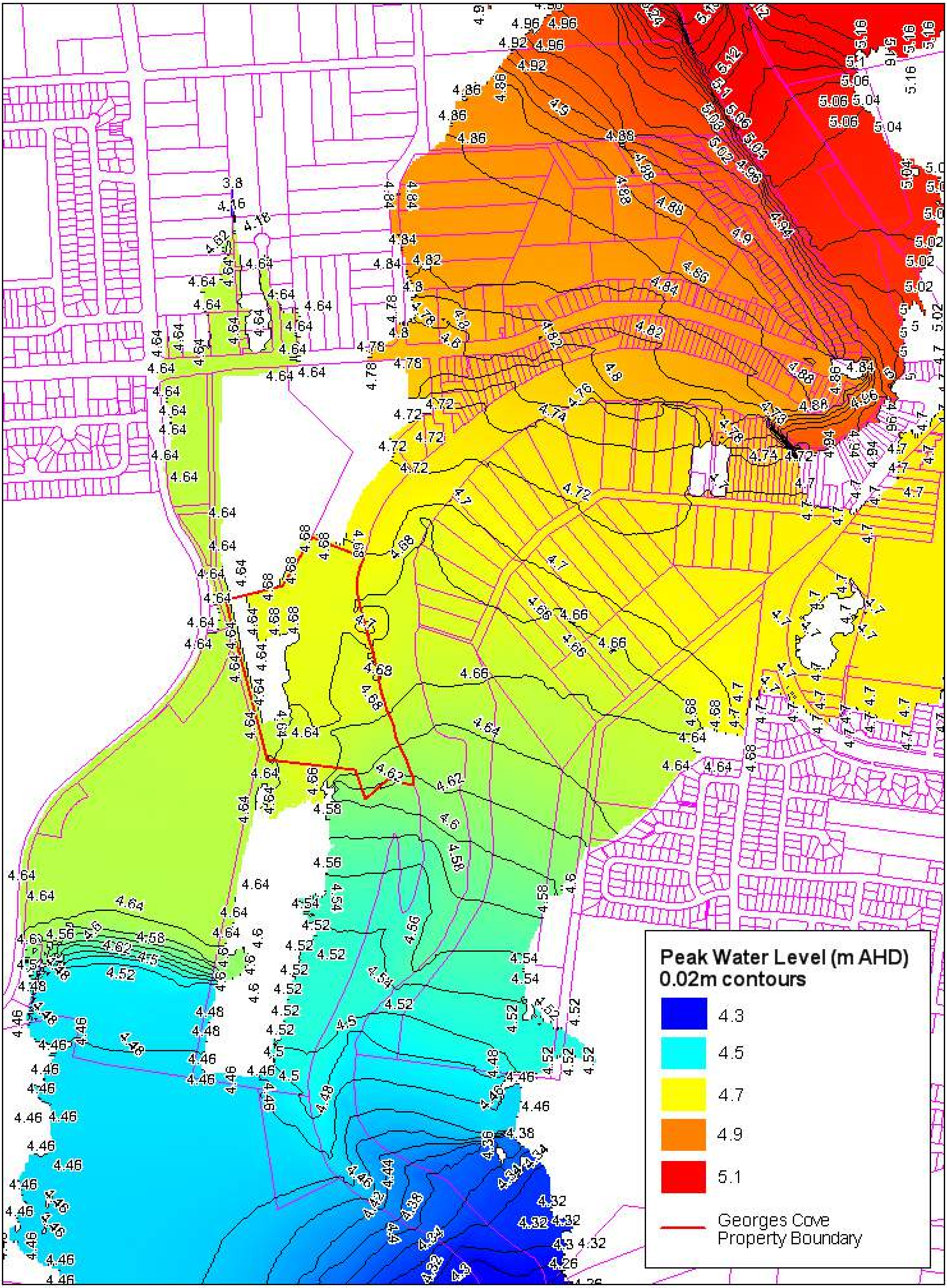
Georges Cove
Flood Impact Assessment

Figure 3-10
100 year ARI
Provisional Hazard
Pre-Development



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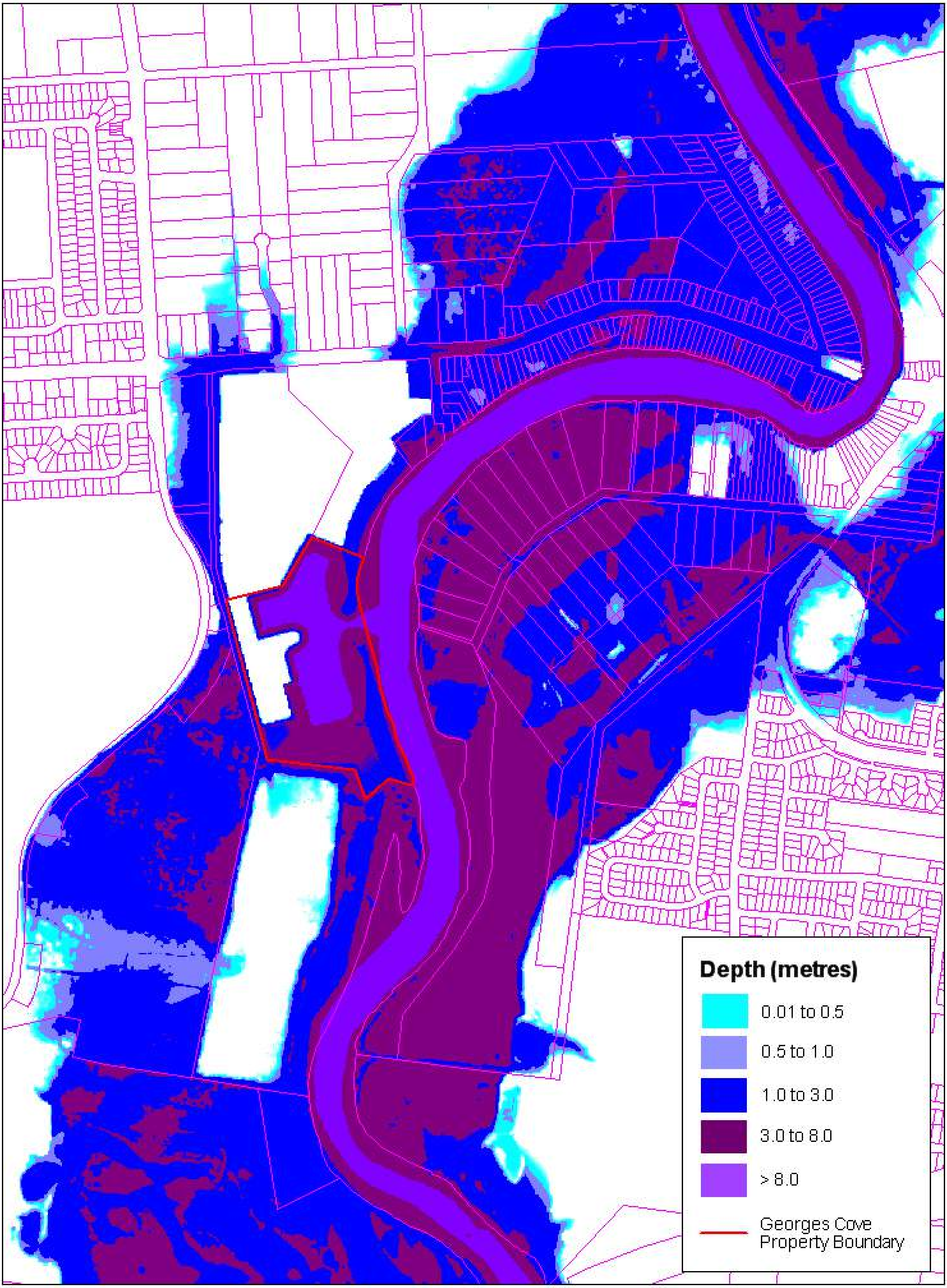
Georges Cove
Flood Impact Assessment

Figure 3-11
20 year ARI
Peak Water Level
Post-development



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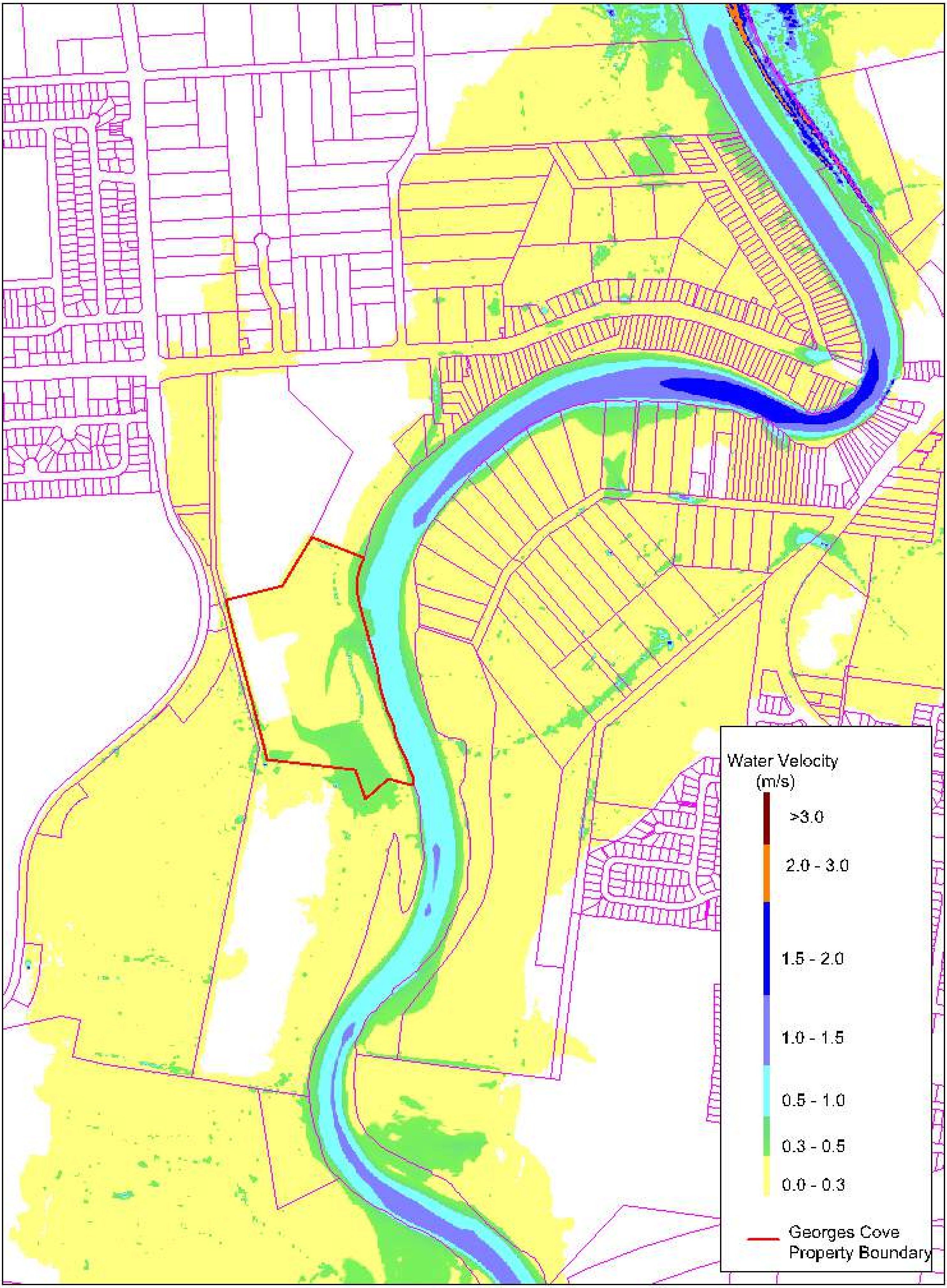
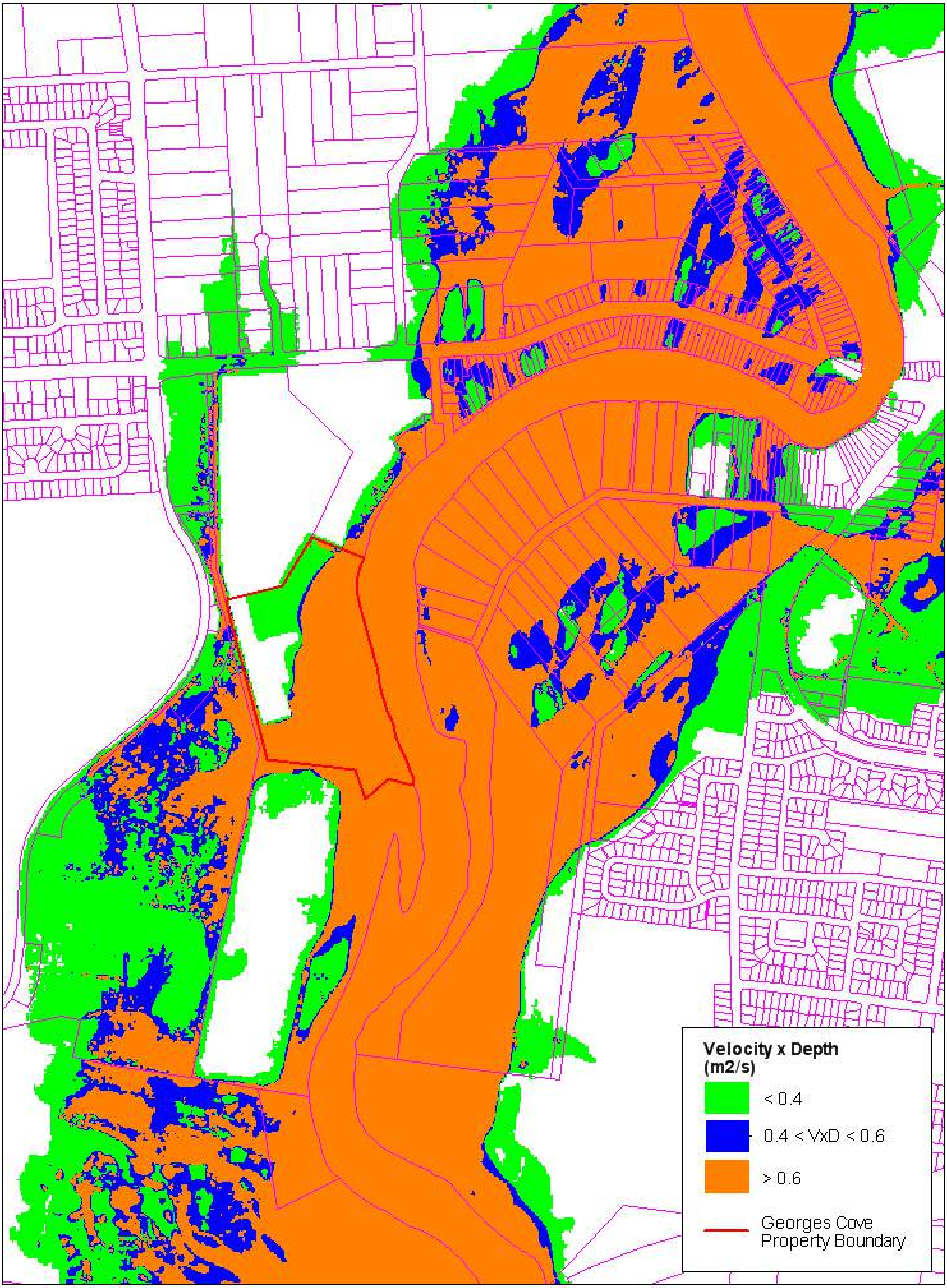
Georges Cove
Flood Impact Assessment

