STATE EMERGENCY SERVICE

TASMANIAN STRATEGIC FLOOD MAP WELCOME-DUCK STUDY AREA DESIGN FLOOD MODELLING

ADDENDUM TO CALIBRATION REPORT

MARCH 2023

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Project Tasmanian Strategic Flood Map Welcome-Duck Study Area Design Flood Modelling	**Project Number** **120038**
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Project Manager Fiona Ling	

Revision History

Revision	Description	Distribution	Authors	Reviewed by	Verified by	Date
0	Draft report for review	Chris Irvine, SES	Sarah Blundy, Holly Taylor, Evmen Wong	Daniel Wood	Fiona Ling	AUG 22
1	Design Report	Chris Irvine, SES	Sarah Blundy, Evmen Wong	Daniel Wood	Fiona Ling	AUG 22
2	Report with minor revisions	Chris Irvine, SES	Sarah Blundy, Evmen Wong	Daniel Wood	Fiona Ling	MAR 23

Cover image: Flooded Montagu River in far north west Tasmania October 2019. https://www.abc.net.au/news/2019-10-24/flooded-montagu-river-in-far-north-west-tasmania-october-2019-1/11632524?nw=0

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LIST OF ACRONYMS

AEP	Annual Exceedance Probability
AMS	Annual Maximum Series
ARF	Areal Reduction Factor
ARR	Australian Rainfall and Runoff
ATP	Areal Temporal Patterns
Bureau/BoM	Bureau of Meteorology
CC	Climate Change
CFEV	Conservation of Freshwater Ecosystem Values (DPIPWE/DNRE)
CL	Continuing Loss
DEM	Digital Elevation Model
DNRE	Department of Natural Resources and Environment Tasmania (formerly DPIPWE)
DPIPWE	Department of Primary Industries, Water and Environment
DRM	Direct Rainfall Method
DTM	Digital Terrain Model
FFA	Flood Frequency Analysis
FLIKE	Software for flood frequency analysis
FSL	Full Supply Level
GIS	Geographic Information System
GEV	Generalised Extreme Value distribution
HAT	Highest Astronomical Tide
HSA	Human Settlement Area
ICM	Infoworks ICM software (Innovyze)
IL	Initial Loss
IFD	Intensity, Frequency and Duration (Rainfall)
ISIS	ISIS 2D modelling software
LiDAR	Light Detection and Ranging
mAHD	meters above Australian Height Datum
NTC	National Tide Centre
PERN	Catchment routing parameter in RAFTS
Pluvi	Pluviograph – Rain gauge with ability to record rain in real time
PTP	Point Temporal Patterns
R	Channel routing param in WMAWater RAFTS WBNM hybrid model
RAF	RAFTS Adjustment Factor
RAFTS	hydrologic model
RCP	Representative Concentration Pathways (RCPs) (CC scenarios)
RORB	RORB hydrological modelling software
SES	State Emergency Service
TUFLOW	one-dimensional (1D) and two-dimensional (2D) flood and tide simulation software (hydrodynamic model)
TP	Rainfall Temporal Patterns

1. INTRODUCTION

This report is an addendum to the Tasmanian Strategic Flood Map Welcome-Duck Study Area Calibration Report (WMAwater, 2023). The study area, available data, model calibration, limitations and uncertainty statements are provided in the calibration report.

This report outlines the data, methodology and the results of modelling the design flood events for the Welcome-Duck Study Area.

2. DATA

2.1. Previous Flood Studies

There were no previous flood studies provided to WMAwater as part of the project data library.

2.2. Flow Data

Flood Frequency Analysis (FFA) was performed on annual maximum series (AMS) from flow gauges within the catchment. The gauges used for FFA are shown in Table 1. The other gauges in the study area were not included in the FFA due to insufficient record length, inconsistent datasets and/or unreliable rating curves. More detail on the quality of the gauge data is provided in the calibration report (WMAwater, 2023).

A local hydrodynamic model was used to create theoretical rating curves at the Duck River and Montagu River gauges (WMAwater, 2021c). At the Duck River the revised rating was applied to AMS events with a stage height of greater than 2m since 1989, when there was a significant shift in the existing rating curves. At Montagu River there was a data gap from 1990 to 1998, and the revised rating was applied to AMS events after this gap, with a recorded stage height over 4m, which is where the ratings diverged.

Table 1: Flow gauges used for FFA

Gauge number	Gauge name	River	Period of record	Number of points in AMS
14214-1	Duck River @ Scotchtown Rd	Duck River	1966-2020	55
14200-1	Montagu River at Stuarts Rd	Montagu River	1965-2020	46

2.3. Design Inputs

The design inputs used in the study (Intensity Frequency Duration (IFD) depths, losses, pre-burst rainfalls, Areal Reduction Factors (ARFs) and temporal patterns) were obtained through the ARR Data Hub (Babister et al, 2016) and the Bureau of Meteorology website (Bureau of Meteorology, 2019).

2.3.1. Design Rainfall Depths and Spatial Pattern

Intensity Frequency Duration (IFD) information was sourced from the Bureau of Meteorology website (Bureau of Meteorology, 2019). IFD information was sourced for each individual sub-catchment to give a spatial pattern across the study area. Examples of sub-catchment rainfalls are shown in Figure A 1 to Figure A 3.

2.3.2. Temporal Patterns

ARR 2016 Book 2 Chapter 5 (Ball et. al., 2019) recommends the use of areal temporal patterns for catchments greater than 75 km^2. Therefore, for the flood frequency analysis, the areal temporal patterns relevant to this location were downloaded from the ARR Data Hub. An example of the temporal patterns downloaded from the Data Hub is shown in Figure A 4.

For selection of the final design runs applicable to the entire study area, areal and point temporal patterns were downloaded from the ARR Data Hub. Temporal patterns were filtered for embedded bursts and in some cases patterns with large, embedded bursts causing significant outliers were removed. When assessing the reference critical flow for each sub-catchment (as described in the Hydrology Methods Report (WMAwater, 2021a)), point temporal patterns were used for sub-catchments with an upstream area of less than 75 km^2 or used to assess shorter storms if the critical duration on a larger catchment was identified as 12 hours (the shortest duration available with areal temporal patterns).

2.3.3. Pre-burst

Pre-burst rainfall depths were taken from the ARR Data Hub as a ratio of the IFD depths. As ILs calibrated to the FFA were greater than 0 there was no need to include sensitivity to adding a pre-burst temporal pattern for this study area, as the pre-burst has effectively been removed from the IL with some IL depth remaining.

2.3.4. Losses

Initial values for sub-catchment initial loss (IL) and continuing loss (CL) were derived from the unpublished Hydrologic Soil Groups of Tasmania data that was provided for use in this project (DPIPWE, 2019).

2.3.5. Baseflow

Baseflow was calculated for each calibration event and was found to be less than 5% of the event peaks. In line with ARR 2016 Book 5 Chapter 4 (Ball et. al., 2019), where baseflows of less than 5% are considered a small component compared to runoff, a simplified approach to baseflow calculations was undertaken. Hydrodynamic modelling of the calibration events showed that large flood events in this study area were peak rather than volume driven. Baseflows will be a small component of the hydrograph for the AEPs of interest (2%, 1% and 0.5%) and therefore baseflow was not included in the design events.

2.3.6. Direct Rainfall

Two hour direct rainfall storms were created using each sub-catchment's IFD depths using the method described in the Hydrodynamic Methods Report (WMAwater, 2021b).

2.3.7. Climate Change

2.3.7.1. Rainfall Factors

Climate change factors for the study area were downloaded from the ARR Data Hub. ARR recommends the use of the RCP4.5 and RCP8.5 values, however the Tasmanian Interim Planning Scheme recommends the use of RCP8.5 and this has been adopted for this project. Using RCP8.5 results for the year 2090, gives a rainfall scaling factor of 16.3% to the IFDs.

2.3.7.2. Boundary Conditions

Sea level rise was included in the climate change scenario and was applied at the downstream boundary of the hydrodynamic model. The rise in water level was taken from the Tasmanian Local Council Sea Level Rise Planning Allowances, which uses sea level rise projections based on RCP 8.5 for 2100. This gave a rise in sea level of 0.84 m for the Circular Head Council area.

The levels from this document were deemed most appropriate to be consistent with best practise planning around Tasmanian Councils.

3. OVERVIEW OF METHODOLOGY

The hydrological and hydrodynamic design modelling methodology has been outlined in the Hydrology Methods Report (WMAwater, 2021a) and the Hydrodynamic Methods Report (WMAwater, 2021b). Details on the methods are only included in this report where they deviate from the methods described in these reports or are specific for this catchment.

The modelling method for the design events includes the following steps.

- Data preparation
  - Fitting FFA to suitable flow records
  - Extraction of design data – IFDs, temporal patterns, pre-burst rainfalls from ARR DataHub (automated in the modelling process), derivation of direct rainfall storms
- Hydrologic modelling
  - Identification of flow gauge locations
  - Identification of dam and diversion locations
  - Sub-catchment delineation
  - Include dam storage and spillway ratings where required
  - Event calibration for PERN parameter and event losses, using automated WMAwater RAFTS modelling tool, IDW rainfall surfaces and available flow data.
  - Output event sub-catchment rainfalls, routing parameters and event losses for input to hydraulic model
  - Calibration of design losses to FFA using automated WMAwater RAFTS model
  - Run design events in WMAwater RAFTS modelling tool, with design data, calibrated routing parameters and design losses. Outputs design sub-catchment rainfalls for input to hydrodynamic model.
- Hydrodynamic modelling
  - Run design events and direct rainfall through the calibrated hydrodynamic model with the applicable downstream boundary levels and dam initial conditions.
  - Output design event and direct rainfall results for processing.
- Mapping
  - Convert design event and direct rainfall results to a grid format with a grid resolution of at least 10 m.
  - Envelope design event results to produce the maximum envelope of the inputs.
  - Filter direct rainfall results using a peak flood depth filter of 0.1 m. Clip direct rainfall results to the design event envelope.
  - Map the design event envelope and filtered direct rainfall results.

As discussed in the calibration report (WMAwater, 2023), the Welcome and Montagu River catchments were not able to be calibrated, due to no or little LiDAR coverage. As these areas were not calibrated and updated topographic data was not available, the design mapping in the Welcome and Montagu River catchments should be disregarded until such time that further modelling can be undertaken.

To achieve the best results in the Duck River catchment, the design event selection process (Section 5.1) and errors (Table 6) were focused on this part of the study area only. The Welcome and Montagu River catchments have been shown as areas of low confidence in the design mapping (Section 5.2).

Some deviations from the standard hydrology methods were required to achieve the required error bands for the Welcome Duck study area. The derived scaling factor for the continuing loss was giving very different runoffs in different parts of the catchment. It was determined that this extreme difference was unlikely to be representative of the true flood behaviour. Therefore, the standard continuing loss scaling was adjusted, giving smaller variability between CLs of different soil types.

During the design event selection process, it was discovered that the standard selection process could not select a small number of patterns which were viable across the catchment without the patterns with small ARFs (i.e. higher rainfalls) drowning out all patterns with more appropriate ARF factors in the lower catchment. This was even the case if 0 rainfalls were applied in downstream catchments, as there was enough volume from the upper catchment area to peak higher in the lower catchment. The selected patterns were therefore forcibly applied to their respective regions through the cropping of the design event results prior to the enveloping.

It is acknowledged that the cropping may result in abrupt changes in levels at the boundaries of the selected patterns in the design mapping (Section 5.2). Where possible, the boundaries of the selected patterns were located away from human settlement areas and major infrastructure to minimise the impact of the cropping. Discontinuities in the design mapping in isolated areas should still be expected, however this was deemed to be an acceptable compromise in achieving a better representation in the design mapping across the remainder of the study area.

4. CALIBRATION OF DESIGN LOSSES

FFA was undertaken at the gauges identified in Table 1. The results of the FFA are shown in Figure 1 and Figure 2. The fitting method and distribution that provided the best fit to the data at each site is shown in Table 2.

Table 2: Fitting method and distribution used for FFA

Gauge number	Gauge name	Fitting method	Distribution
14214-1	Duck River at Scotchtown Rd	Bayesian	GEV
14200-1	Montagu River at Stuarts Rd	Bayesian	Log Pearson III

The calibrated external hydrologic model for each study area was run through the solver and the initial and continuing losses that best matched the curve were estimated. As the events of relevance to this study are of 2% AEP or larger, the results were weighted to this end of the FFA curve. The catchment-average continuing loss was distributed across the study area using the hydrological soil group final infiltration rates.

Despite the issues with the hydrodynamic modelling in the Montagu River catchment, the Montagu River gauge has a long record length and less variability between the original and theoretical ratings, which gives more confidence in the AMS flows. Therefore, it was considered alongside the Duck River gauge for loss calibration.

Both gauges showed a mismatch between the slope of the modelled flows and the derived FFA curves. This resulted in fair to poor fits to the observed data (Table 3). The calibration aimed to keep the 2% and 1% modelled flows within the confidence intervals at both sites. Due to the overall poor match in slopes some sensitivity analyses were undertaken using the different rating curves available at each site. Changing the rating curves did not result in a meaningful change in the modelled fit to estimated FFA. There is a change in slope of the IFDs at the 1% AEP in many areas across Tasmania which may partially explain the large errors at the 0.5% AEP; this is discussed further in Section 5.2.1.

Table 3: FFA and modelled peak flows

	Duck River			Montagu River		
Parameter	**2% AEP**	**1% AEP**	**0.5% AEP**	**2% AEP**	**1% AEP**	**0.5% AEP**
FFA peak flow (m^3/s)	85	96	107	57	61	65
Modelled peak flow (m^3/s)	79	104	150	50	65	92
Peak flow difference (%)	-7%	9%	40%	-13%	6%	42%

The adopted loss values are shown in Table 4, and comparisons to site FFAs are shown in Figure 1.