Figure 3-12
20 year ARI
Peak Depth
Post-development



Water Velocity
(m/s)
>3.0
2.0 - 3.0
1.5 - 2.0
1.0 - 1.5
0.5 - 1.0
0.3 - 0.5
0.0 - 0.3
Georges Cove
Property Boundary



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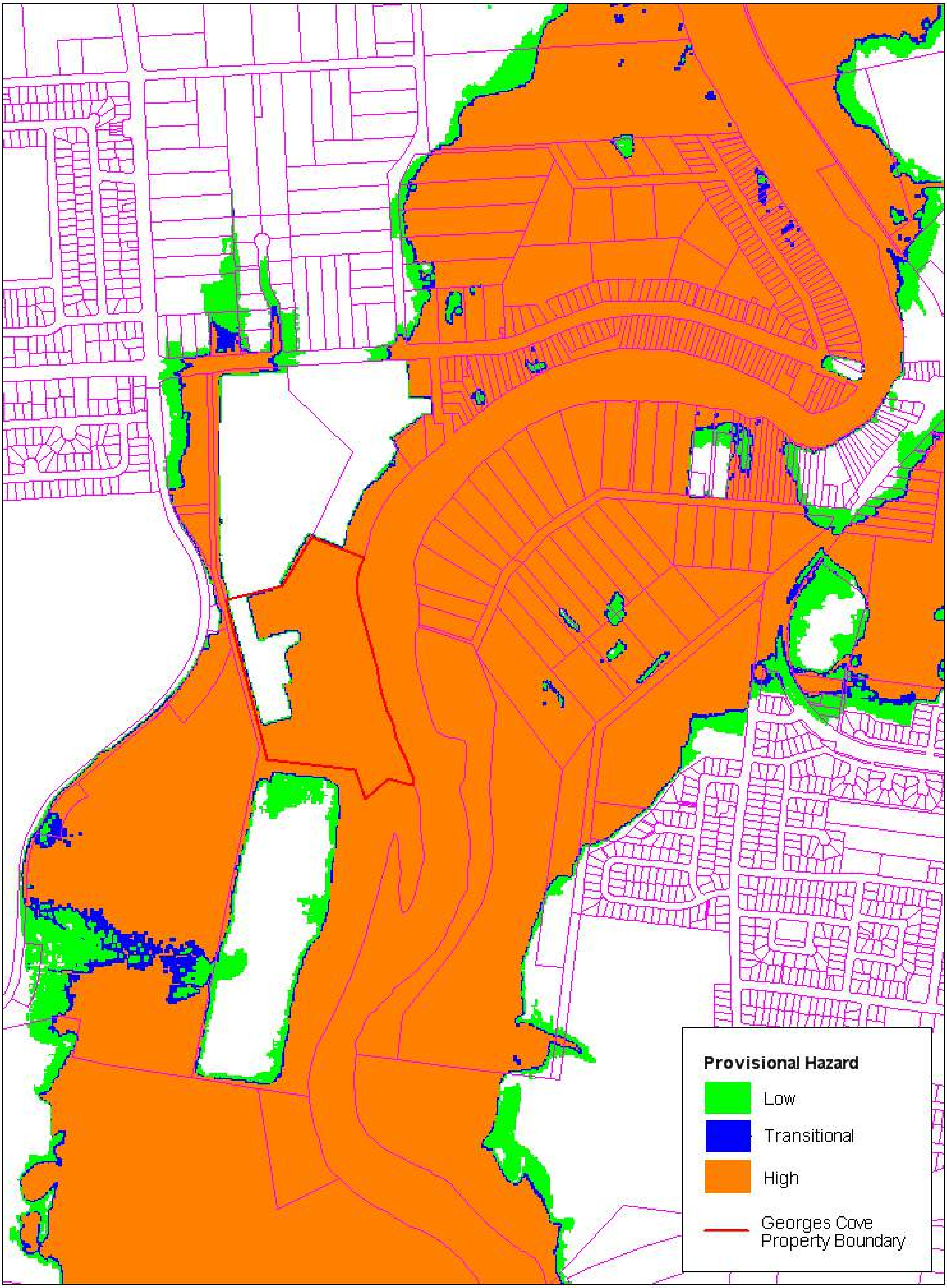
Georges Cove
Flood Impact Assessment

Figure 3-14
20 year ARI
Peak Velocity x Depth
Post-development



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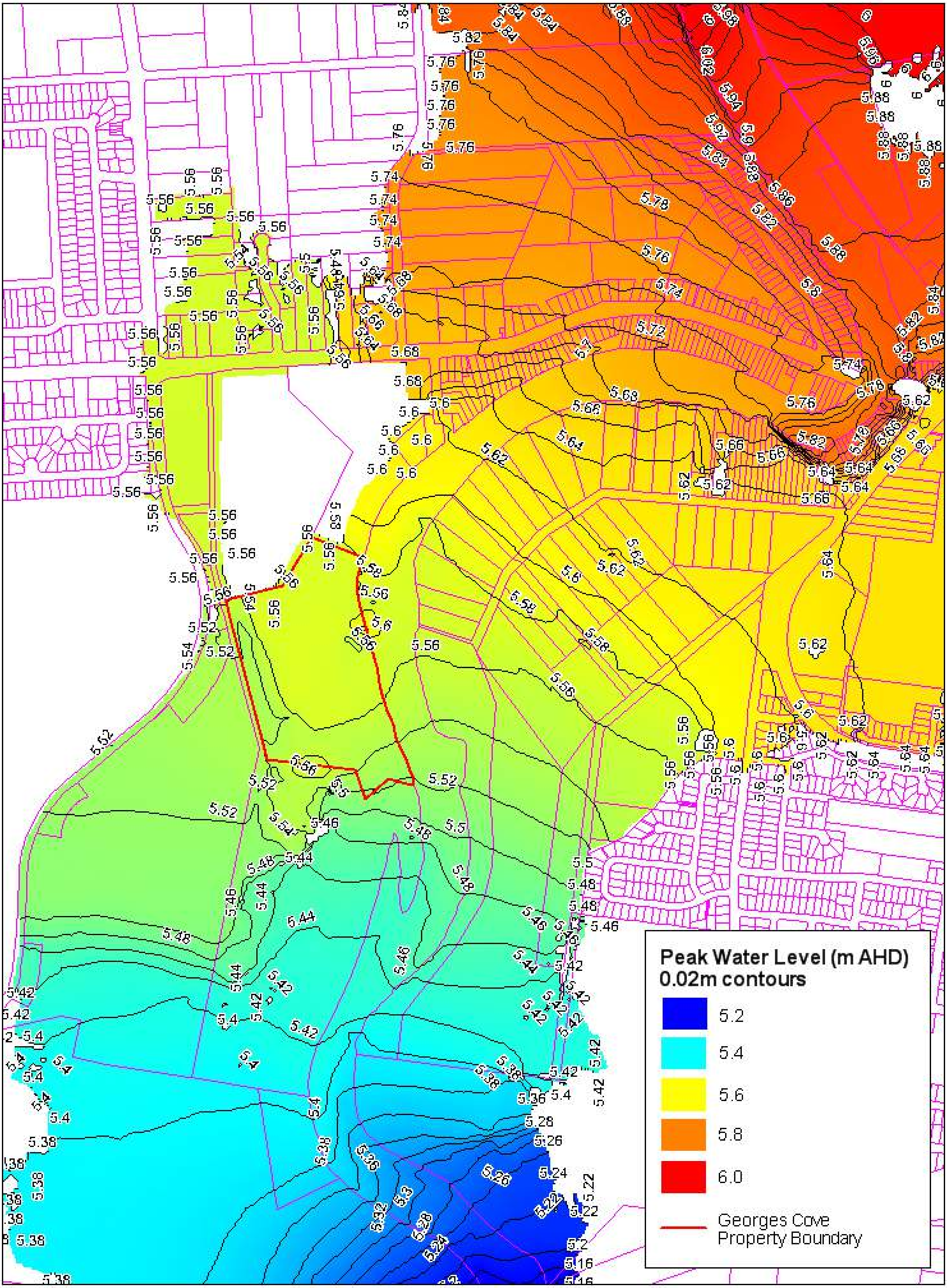
Georges Cove
Flood Impact Assessment

Figure 3-15
20 year ARI
Provisional Hazard
Post-development



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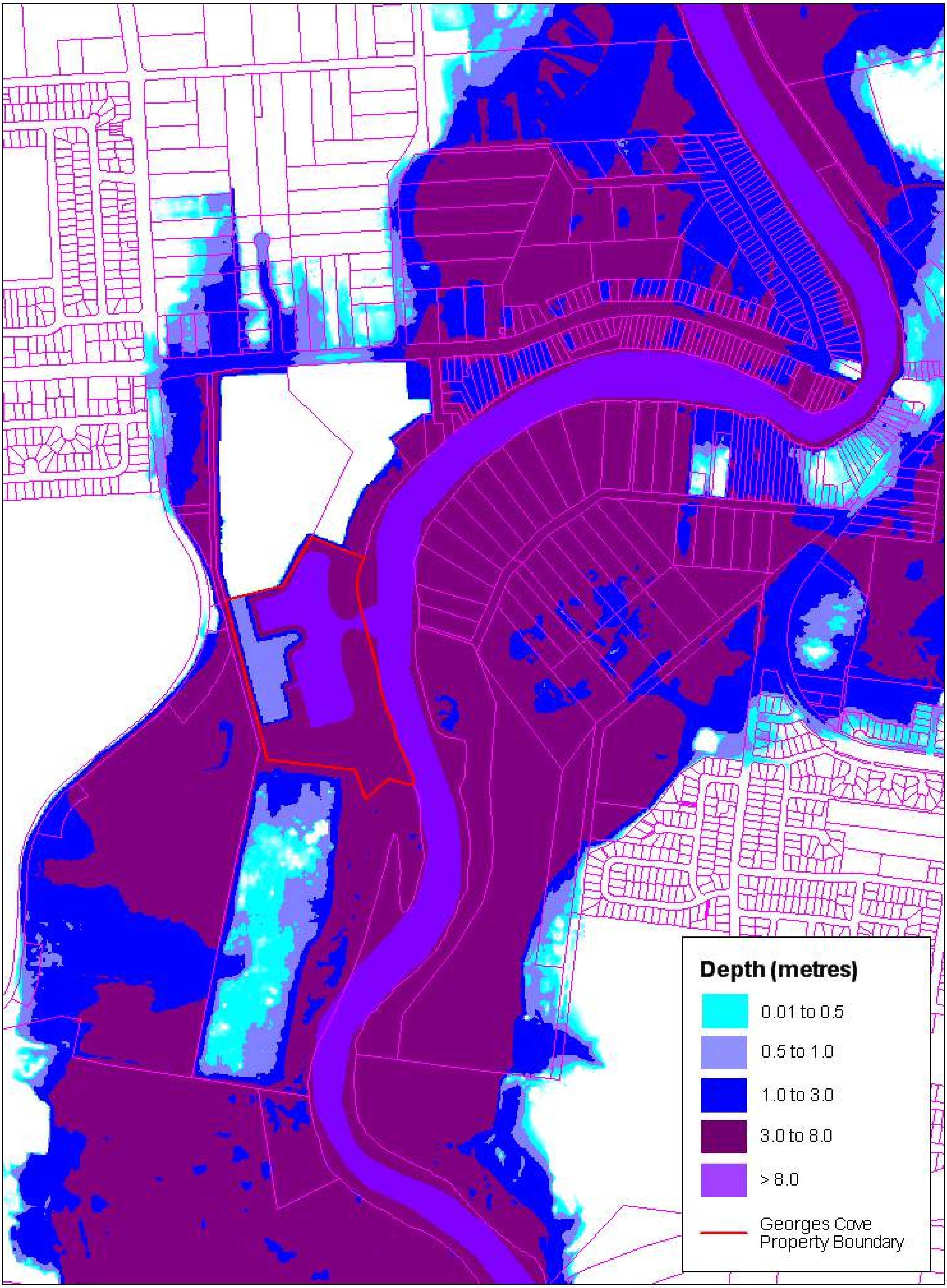
Georges Cove
Flood Impact Assessment

Figure 3-16
100 year ARI
Peak Water Level
Post-development



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Georges Cove
Flood Impact Assessment

Figure 3-17
100 year ARI
Peak Depth
Post-development

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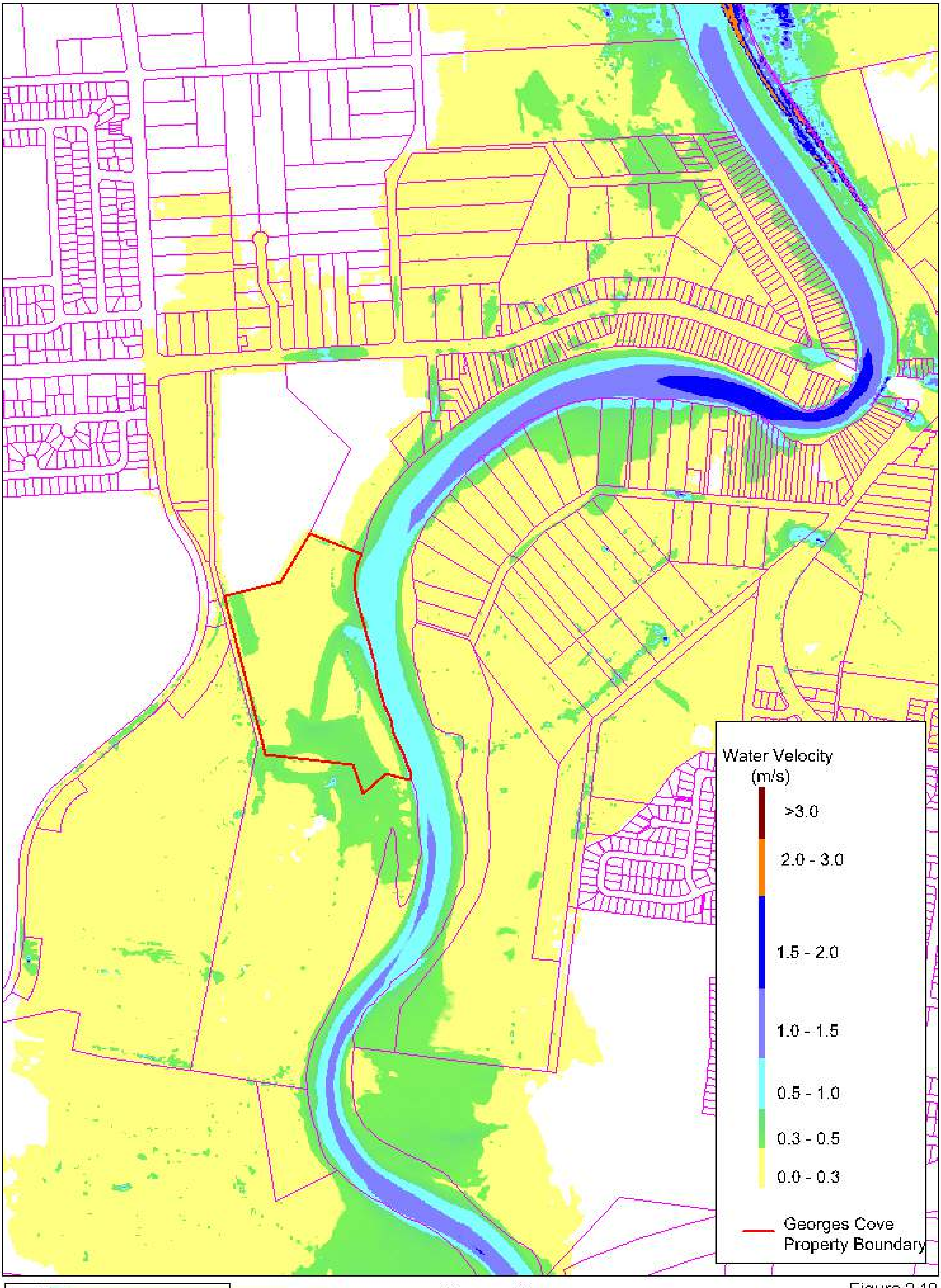
January 2013



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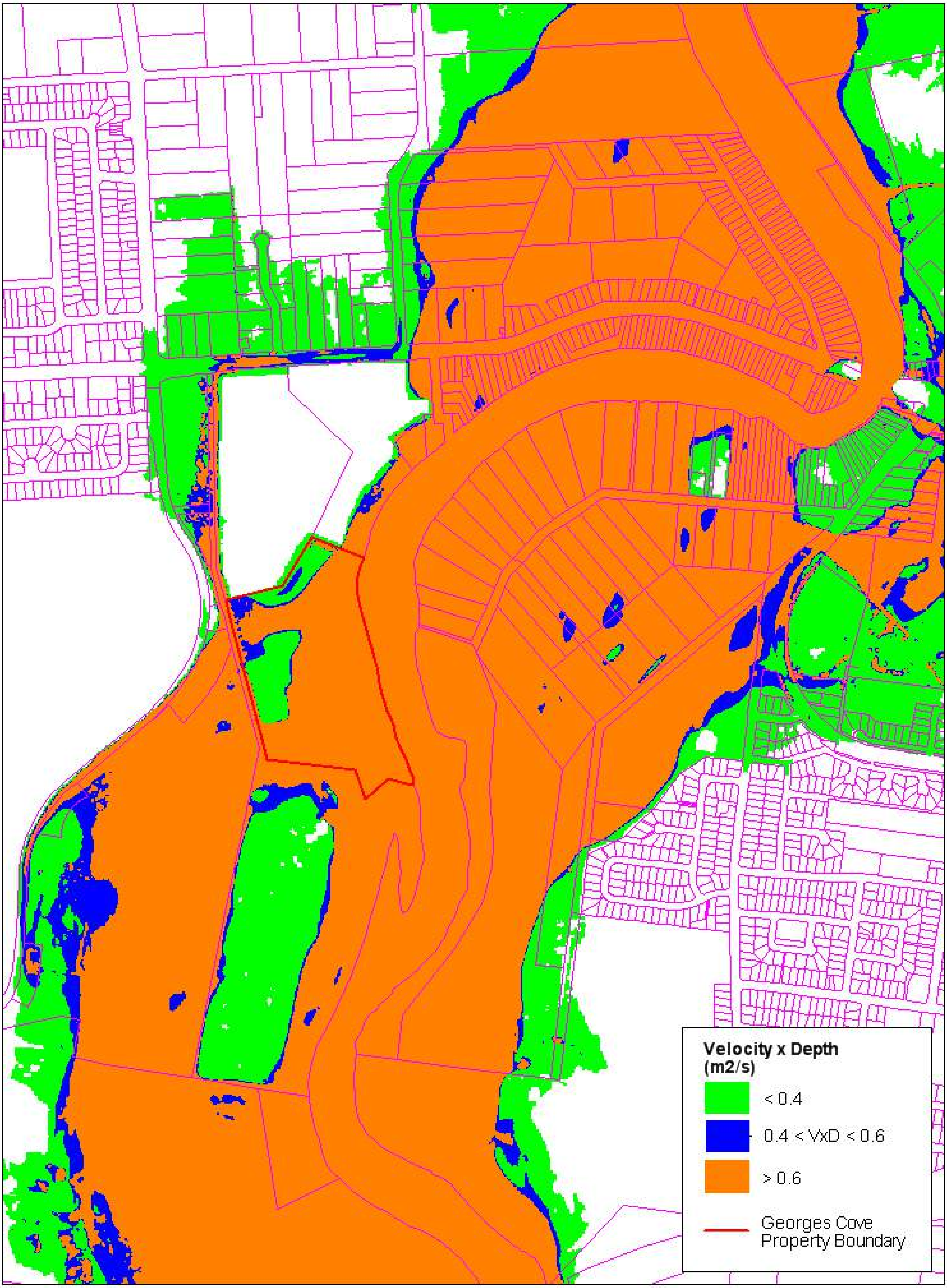
Georges Cove
Flood Impact Assessment

Figure 3-18
100 year ARI
Peak Velocity
Post-development



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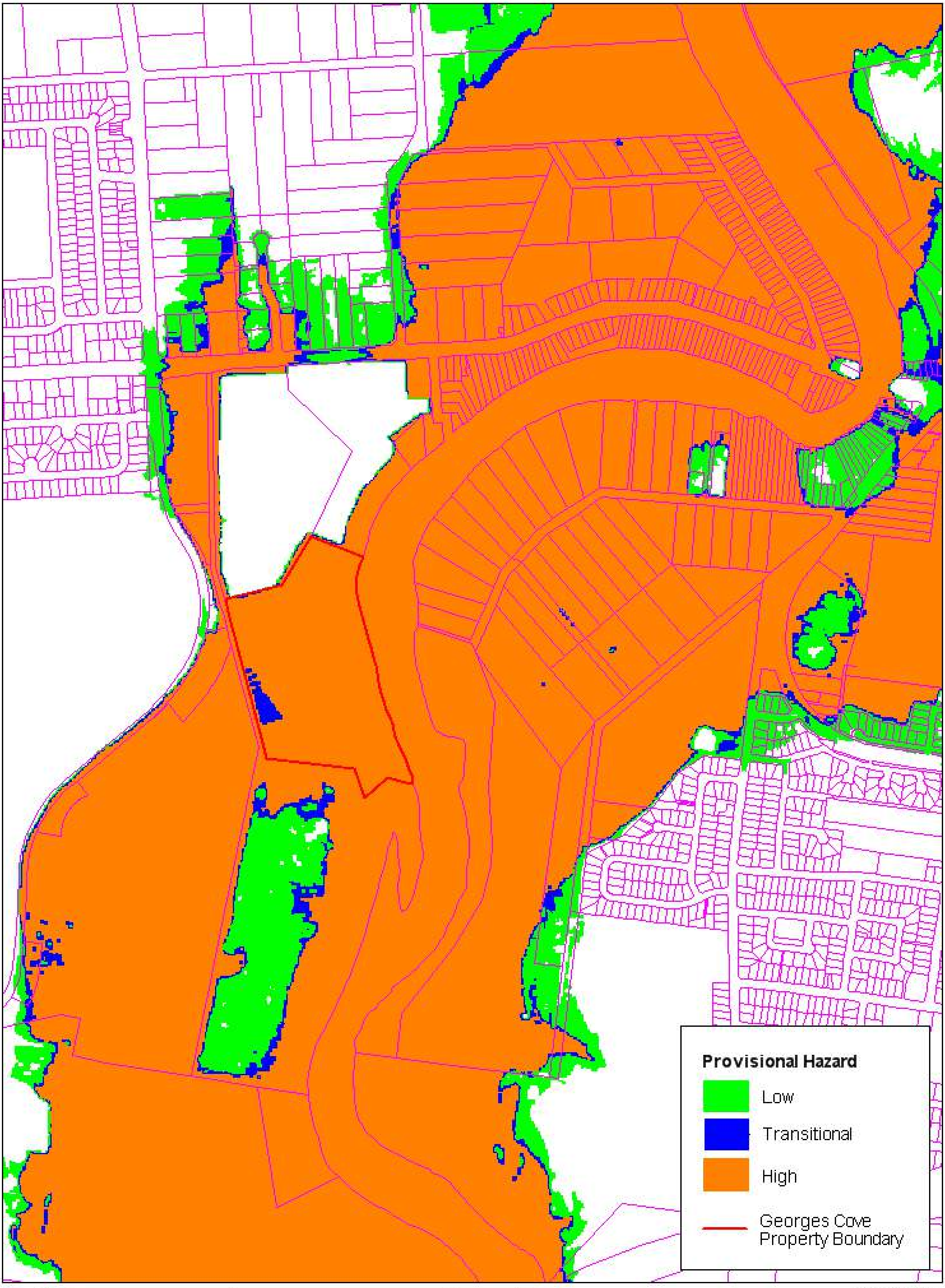
Georges Cove
Flood Impact Assessment