Table 4: Adopted losses

Initial Loss (mm)	Continuing Loss (mm/h)			
	Soil Type A	Soil Type B	Soil Type C	Soil Type D
5	4.4	3.4	2.6	2.2

5. DESIGN EVENT MODELLING

5.1. Design Event Selection

Design inputs were run through the hydrological model across the entire study area with a range of ARFs to select representative ARFs, storm durations and temporal patterns to be run through the hydrodynamic model. The selected storms and the number of sub-catchments best represented by each are shown in Table 5. The temporal patterns for each selected run are shown in Figure 3 and Figure A 4.

Storms with smaller ARF bins are not valid for the main river with large accumulated upstream areas, as rainfalls have not been adjusted down by an appropriate ARF. In initial runs some ARF-duration-TP sets with small (<= 75 km^2) ARFs were being selected along the main river, in areas with a large upstream catchment area (> 75 km^2). Therefore, for the model runs with an ARF bin of 75 km^2 or less, the main river sub-catchments (upstream areas > 75 km^2) were assigned 0 mm rainfall. In some parts of the study area, even with 0 rainfall applied, the smaller ARF patterns were drowning out the more appropriate bins. Therefore, in some places the resulting grids were cropped to the appropriate areas, as detailed in Section 3.

Table 5: Selected storms for each AEP with the number of sub-catchments best represented by each set

AEP	Storm duration (min)	ARF bin	# sub-catchments
2%	60	25	5
2%	720	45	21
2%	1080	250	35
1%	60	25	3
1%	720	45	23
1%	1080	250	35
0.5%	60	25	1
0.5%	720	45	25
0.5%	1080	250	35

Diagram 1 shows the ARF-duration-TP set used to give representative flows for each sub-catchment for the 1% AEP event. Headwater sub-catchments where only direct rainfall is applied are also shown. In the headwater catchments, direct rainfall was defined as the dominating event, with the rainfall intensities factored to account for losses via a runoff coefficient. For this study area, a runoff coefficient of 60% was adopted. Although direct rainfall is applied to all sub-catchments, the mapping process detailed in Section 3 ensures that primary flow paths are not defined by this event.

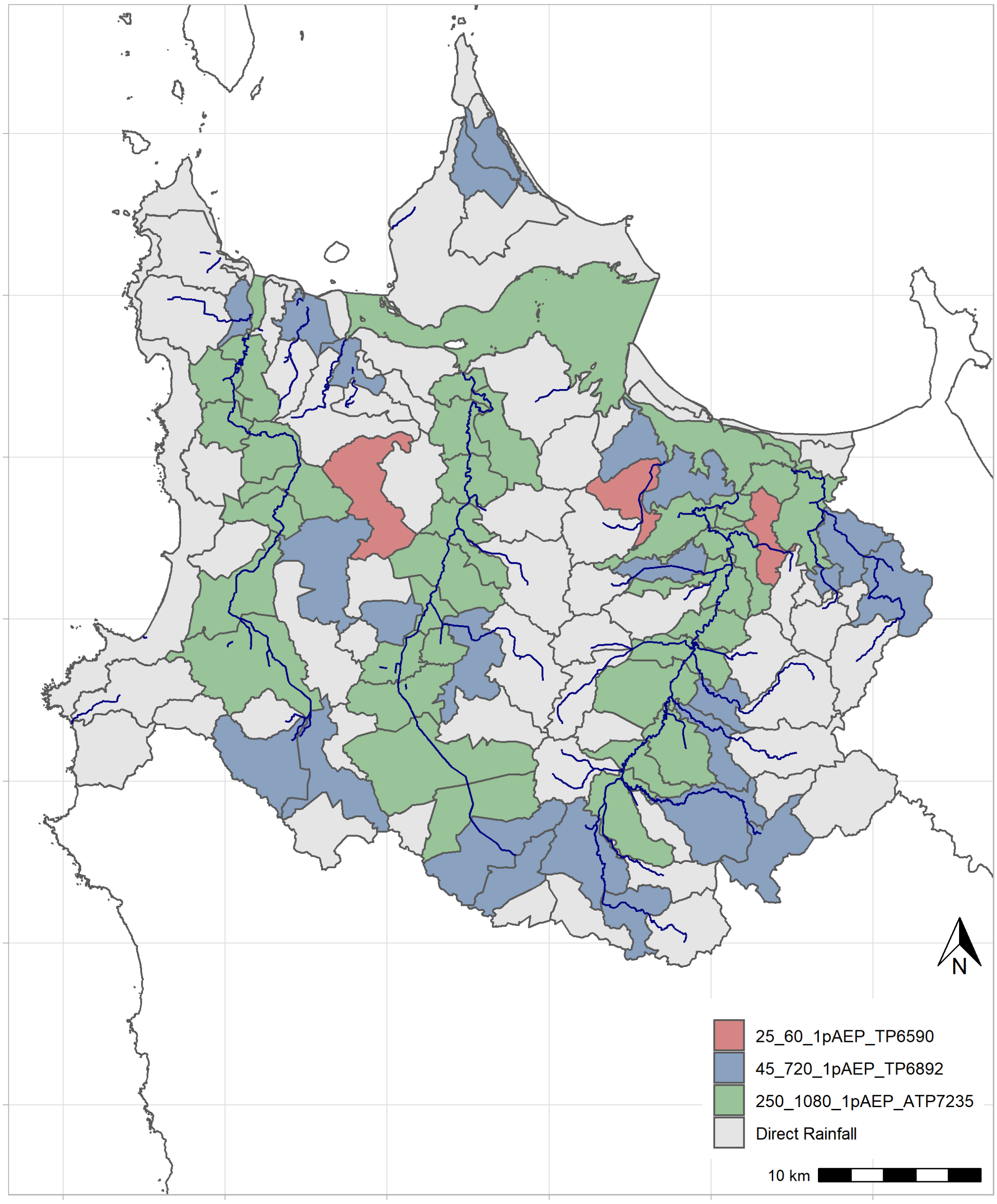

Diagram 1: ARF set relevant for each sub-catchment for the 1% AEP event

The selection of three ARF-duration-TP sets per AEP does introduce errors when compared to running the ideal ARF-duration-TP set through the hydrodynamic model for each sub-catchment, however running thousands of runs of the hydrodynamic model is not computationally feasible. The percentage errors for each sub-catchment are shown in Figure B 1 to Figure B 3 and a summary of the magnitude of the errors for the Duck River catchment is shown in Table 6. Each sub-catchment's absolute percentage error is calculated using the following equation:

$SC\_Q\_Peak_{ref}$ = Sub-catchment peak flow run with ARF from that sub-catchment's ARF bin, with critical duration calculated at this gauge, and TP above the mean selected.

$SC\_Q\_Peak_{sel}$ = Sub-catchment peak flow run with ARF, storm duration and TP from the selected pattern as shown in Diagram 1

$$\text{Absolute subcatchment percentage error} = \left| \frac{(\text{SC\_Q\_Peak}_{sel} - \text{SC\_Q\_Peak}_{ref})}{\text{SC\_Q\_Peak}_{ref}} \right| \times 100$$

Table 6: Sub-catchment errors using the ARF-TP-duration sets shown in Table 5 for each AEP in the Duck River catchment

AEP	Absolute sub-catchment error		
	Mean across sub-catchments	**90th %ile across sub-catchments**	**Max of all sub-catchments**
2%	4.3%	9.1%	9.7%
1%	4.1%	7.3%	7.8%
0.5%	2.7%	4.5%	6.3%

The selected storms and direct rainfall were then run through the calibrated hydrodynamic model as documented in the calibration report (WMAwater, 2023). For the design event modelling, a static tailwater level set to the highest astronomical tide was adopted for the downstream boundary. This data was provided by the National Tide Centre (NTC) in 5 km² grid cells, and the mean value of these grid cells within the study area was used.

Table 7 below summarises the downstream boundary levels and dam initial conditions for each design event.

Table 7. Downstream boundary levels and dam initial conditions for each AEP

AEP	Downstream boundary	Mikany Dam
2%	HAT (1.25 mAHD)	FSL (35.4 mAHD)
1%		
0.5%		
1% CC	HAT + sea level rise (2.09 mAHD)	

The following items were raised in the calibration report as items that may require further attention in the design modelling (data permitting):

- A breach was incorrectly applied to the river channel between the quarry in Smithton and the Duck River bridge in the supplied DEM, resulting in erroneous levels being applied to the river channel (Section 5.1 of the calibration report).

Additional data was not available to enable the further refinement of the river channel.

5.2. Design Event Results

The results of the design event modelling are shown in Figure 4 to Figure 19 in terms of peak flood level, depth, velocity, and hydraulic hazard for the 2%, 1%, 1% CC, and 0.5% AEP design events. The results shown are of the design event envelope and filtered direct rainfall results, as detailed in Section 3. A critical event plot for the 1% AEP design event is provided in Figure 20.

It is noted that bathymetry of Duck Bay was not available in the supplied DEM (which adopts a value of -10 mAHD through this area). It is recommended that the design mapping in this area is disregarded until such time updated topographic data is available and further modelling is undertaken. The Welcome and Montagu River catchments have been shown as areas of low confidence in the design mapping, as discussed in Section 3.

For direct rainfall only, in some areas the peak flow for headwater catchments was found to be higher in the hydrodynamic model than in the external hydrologic model. To ensure that the overestimation of these peak flows in the headwater catchments would not impact the design results, the direct rainfall results were clipped to the design event envelope.

The outcomes of the design event modelling have been reviewed against the gauge FFA. There were no existing studies provided to compare design extents and levels to.

5.2.1. Review of Results at Duck River u/s Scotchtown Road

A review of the design flows produced from the hydrodynamic model at Duck River u/s Scotchtown Road was undertaken, by comparing to the flows derived from the FFA. The modelled peak flows show a fair to poor match to the 2% and 1% AEP FFA peak flows at this location (Table 8), as discussed in Section 4. There is an overestimation in the 0.5% AEP. There is a notable change in slope in the IFD rainfalls in many areas across Tasmania (example shown in Diagram 2) which results in a widescale trend of overestimation of the modelled 0.5% AEP event when using the same losses as the 1% AEP.

A breakout along Geales Creek, just upstream of the Duck River confluence and about 900 m upstream of the Duck River gauge, was observed in the 1% and 0.5% AEP events. At these events, flows appear to breakout of Geales Creek, over Giddens Road, across the fields to the north, and re-join Duck River about 700 m downstream of the gauge.

As the July 2000 event used in calibration is smaller than the 1% and 0.5% AEP events, the function of the breakout was not able to be verified in calibration. Further detailed modelling in the area should look to verify this breakout, as it may influence the flood levels along the 1.6 km section of Duck River, depending on the true distribution of flows. If there is a breakout from the river, then flows at the gauge will be impacted for larger events.

Table 8: Design flows at Duck River u/s Scotchtown Road

Parameter	2% AEP	1% AEP	1% AEP CC	0.5% AEP
Modelled peak flow (m3/s)	81	116	177	178
FFA peak flow (m3/s)	85	96	n/a	107
Peak flow difference (%)	-5%	+21%	n/a	+66%

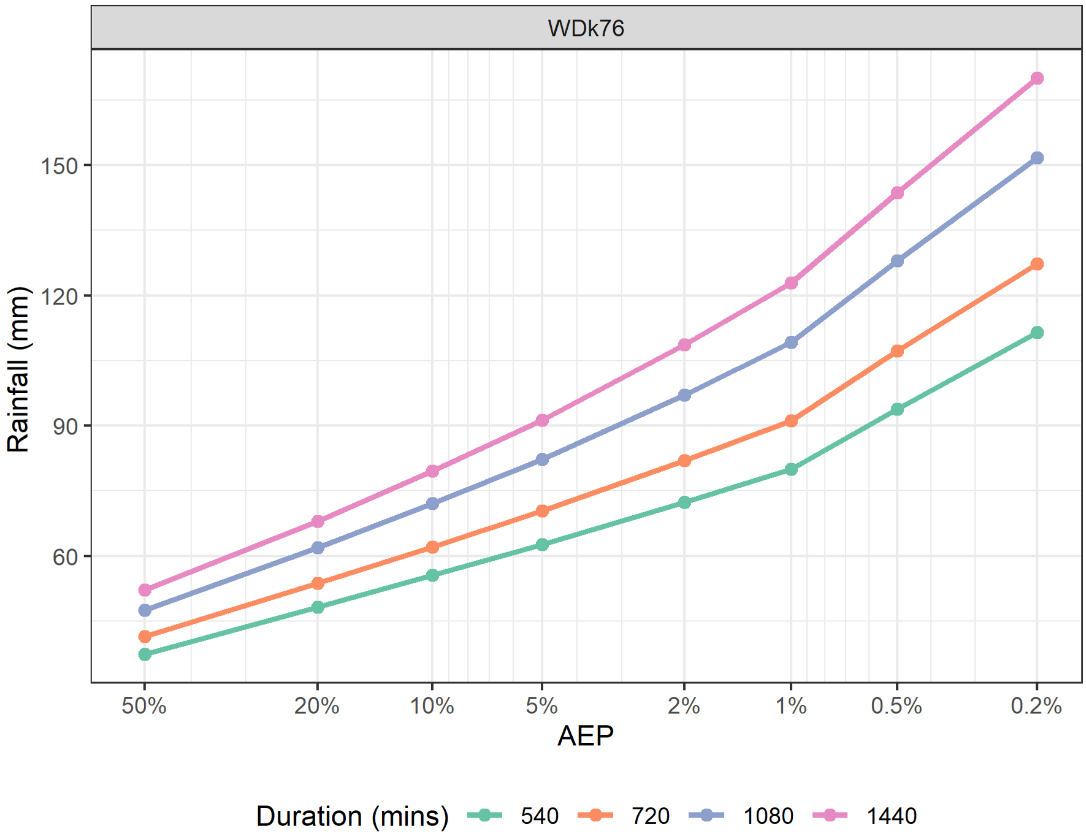

Diagram 2 Sub-catchment IFD rainfall totals showing change in slope at 1% AEP

6. LIMITATIONS

A detailed uncertainty assessment of the data, hydrological calibration and hydrodynamic model is contained in the Welcome-Duck Report (WMAwater, 2023)

As discussed in Section 3, the design mapping in the Welcome and Montagu River catchments should be disregarded until such time that further modelling can be undertaken. To achieve the best results in the Duck River catchment, the design event selection process was focused on this part of the study area only.