Figure 3-19
100 year ARI
Peak Velocity x Depth
Post-development



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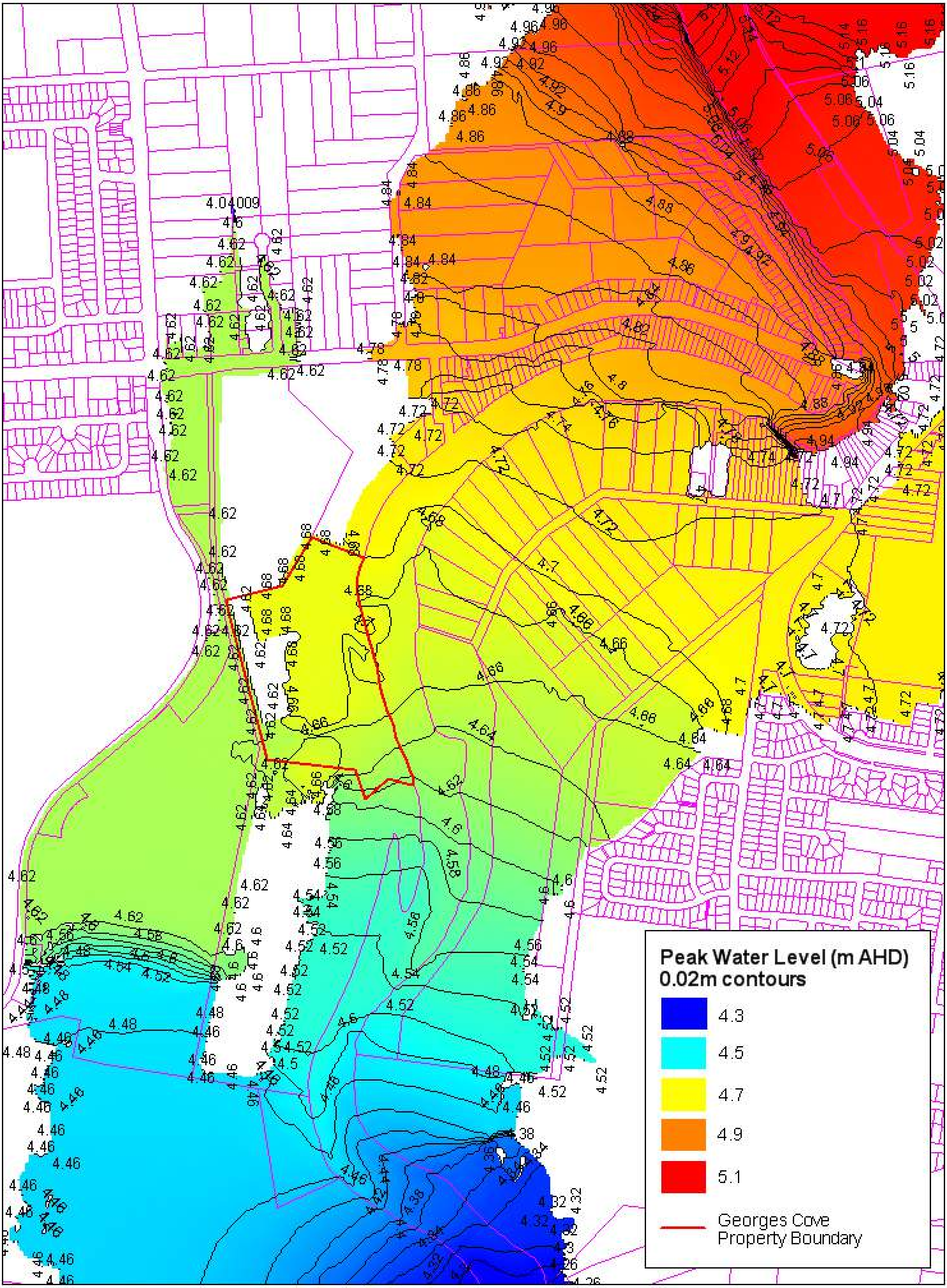
Georges Cove
Flood Impact Assessment

Figure 3-20
100 year ARI
Provisional Hazard
Post-development



Georges Cove
Flood Impact Assessment

Figure 3-21
20 year ARI
Peak Water Level
Post-development-Blockage

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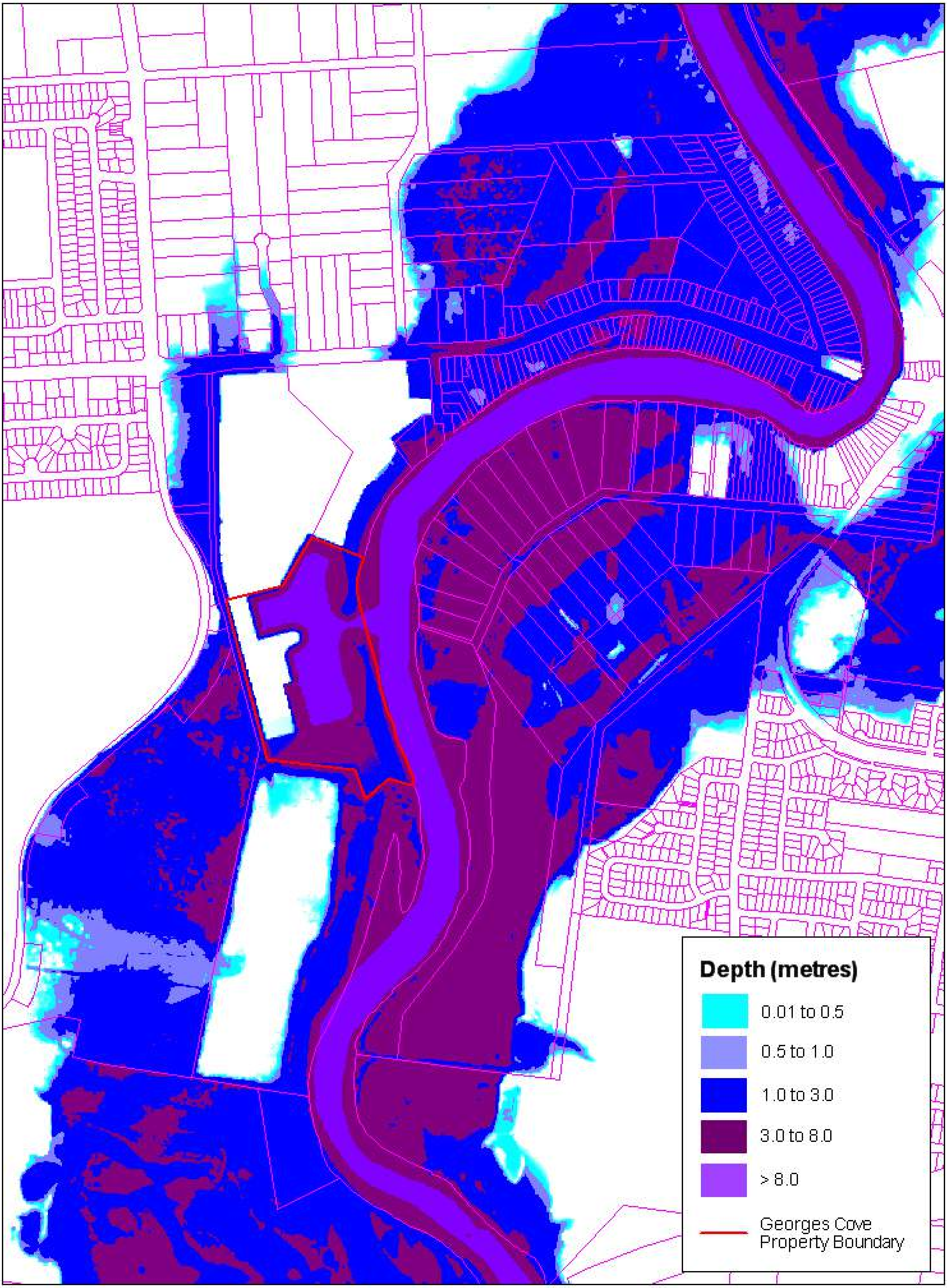
January 2013



Georges Cove
Flood Impact Assessment

Figure 3-22
20 year ARI
Peak Depth
Post-development-Blockage

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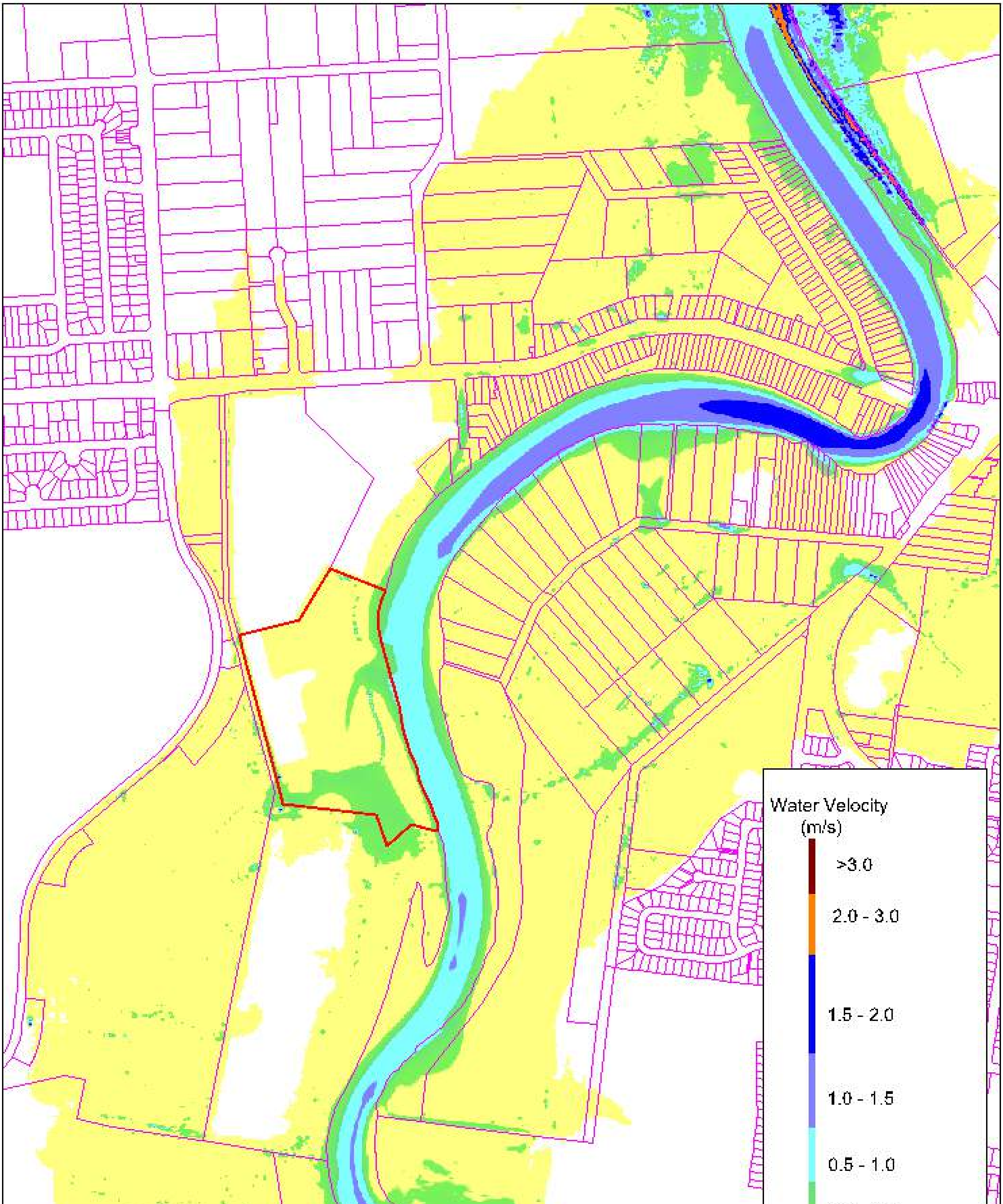
January 2013



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Georges Cove
Flood Impact Assessment

Figure 3-23
20 year ARI
Peak Velocity
Post-development-Blockage

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Georges Cove
Flood Impact Assessment