The selection of limited duration-TP-ARF sets introduces some errors across the catchment as described in Section 5.1. This is appropriate for a regional method, however site-specific ARFs, critical durations and TP selection should be used for detailed design modelling at specific locations. In this study area, some deviations from the standard methods were required to achieve the required error bands for the Duck River catchment. Discontinuities in the design mapping in isolated areas should be expected

As noted in Section 5.2, the design mapping in Duck Bay should be disregarded until such time that updated topographic data is available and further modelling is undertaken. It was also noted that there is some uncertainty introduced by the direct rainfall application on the headwater catchments. While the method used is appropriate for broad scale mapping, a full design event assessment should be undertaken for any future focussed studies in this area.

It is acknowledged that there is a poor match between the modelled and FFA peak flow at the Duck River gauge, particularly for the 0.5% AEP event (Table 8). Uncertainties in gauge rating curves, the quality of the DEM, and lack of bathymetry limit the ability to reduce errors in this regional assessment. There is also some uncertainty in 0.5% AEP design rainfall estimates over many areas of Tasmania. It is recommended that these issues are further investigated and that improved survey and topographic data is used if further detailed studies are undertaken in this area.

7. REFERENCES

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Figures

FIGURE 1

Duck River at Scotchtown Road

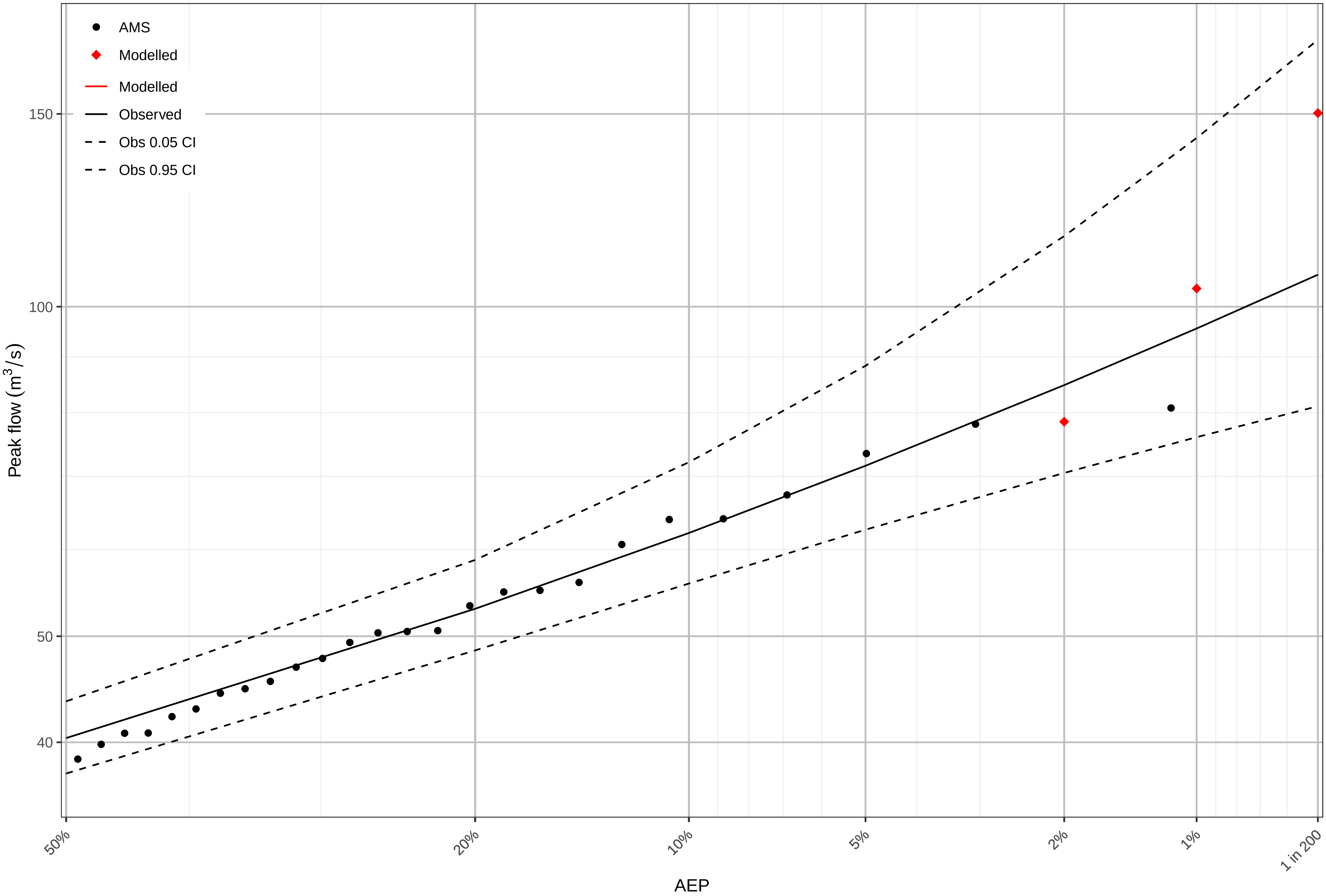


FIGURE 2

Montagu River at Stuarts Rd

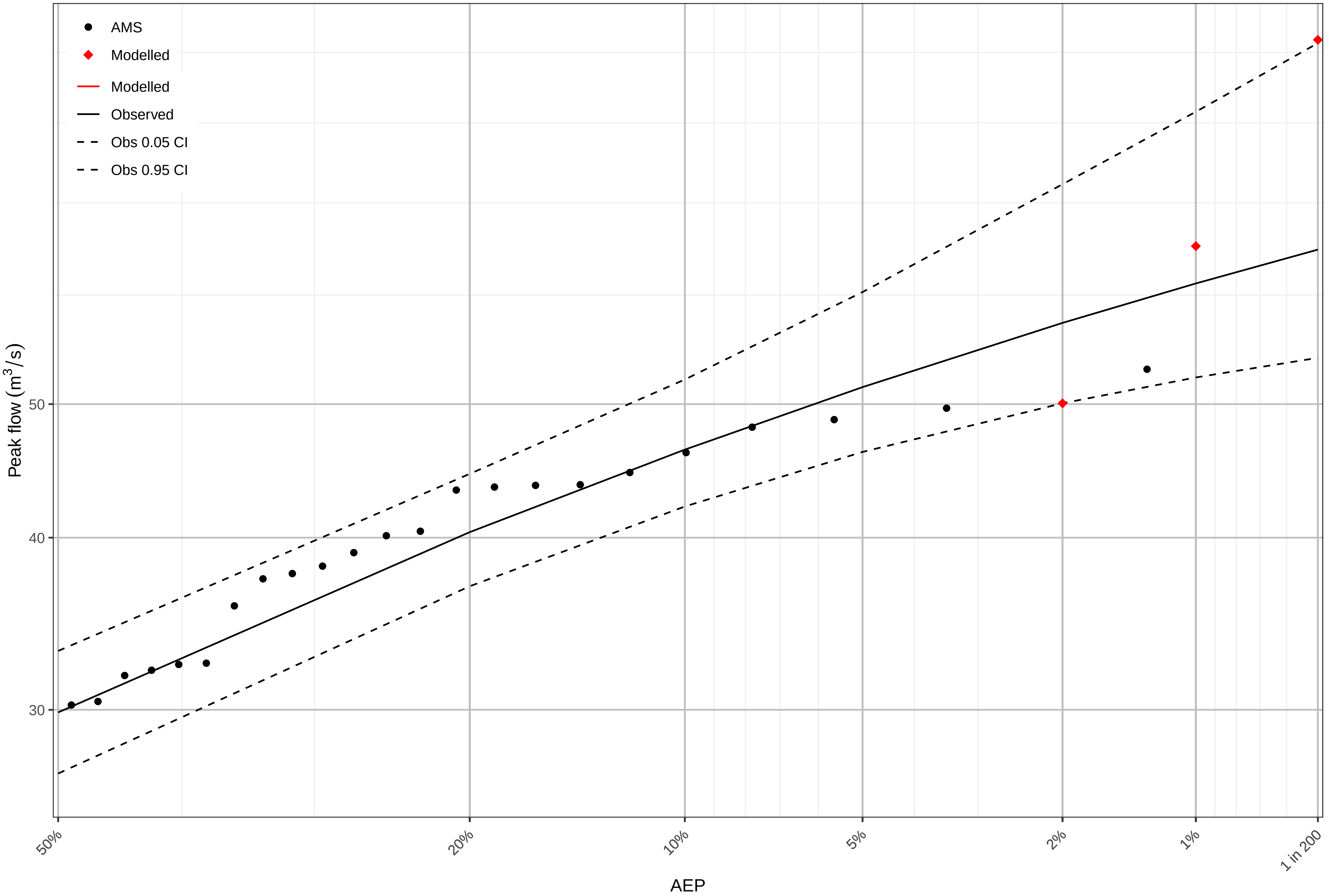
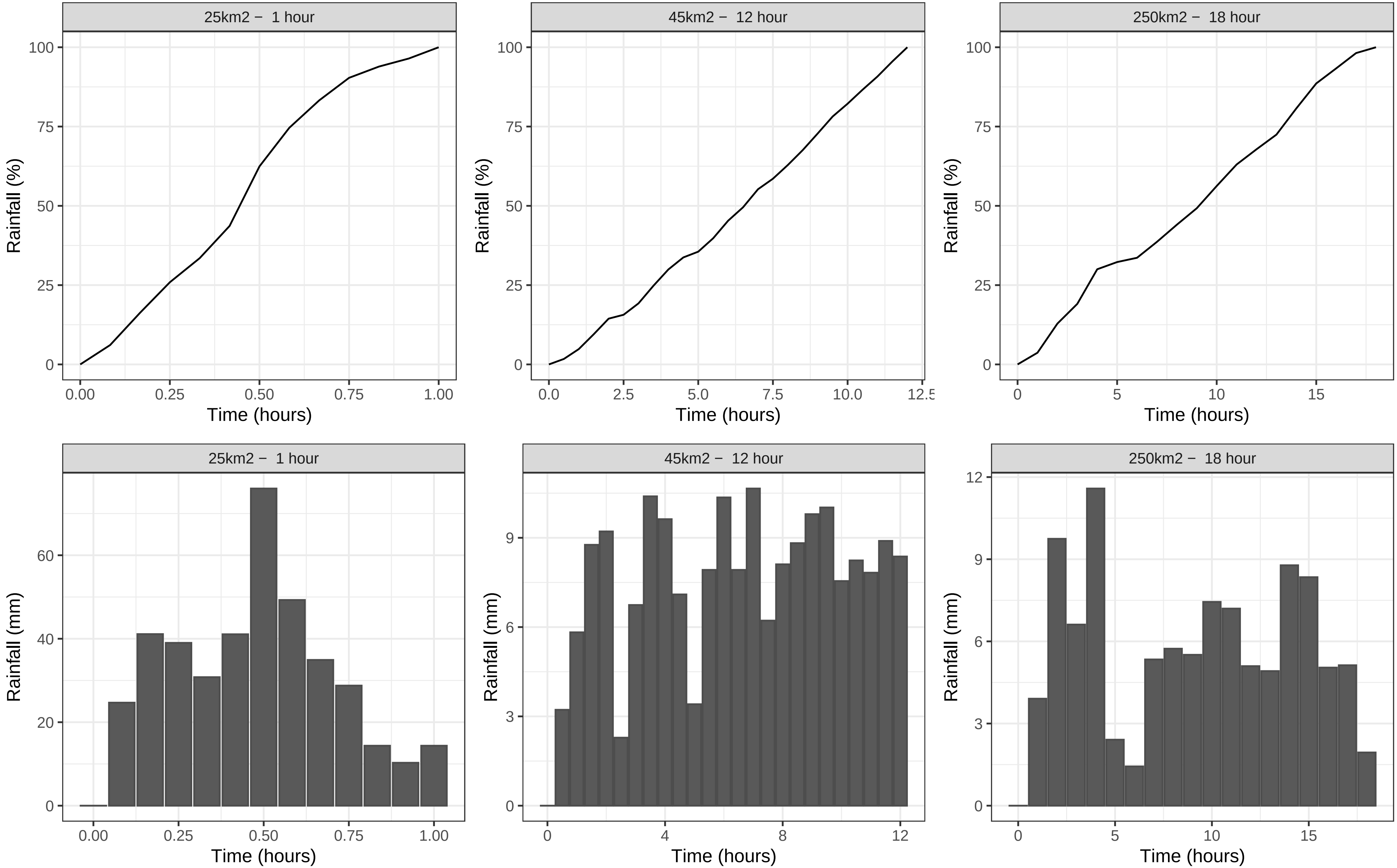


FIGURE 3

SELECTED DESIGN TEMPORAL PATTERNS ALL AEPS BY STORM DURATION AND ARF AREA



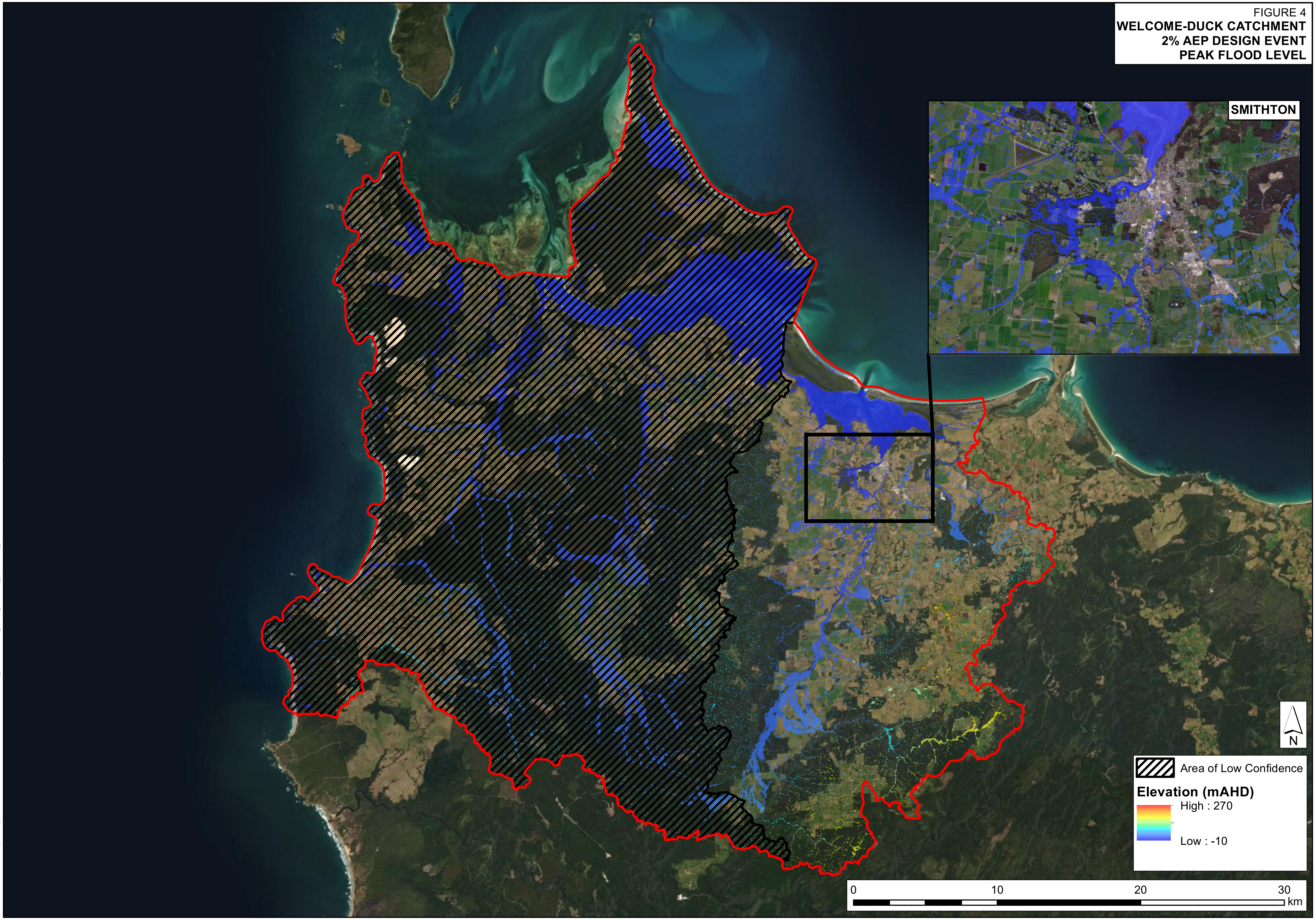


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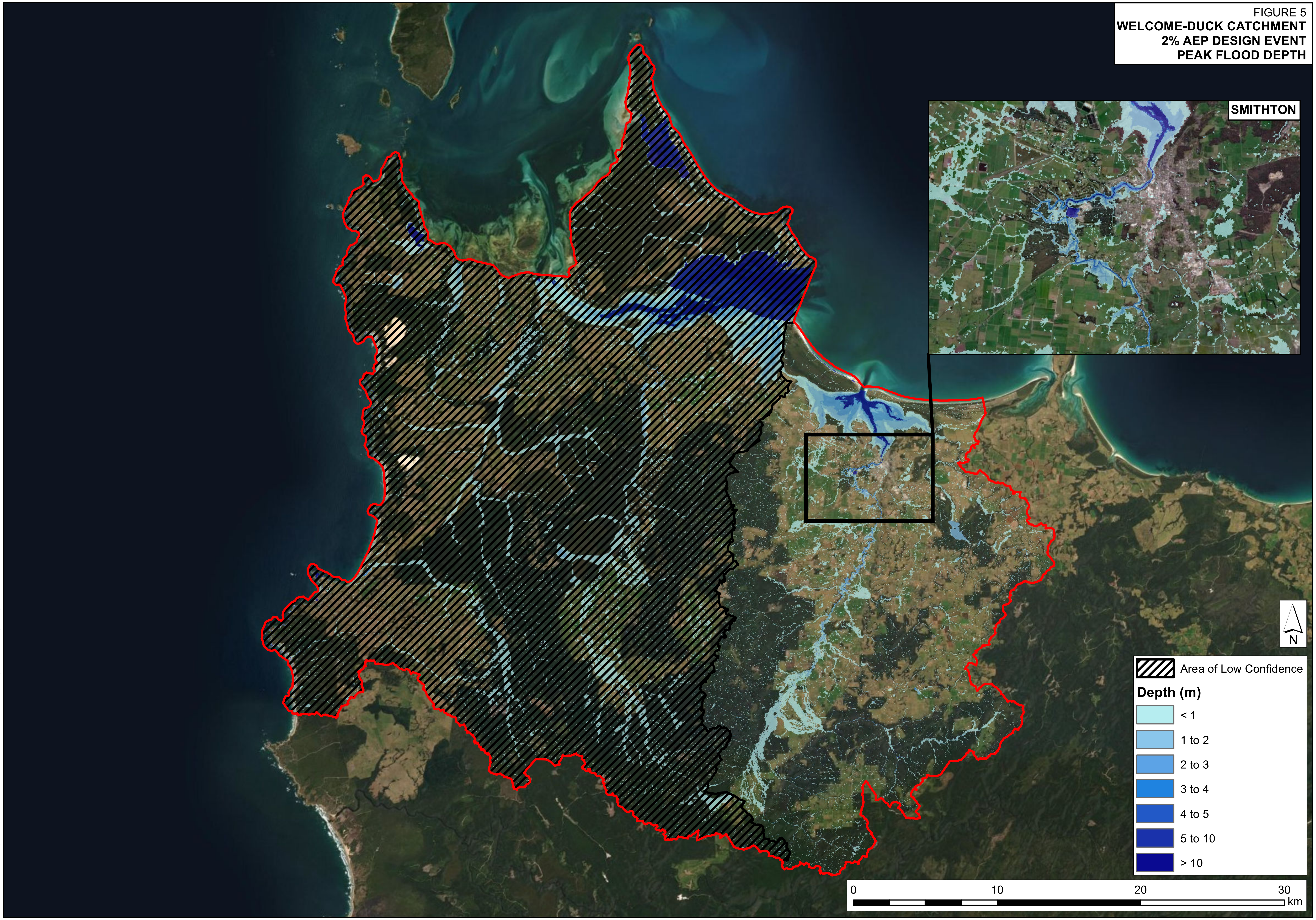
FIGURE 5
WELCOME-DUCK CATCHMENT
2% AEP DESIGN EVENT
PEAK FLOOD DEPTH



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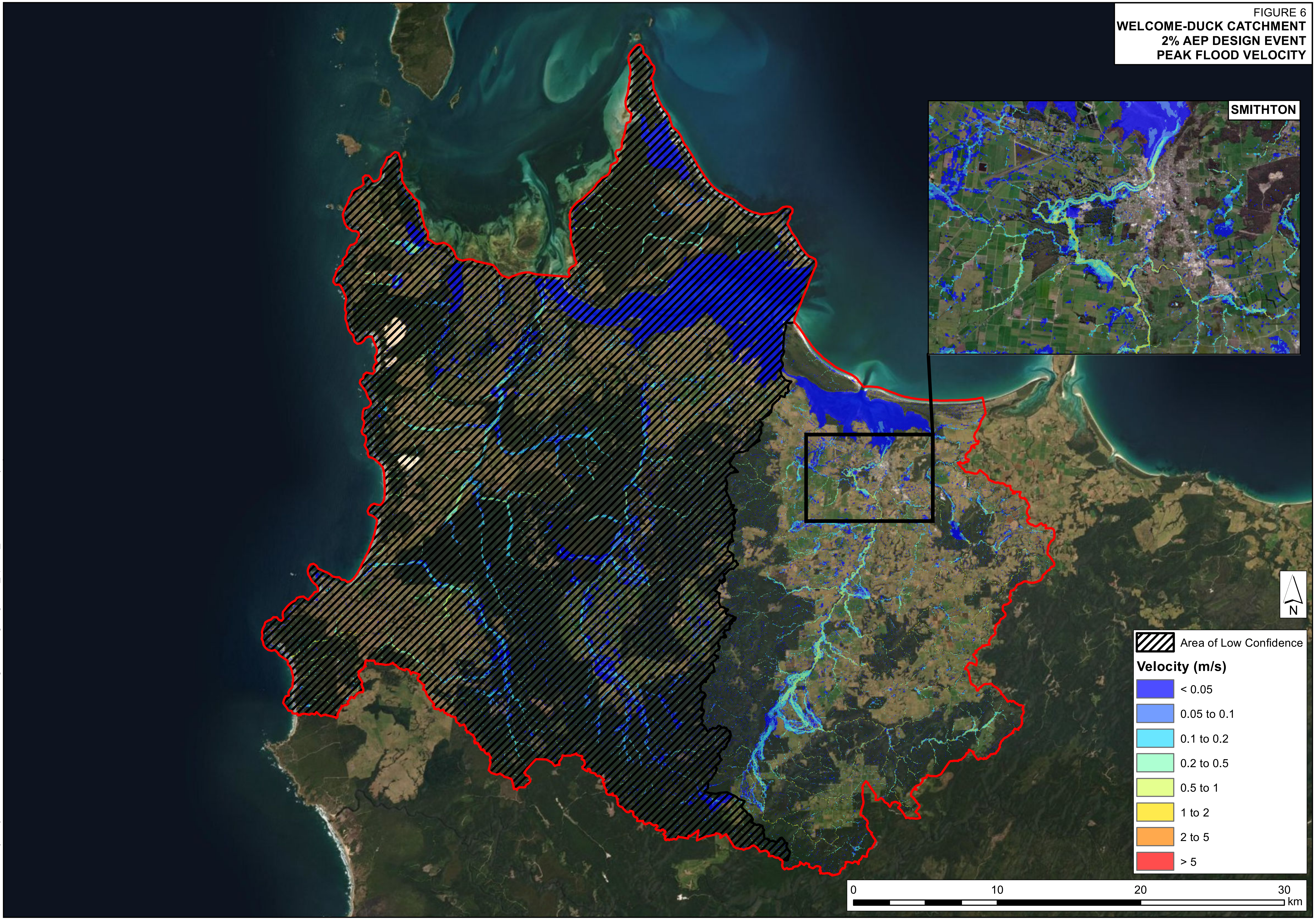

FIGURE 6
WELCOME-DUCK CATCHMENT
2% AEP DESIGN EVENT
PEAK FLOOD VELOCITY
SMITHTON
N
Area of Low Confidence
Velocity (m/s)
< 0.05
0.05 to 0.1
0.1 to 0.2
0.2 to 0.5
0.5 to 1
1 to 2
2 to 5
> 5
0
10
20
30
km
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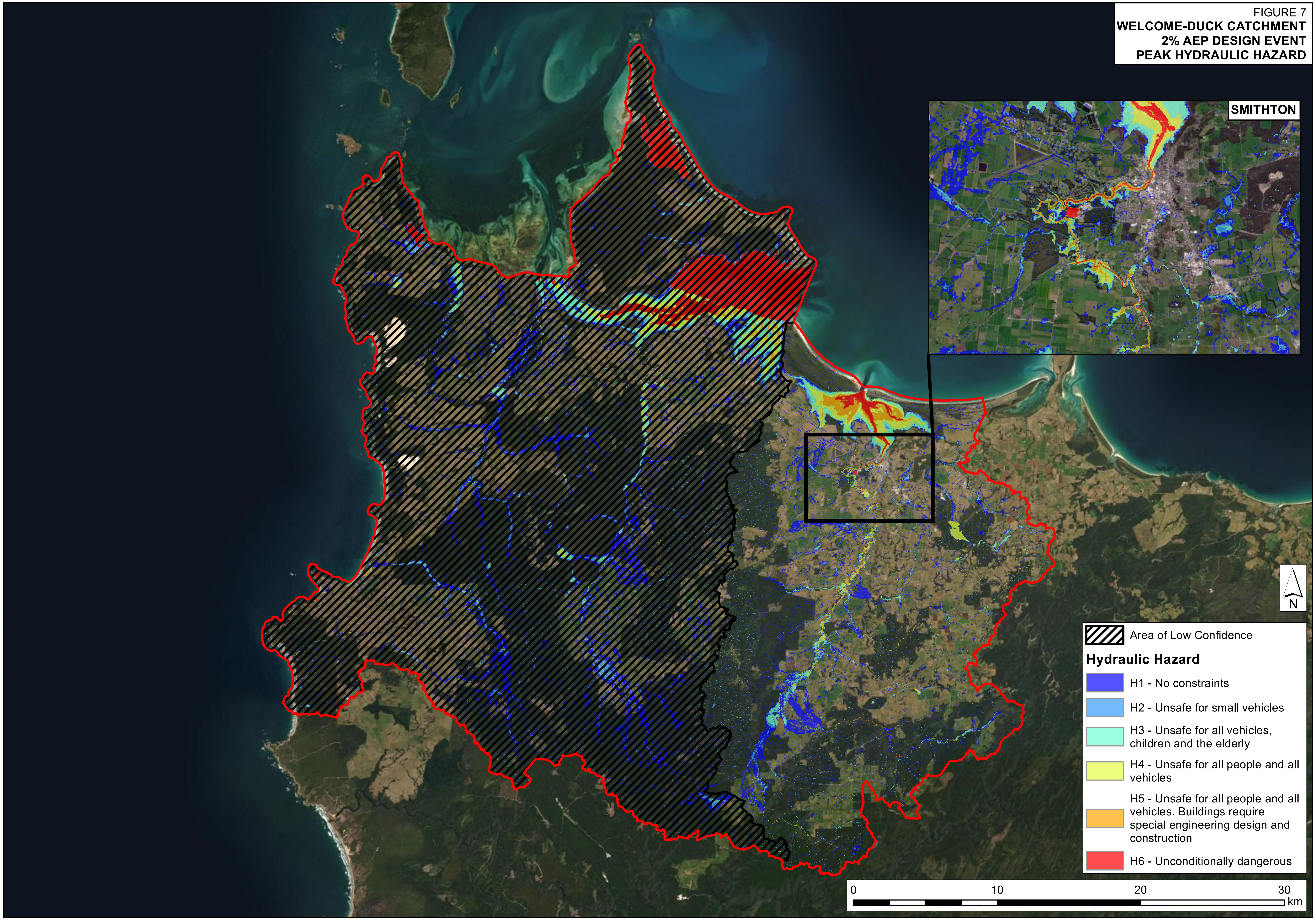