Figure 3-24
20 year ARI
Peak Velocity x Depth
Post-development-Blockage

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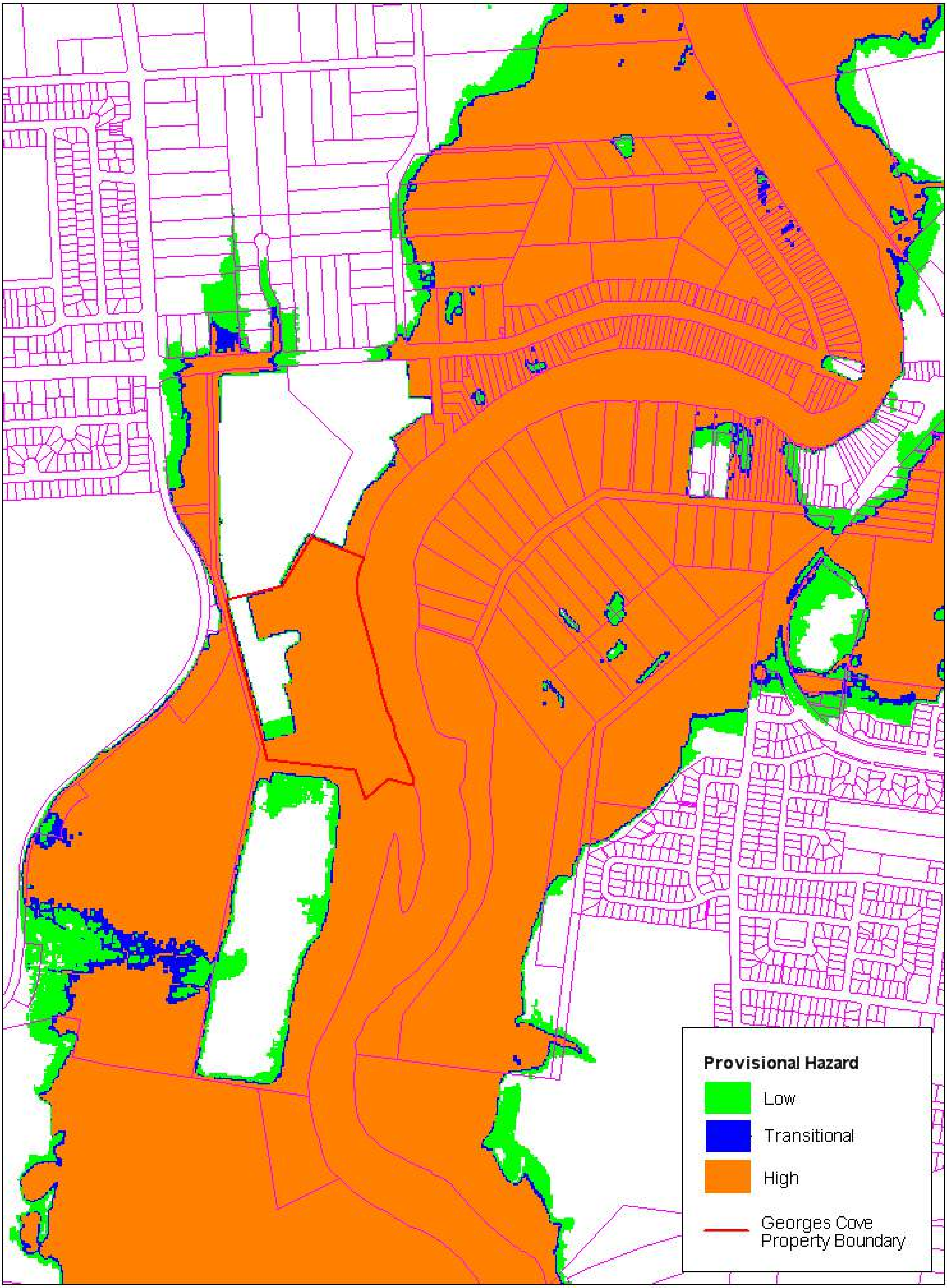
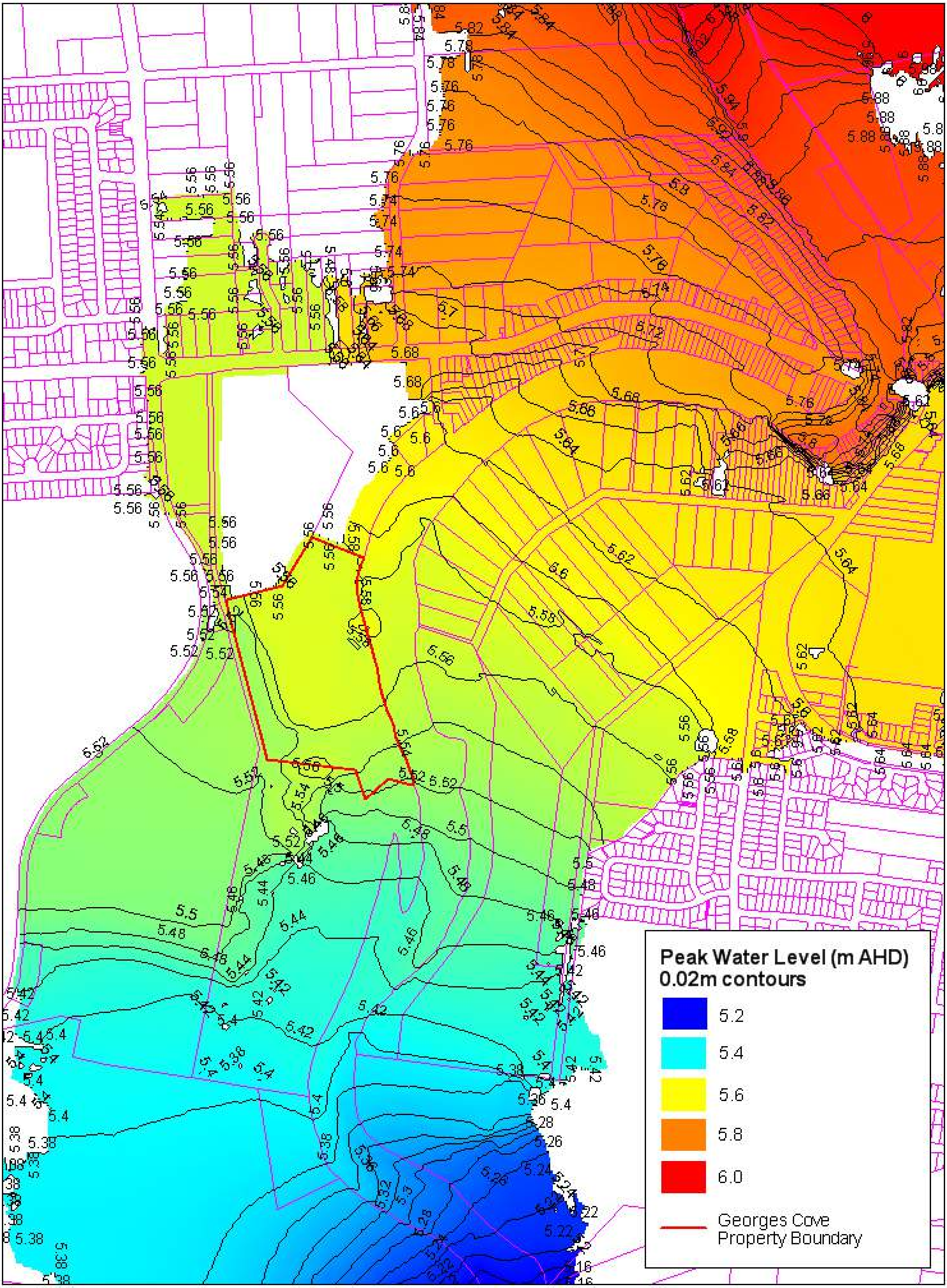


Georges Cove
Flood Impact Assessment

Figure 3-25
20 year ARI
Provisional Hazard
Post-development-Blockage



Georges Cove
Flood Impact Assessment

Figure 3-26
100 year ARI
Peak Water Level
Post-development-Blockage

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January 2013

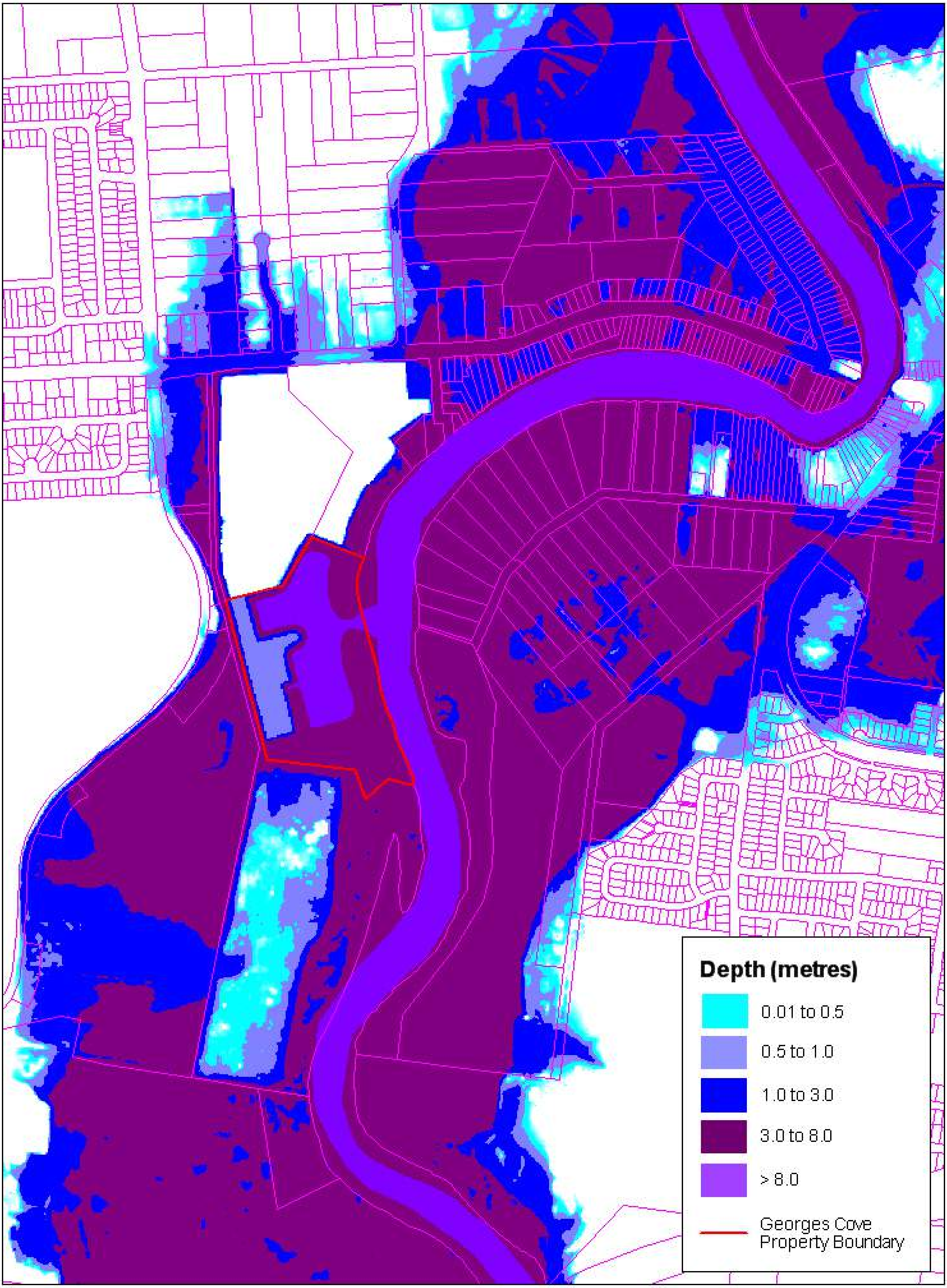
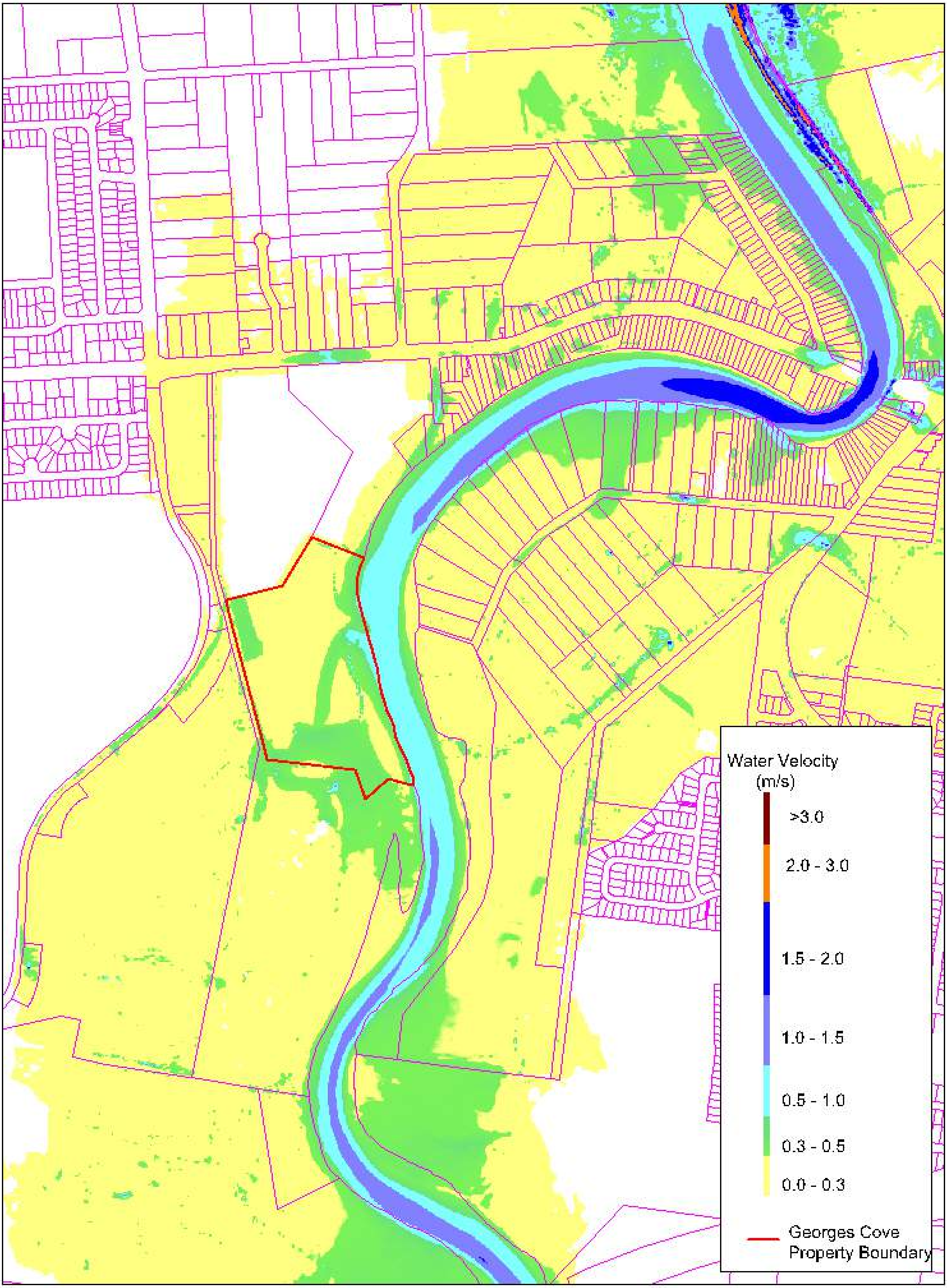