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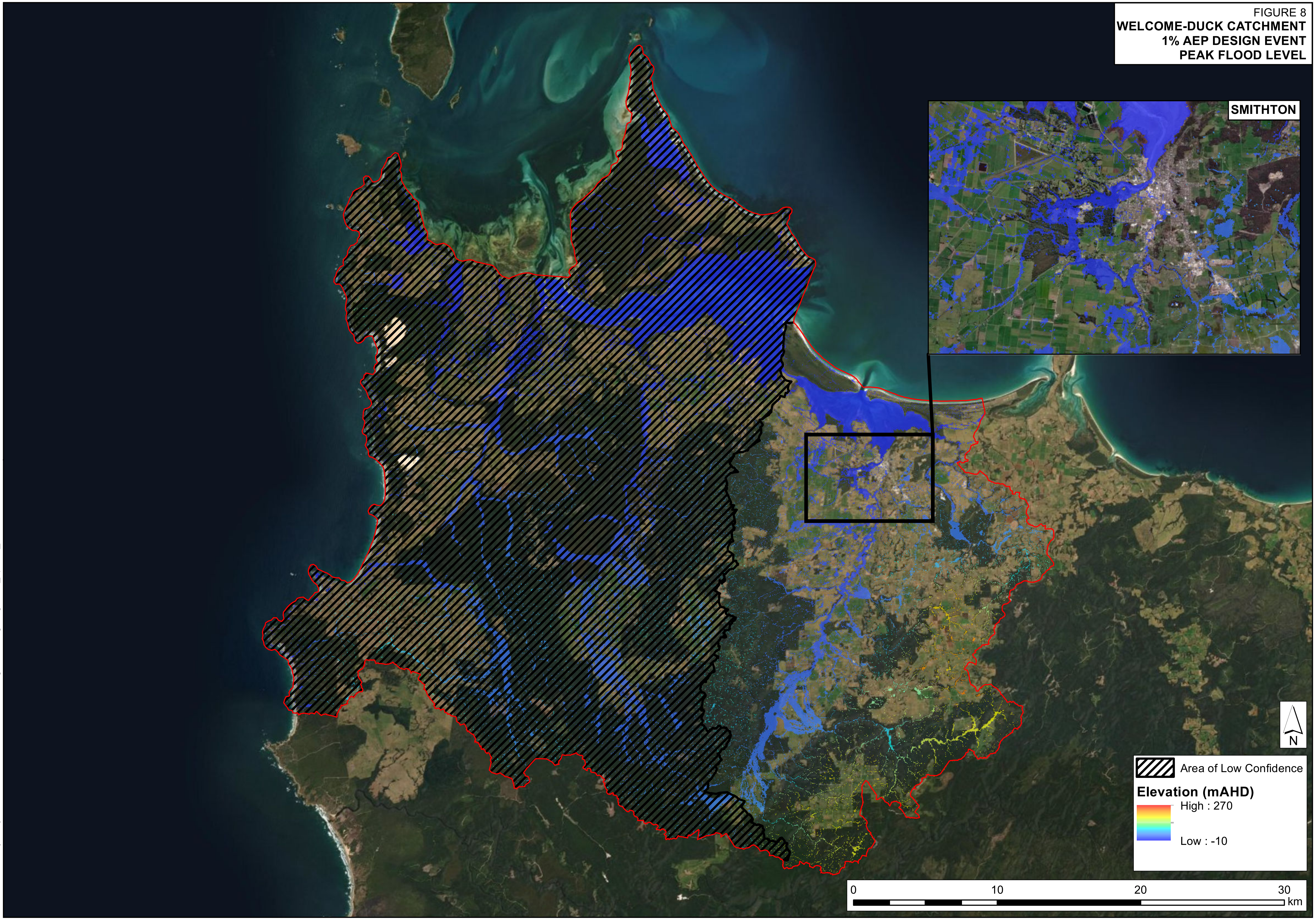

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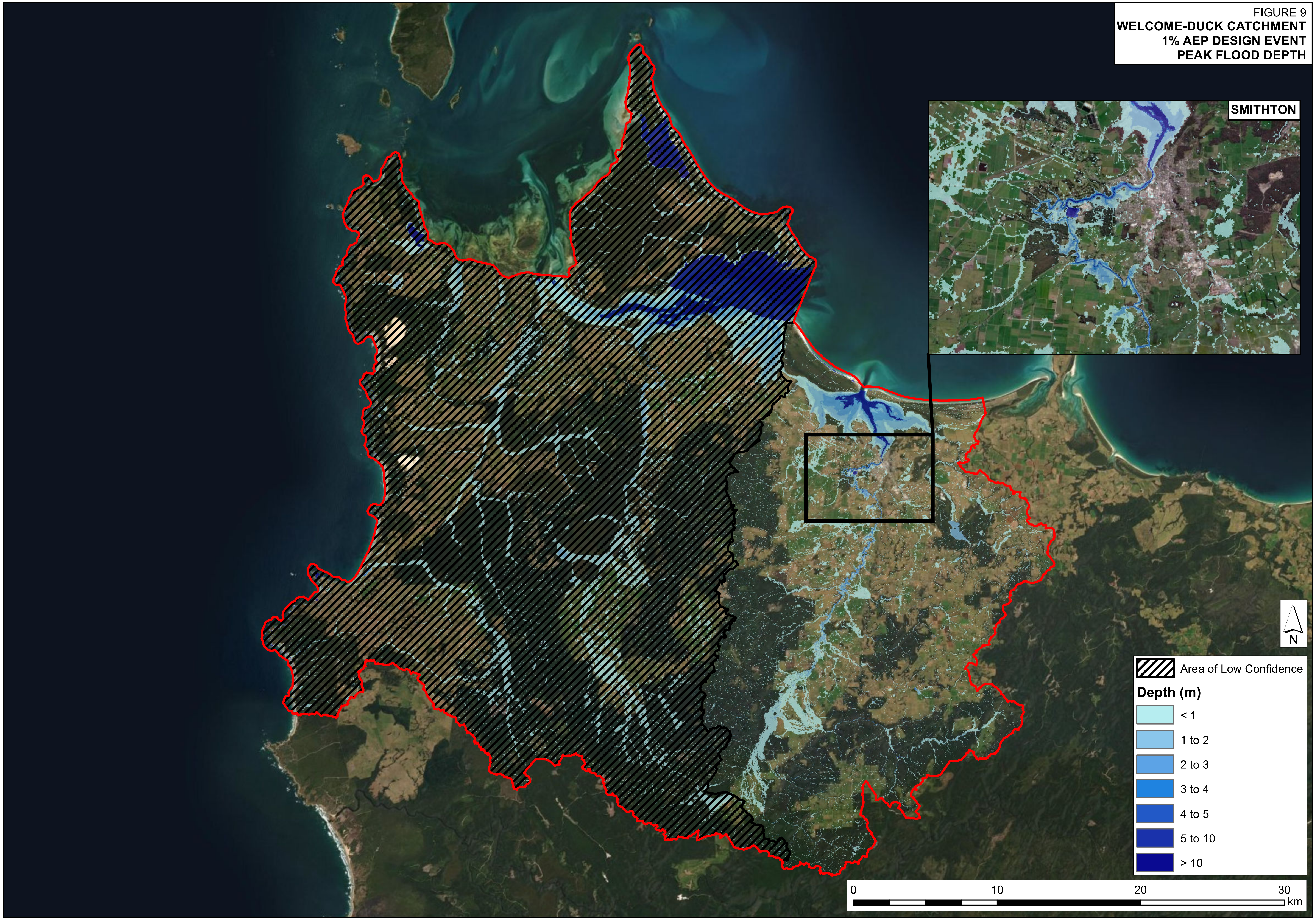
FIGURE 9
WELCOME-DUCK CATCHMENT
1% AEP DESIGN EVENT
PEAK FLOOD DEPTH



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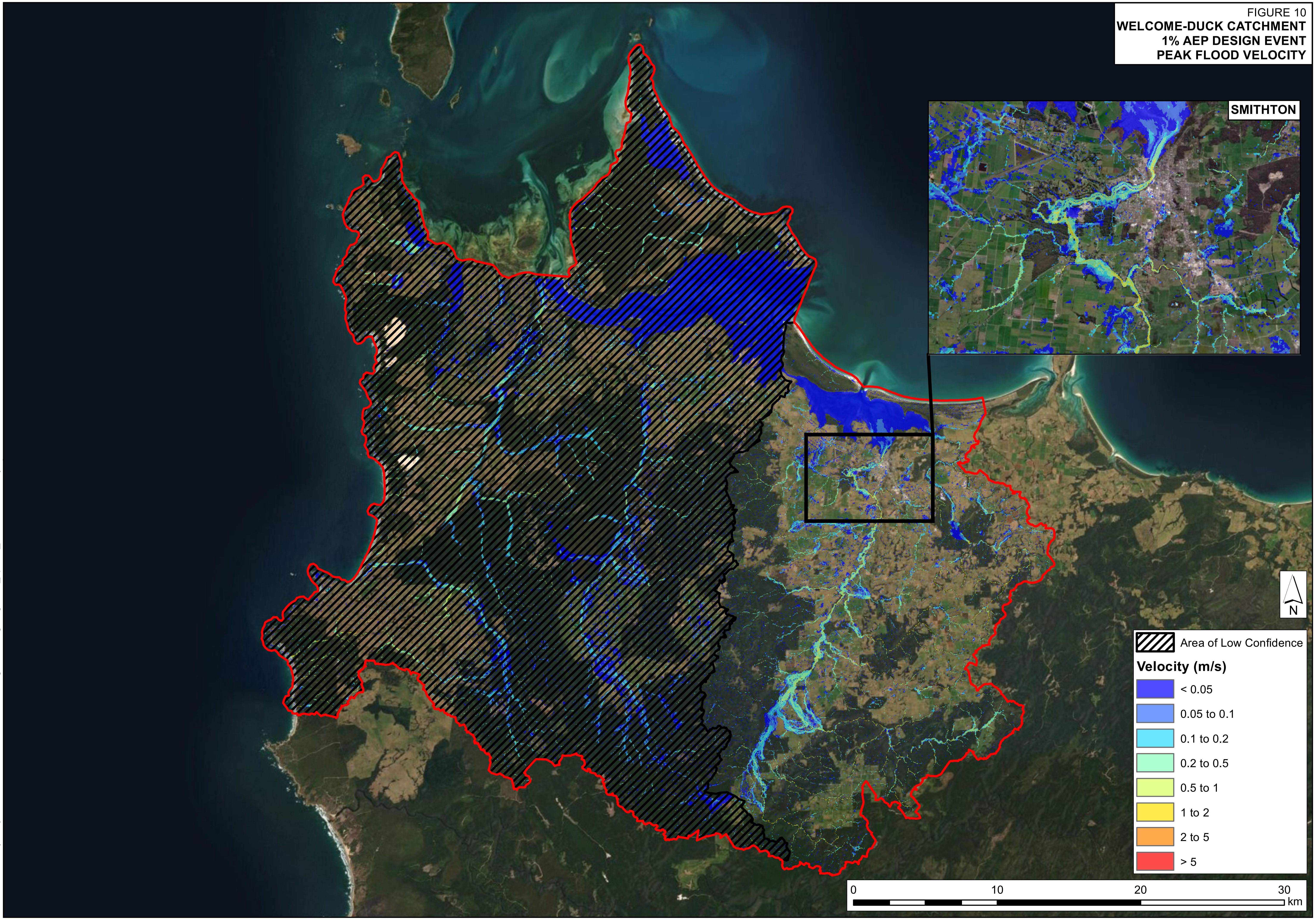


J:\Jobs\120038\Hydrodynamic\Statewide\Welcome-Duck\Figures\Design\Figure10_1pAEP_PeakFloodVelocity.mxd