Figure 3-27
100 year ARI
Peak Depth
Post-development-Blockage



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Georges Cove
Flood Impact Assessment

Figure 3-28
100 year ARI
Peak Velocity
Post-development-Blockage

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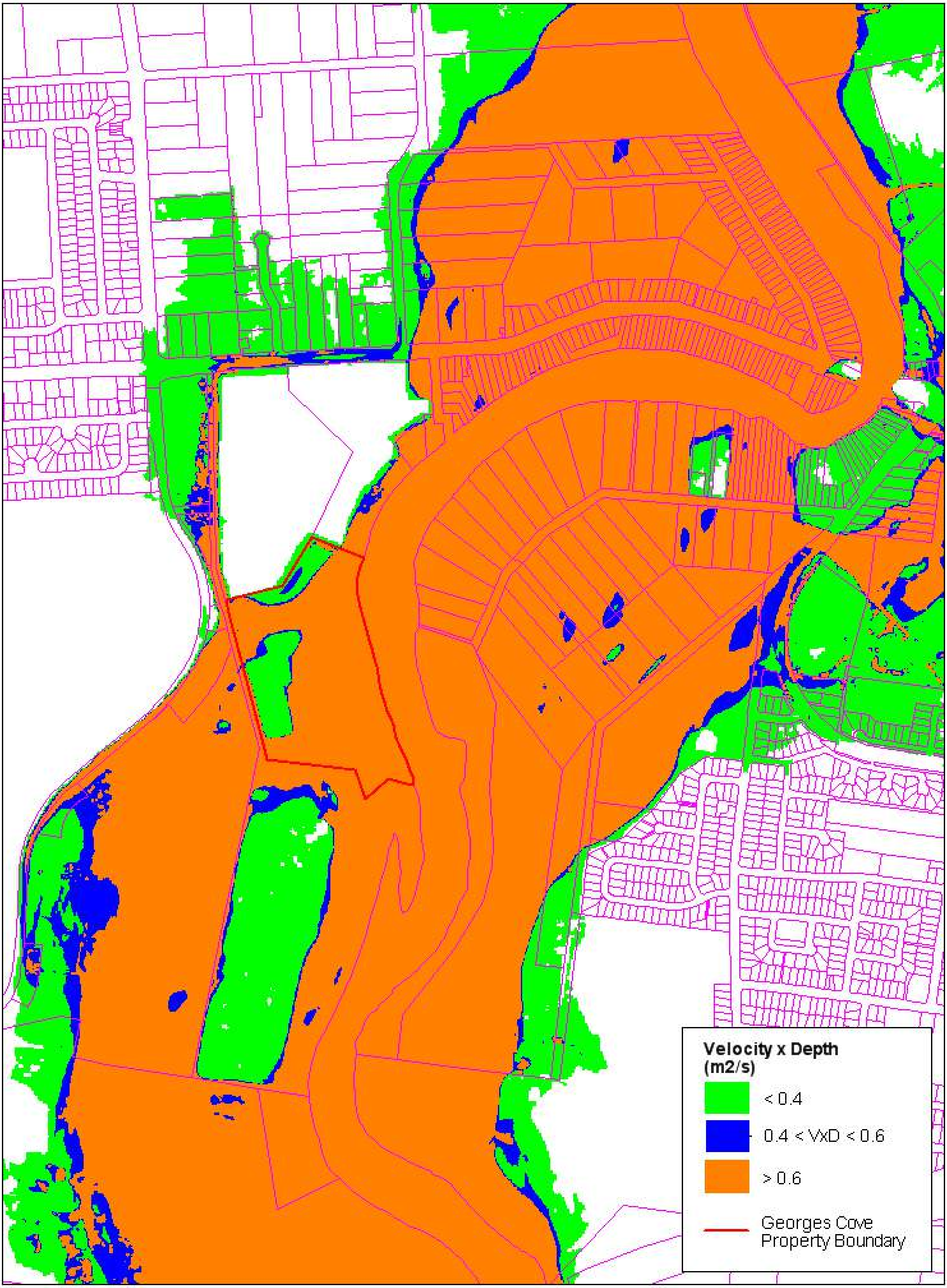

Georges Cove
Flood Impact Assessment

Figure 3-29
100 year ARI
Peak Velocity x Depth
Post-development-Blockage

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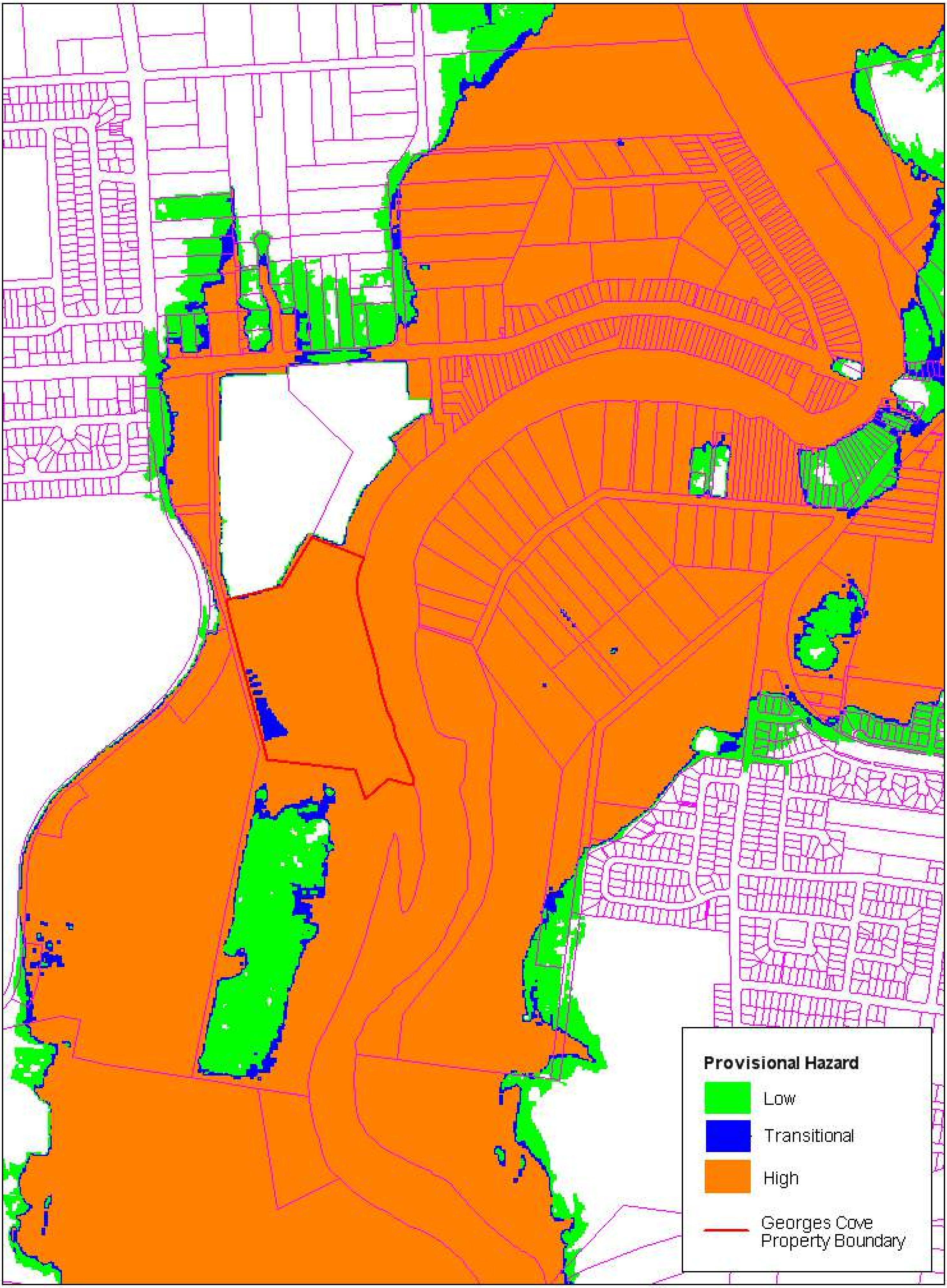

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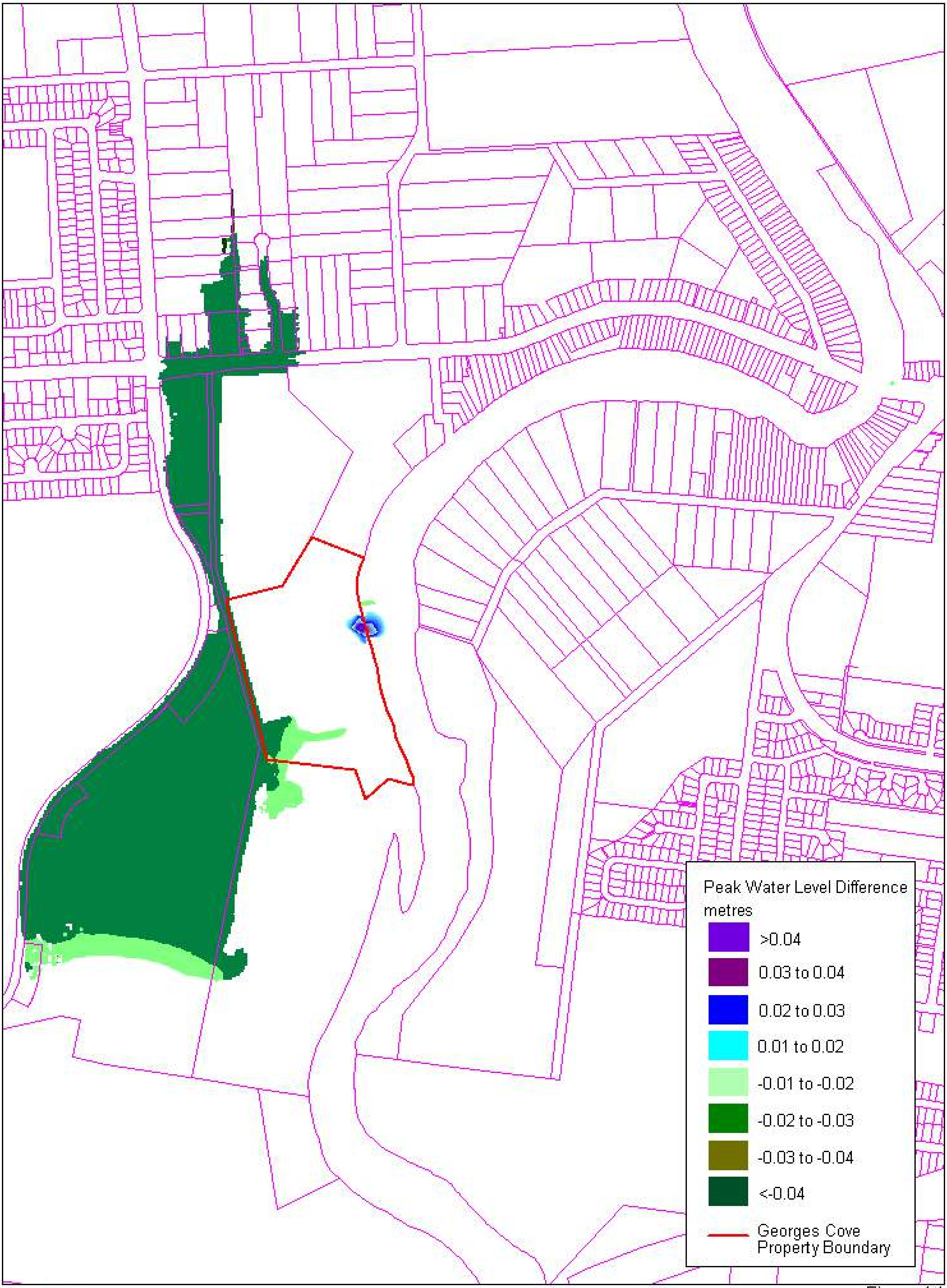
Georges Cove
Flood Impact Assessment