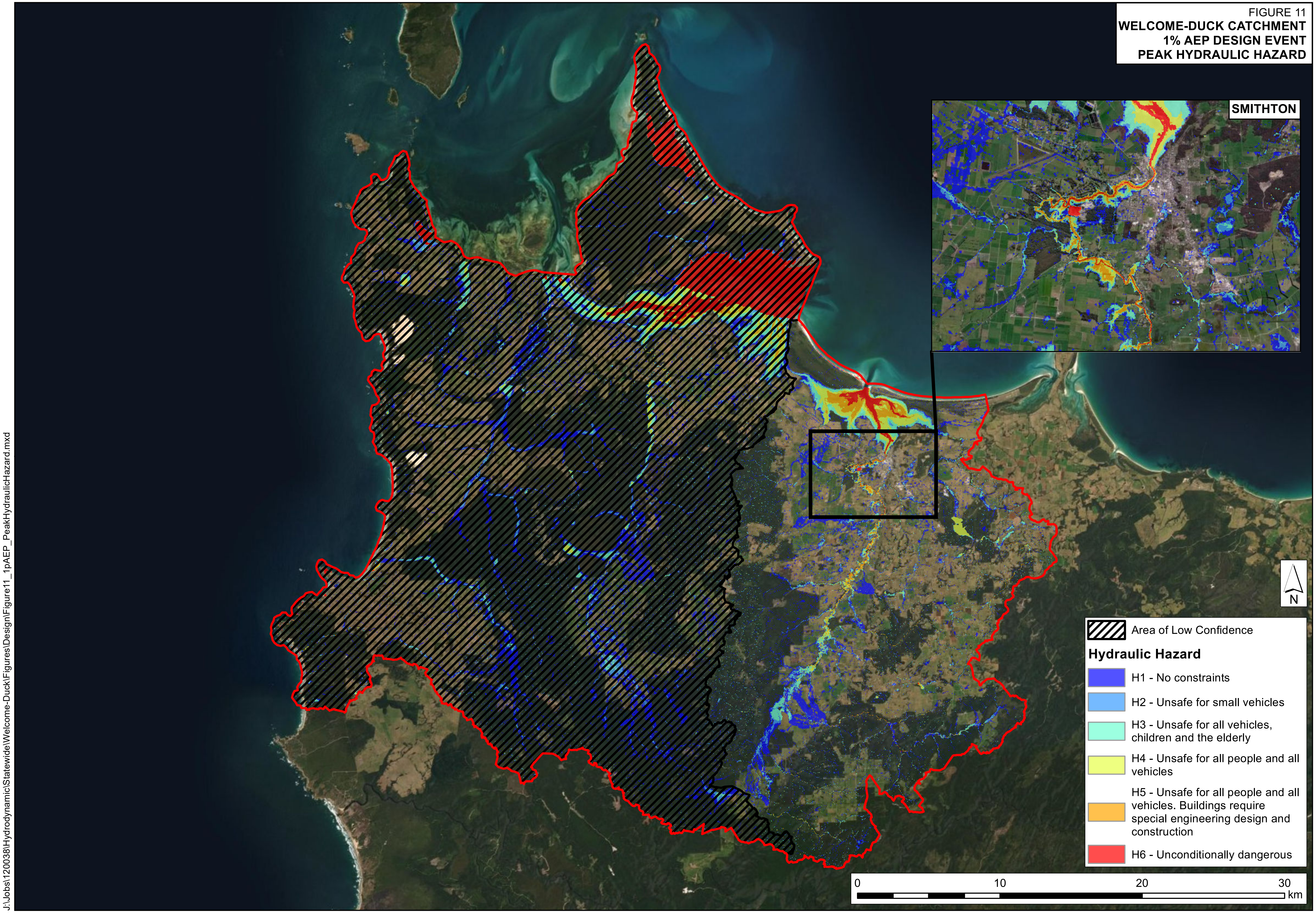


FIGURE 11
WELCOME-DUCK CATCHMENT
1% AEP DESIGN EVENT
PEAK HYDRAULIC HAZARD
SMITHTON
N
Area of Low Confidence
Hydraulic Hazard
H1 - No constraints
H2 - Unsafe for small vehicles
H3 - Unsafe for all vehicles, children and the elderly
H4 - Unsafe for all people and all vehicles
H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction
H6 - Unconditionally dangerous
0
10
20
30
km
J:\Jobs\120038\Hydrodynamic\Statewide\Welcome-Duck\Figures\Design\Figure11_1pAEP_PeakHydraulicHazard.mxd

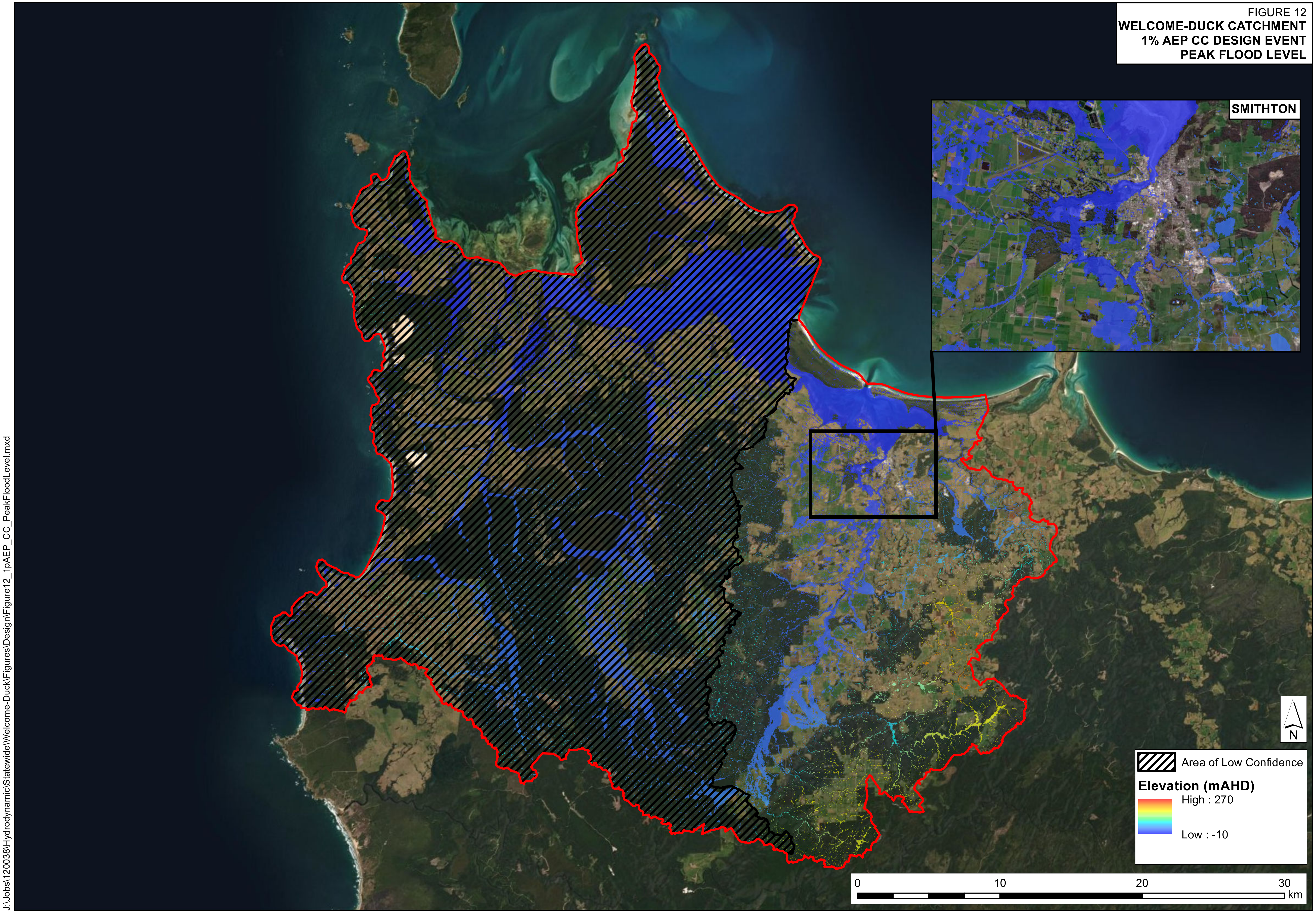
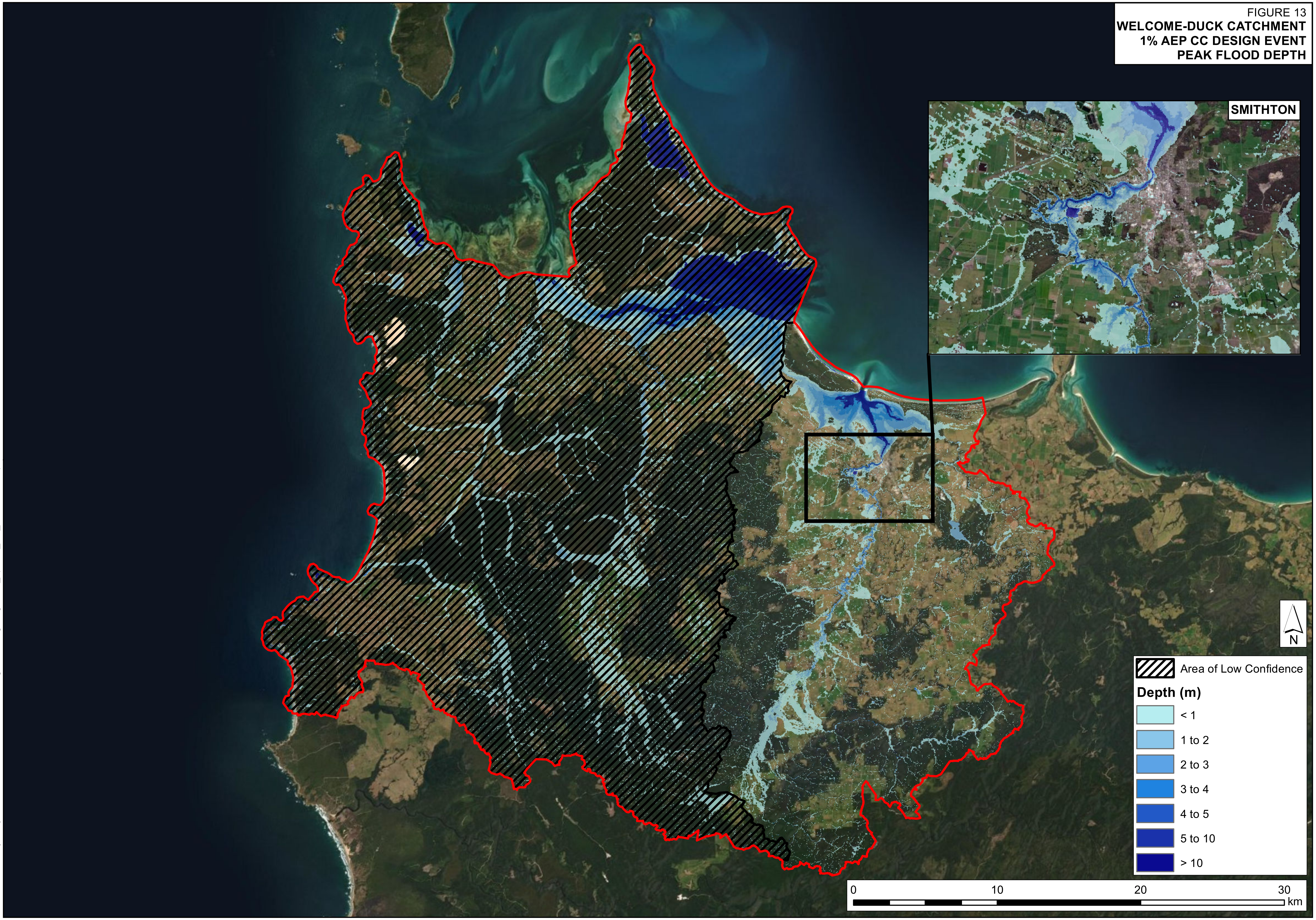


FIGURE 12
WELCOME-DUCK CATCHMENT
1% AEP CC DESIGN EVENT
PEAK FLOOD LEVEL
SMITHTON
N
Area of Low Confidence
Elevation (mAHD)
High : 270
Low : -10
0
10
20
30
km
J:\Jobs\120038\Hydrodynamic\Statewide\Welcome-Duck\Figures\Design\Figure12_1pAEP_CC_PeakFloodLevel.mxd



J:\Jobs\120038\Hydrodynamic\Statewide\Welcome-Duck\Figures\Design\Figure13_1pAEP_CC_PeakFloodDepth.mxd