Figure 3-30
100 year ARI
Provisional Hazard
Post-development-Blockage



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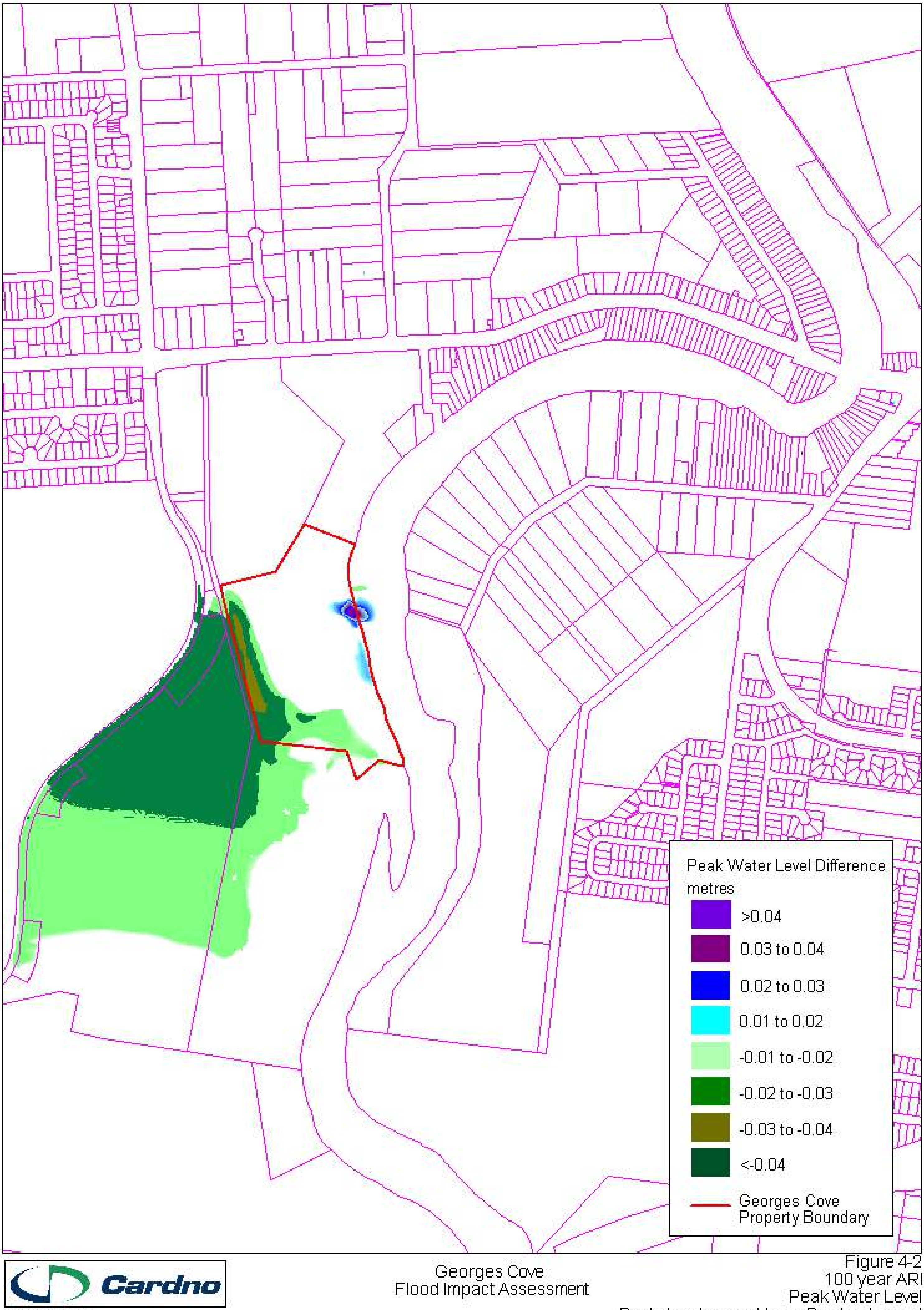
Georges Cove
Flood Impact Assessment

Figure 4-1
20 year ARI
Peak Water Level
Post-development Less Predevelopment



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Georges Cove
Flood Impact Assessment

Figure 4-2
100 year ARI
Peak Water Level
Post-development Less Predevelopment

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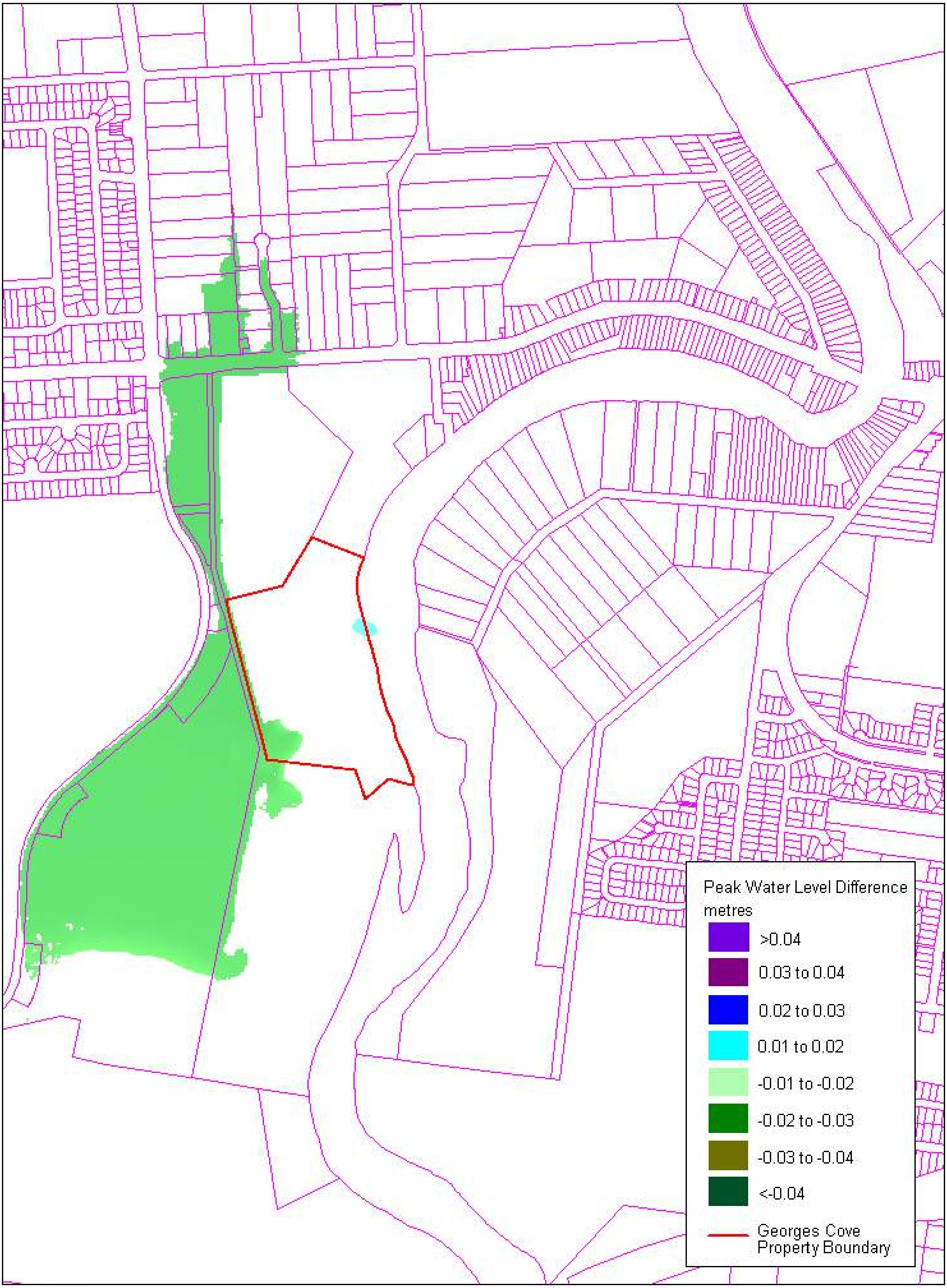

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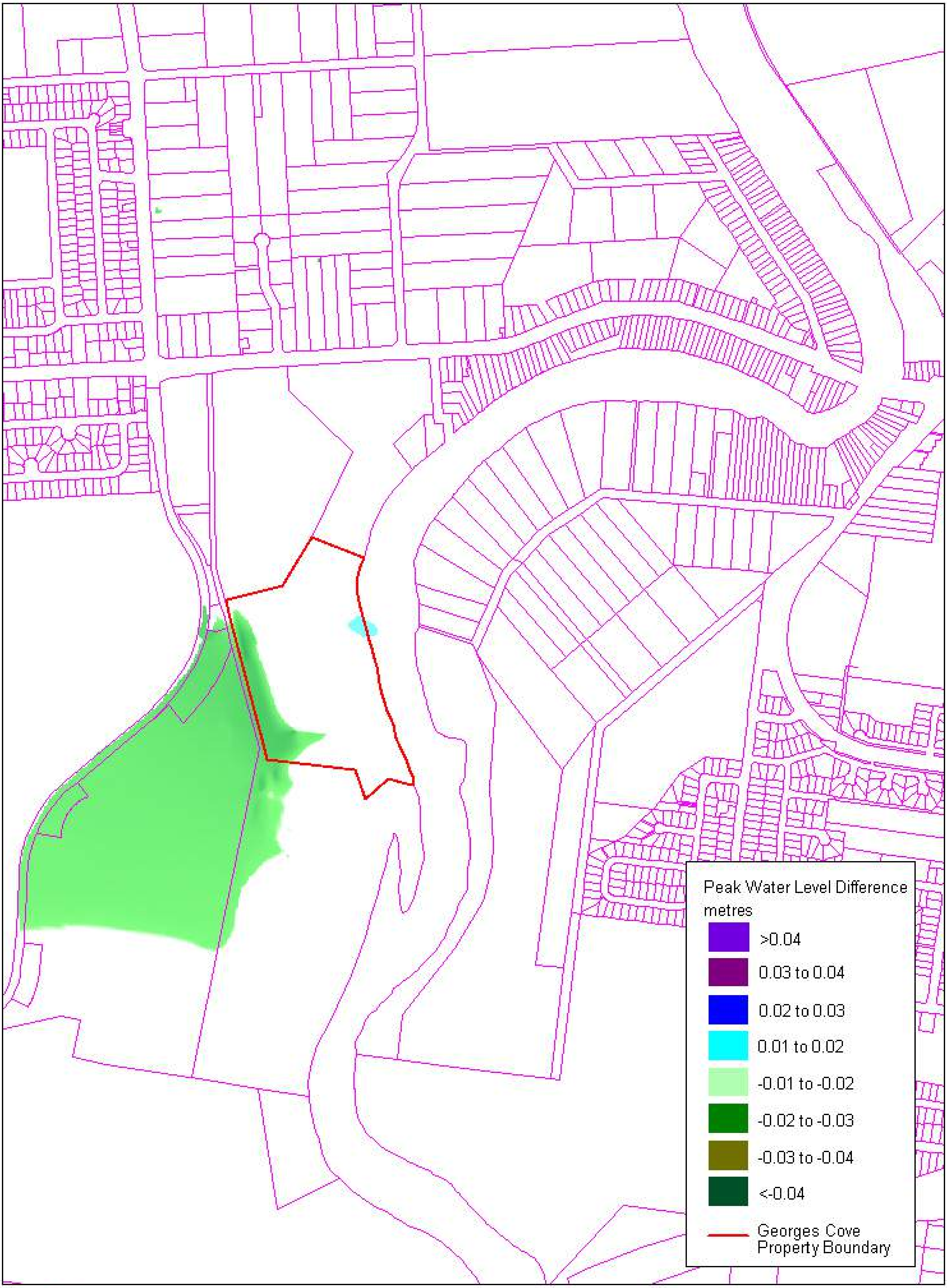
Georges Cove
Flood Impact Assessment

Figure 4-3
20 year ARI
Peak Water Level
Post-development-Blockage Less Predevelopment



Georges Cove
Flood Impact Assessment

Figure 4-4
100 year ARI
Peak Water Level
Post-development-Blockage Less Predevelopment

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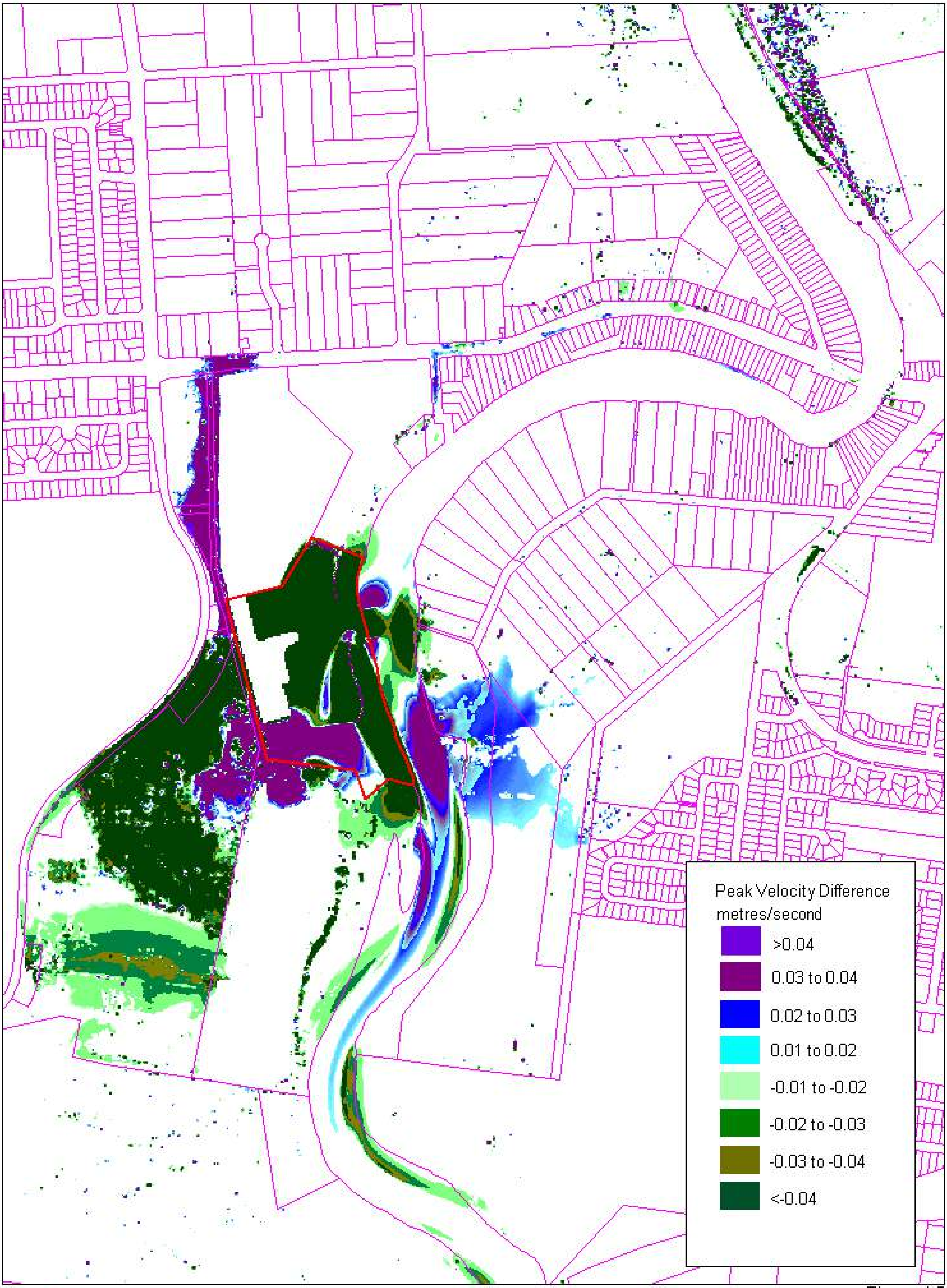