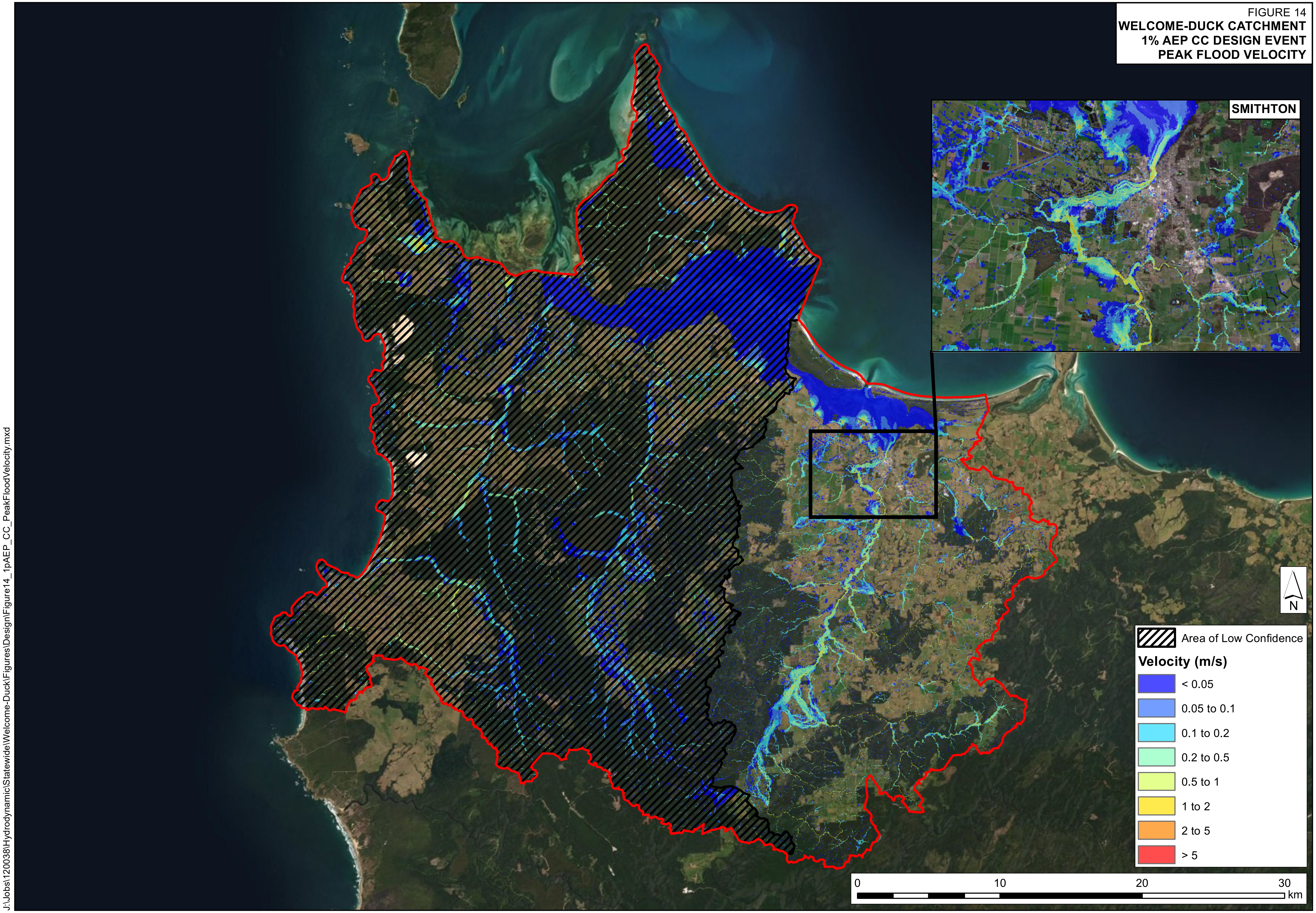


FIGURE 14
WELCOME-DUCK CATCHMENT
1% AEP CC DESIGN EVENT
PEAK FLOOD VELOCITY
SMITHTON
N
Area of Low Confidence
Velocity (m/s)
< 0.05
0.05 to 0.1
0.1 to 0.2
0.2 to 0.5
0.5 to 1
1 to 2
2 to 5
> 5
0
10
20
30
km
J:\Jobs\120038\Hydrodynamic\Statewide\Welcome-Duck\Figures\Design\Figure14_1pAEP_CC_PeakFloodVelocity.mxd

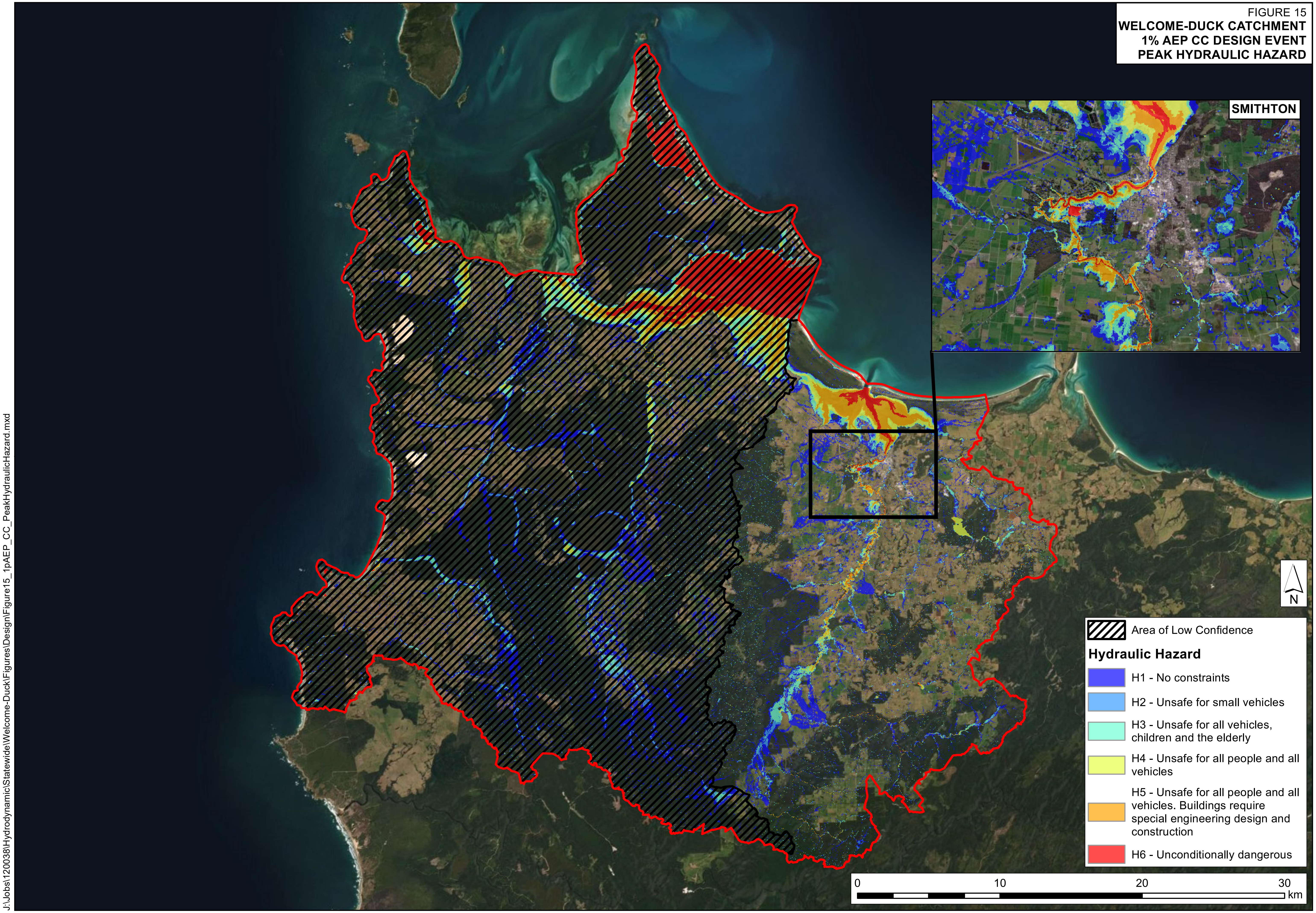
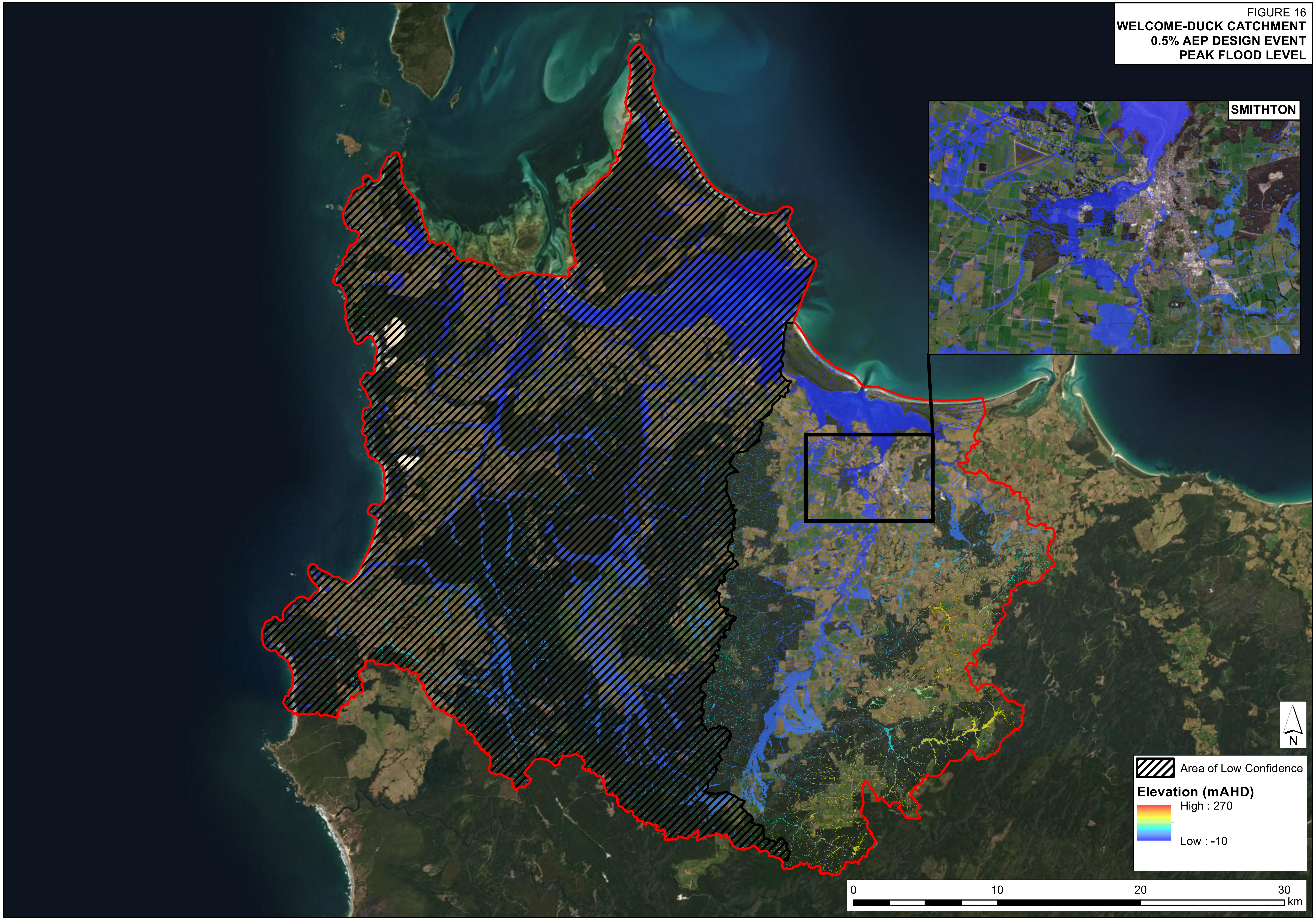


FIGURE 15
WELCOME-DUCK CATCHMENT
1% AEP CC DESIGN EVENT
PEAK HYDRAULIC HAZARD
SMITHTON
N
Area of Low Confidence
Hydraulic Hazard
H1 - No constraints
H2 - Unsafe for small vehicles
H3 - Unsafe for all vehicles, children and the elderly
H4 - Unsafe for all people and all vehicles
H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction
H6 - Unconditionally dangerous
0
10
20
30
km
J:\Jobs\120038\Hydrodynamic\Statewide\Welcome-Duck\Figures\Design\Figure15_1pAEP_CC_PeakHydraulicHazard.mxd