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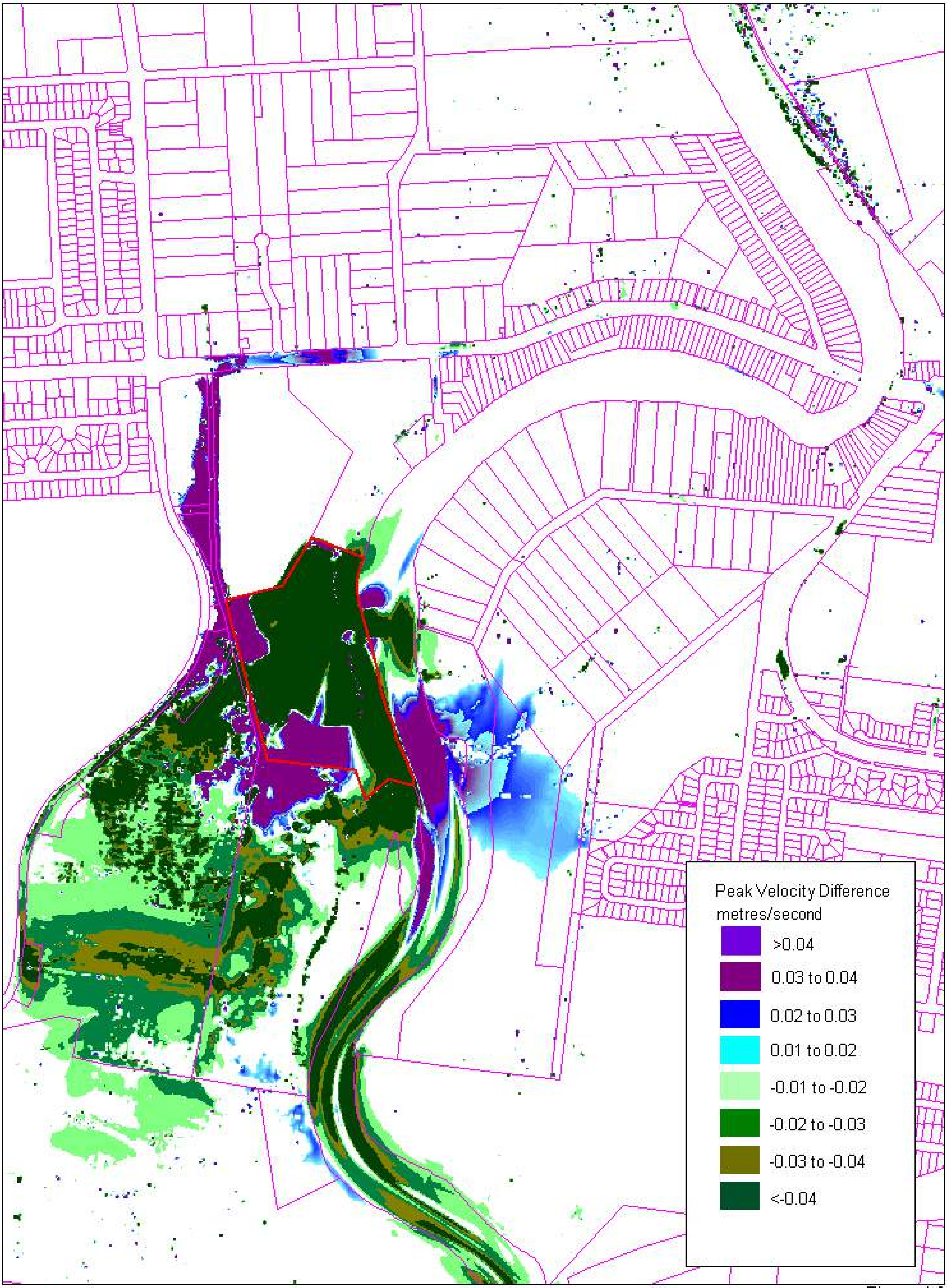
Georges Cove
Flood Impact Assessment

Figure 4-5
20 year ARI
Peak Water Velocity
Post-development Less Predevelopment



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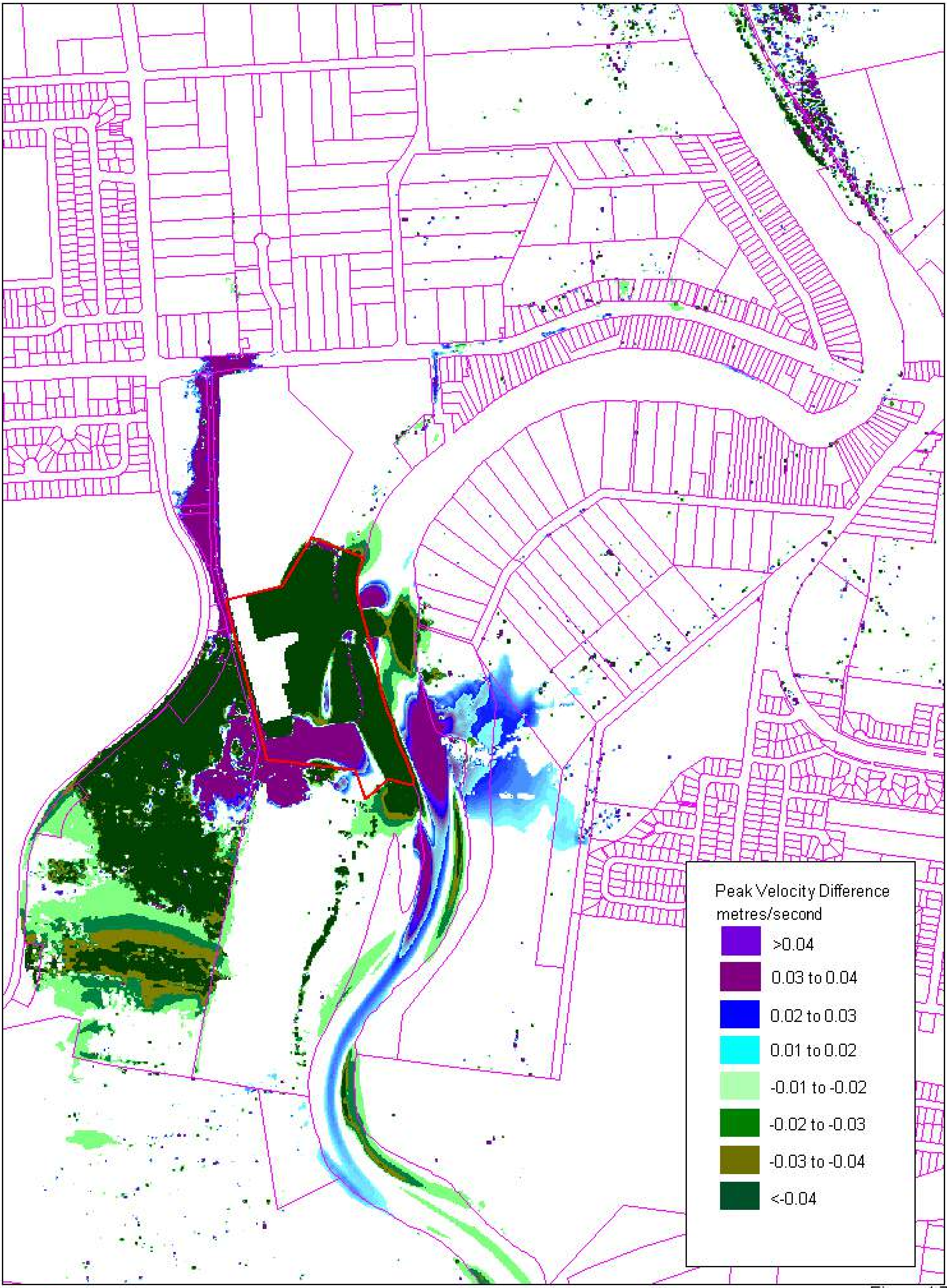
Georges Cove
Flood Impact Assessment

Figure 4-6
100 year ARI
Peak Water Velocity
Post-development Less Predevelopment



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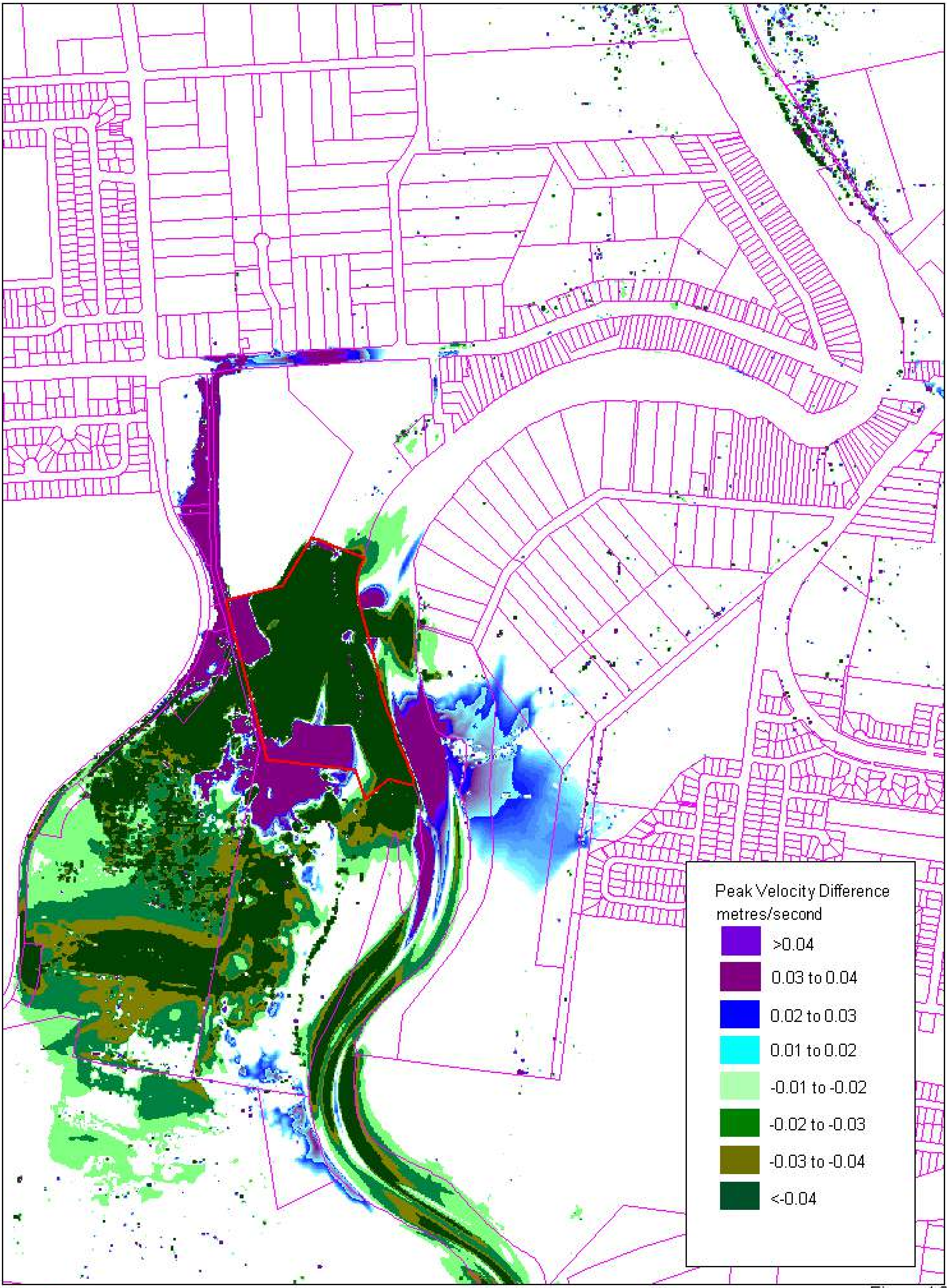
Georges Cove
Flood Impact Assessment

Figure 4-7
20 year ARI
Peak Water Velocity
Post-development-Blockage Less Predevelopment



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Georges Cove
Flood Impact Assessment

Figure 4-8
100 year ARI
Peak Water Velocity
Post-development-Blockage Less Predevelopment