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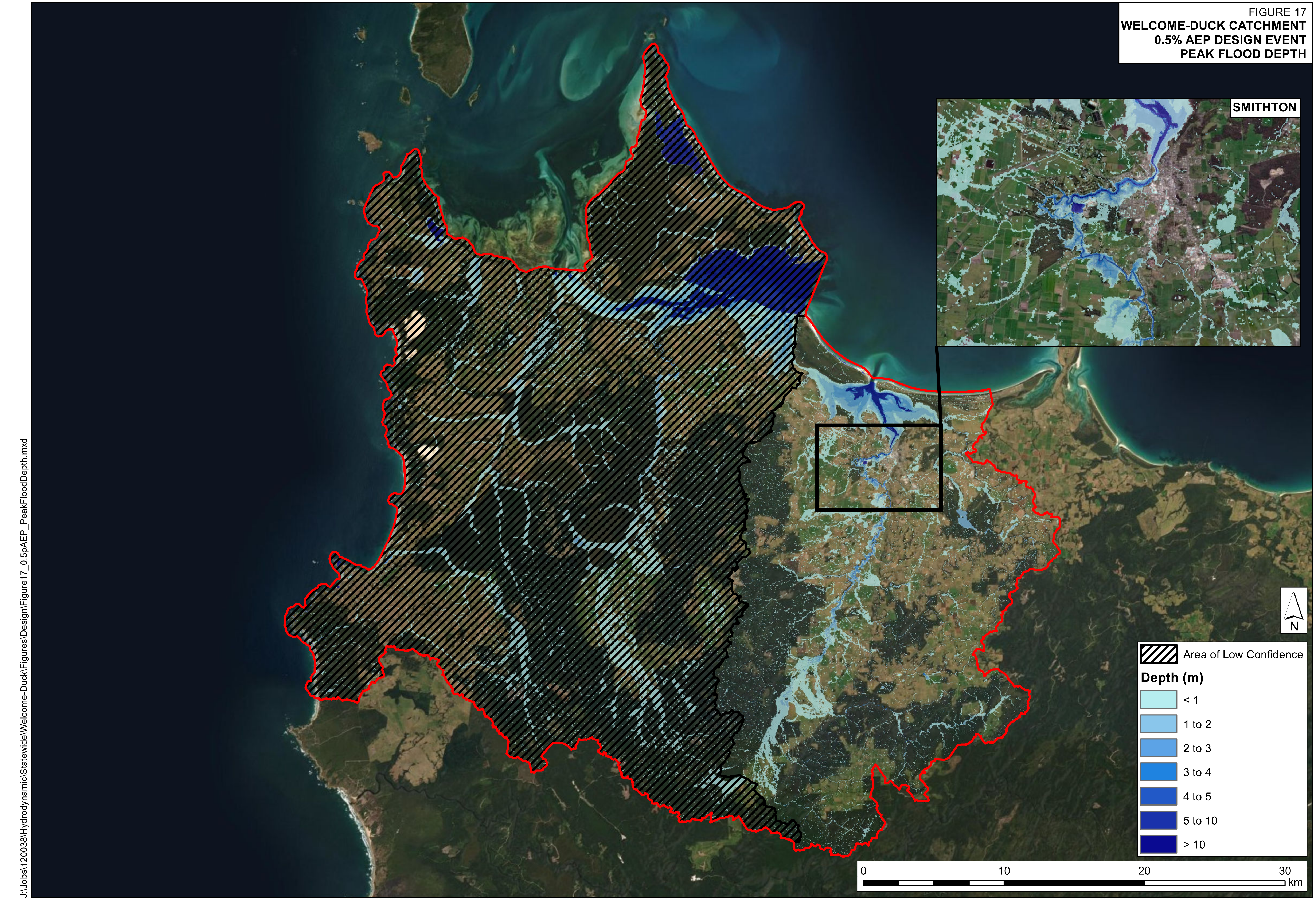
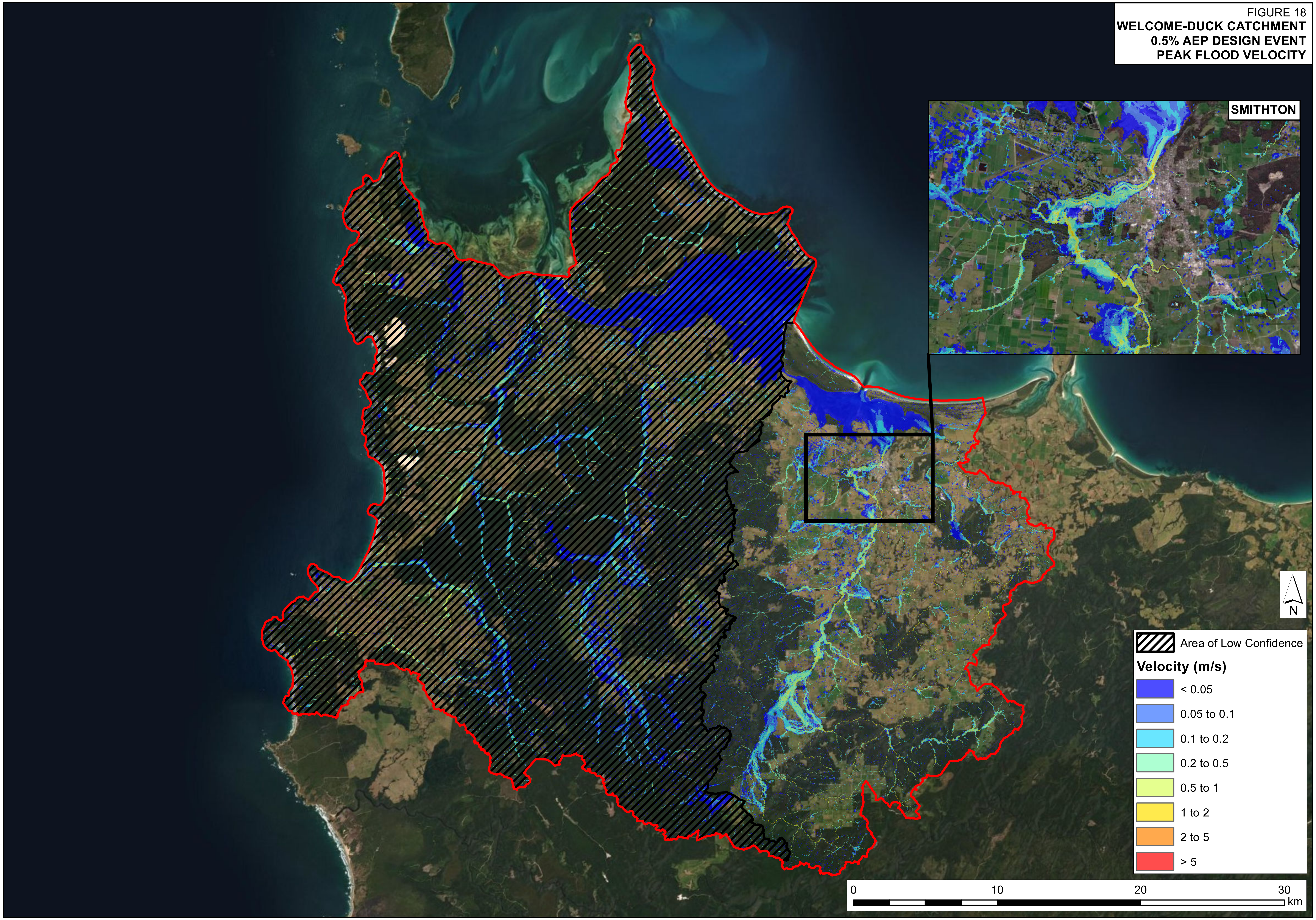


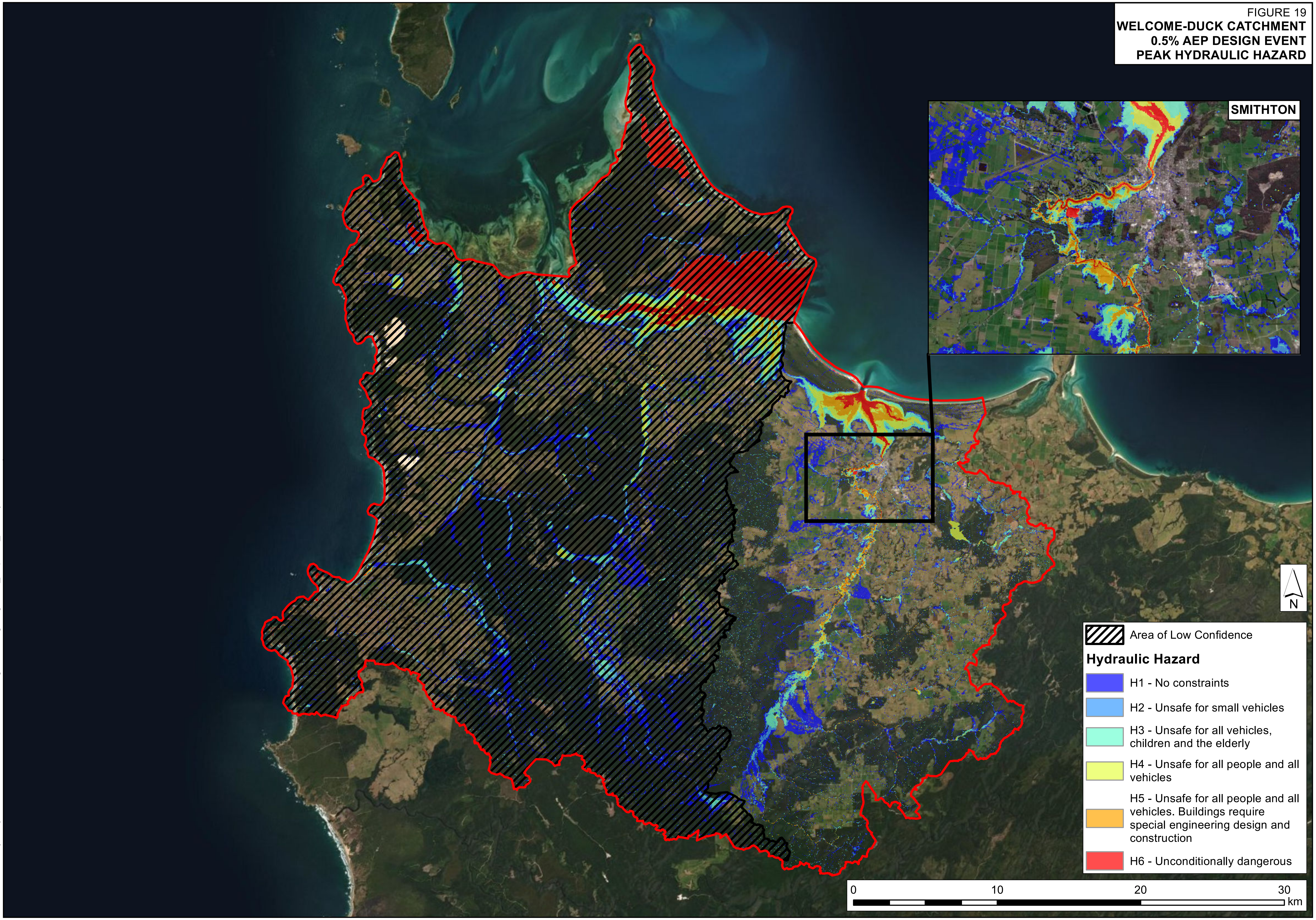
FIGURE 17
WELCOME-DUCK CATCHMENT
0.5% AEP DESIGN EVENT
PEAK FLOOD DEPTH
SMITHTON
N
Area of Low Confidence
Depth (m)
< 1
1 to 2
2 to 3
3 to 4
4 to 5
5 to 10
> 10
0
10
20
30
km
J:\Jobs\120038\Hydrodynamic\Statewide\Welcome-Duck\Figures\Design\Figure17_0.5pAEP_PeakFloodDepth.mxd

FIGURE 18
WELCOME-DUCK CATCHMENT
0.5% AEP DESIGN EVENT
PEAK FLOOD VELOCITY



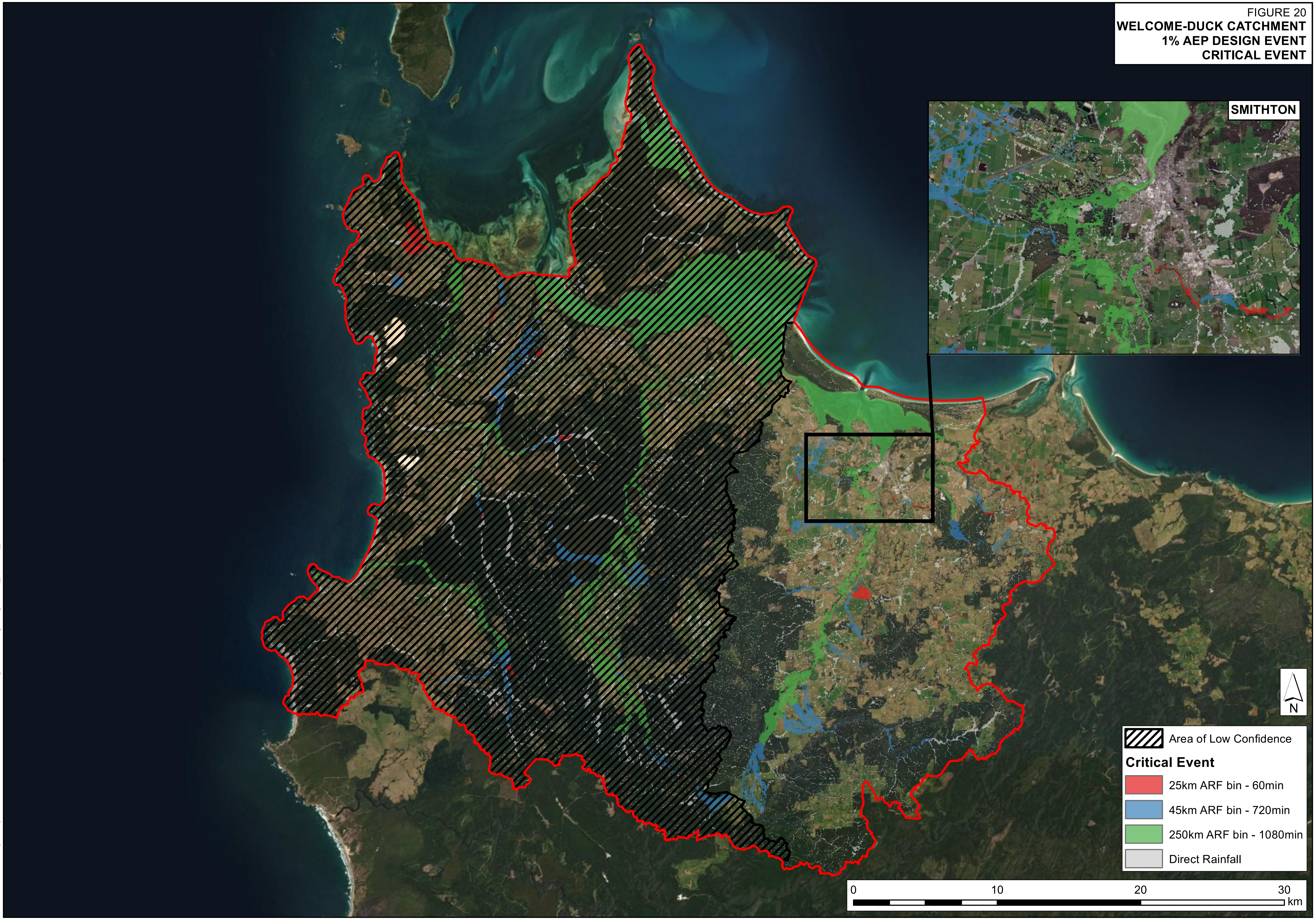
J:\Jobs\120038\Hydrodynamic\Statewide\Welcome-Duck\Figures\Design\Figure18_0.5pAEP_PeakFloodVelocity.mxd

FIGURE 19
WELCOME-DUCK CATCHMENT
0.5% AEP DESIGN EVENT
PEAK HYDRAULIC HAZARD



J:\Jobs\120038\Hydrodynamic\Statewide\Welcome-Duck\Figures\Design\Figure19_0.5pAEP_PeakHydraulicHazard.mxd

FIGURE 20
WELCOME-DUCK CATCHMENT
1% AEP DESIGN EVENT
CRITICAL EVENT



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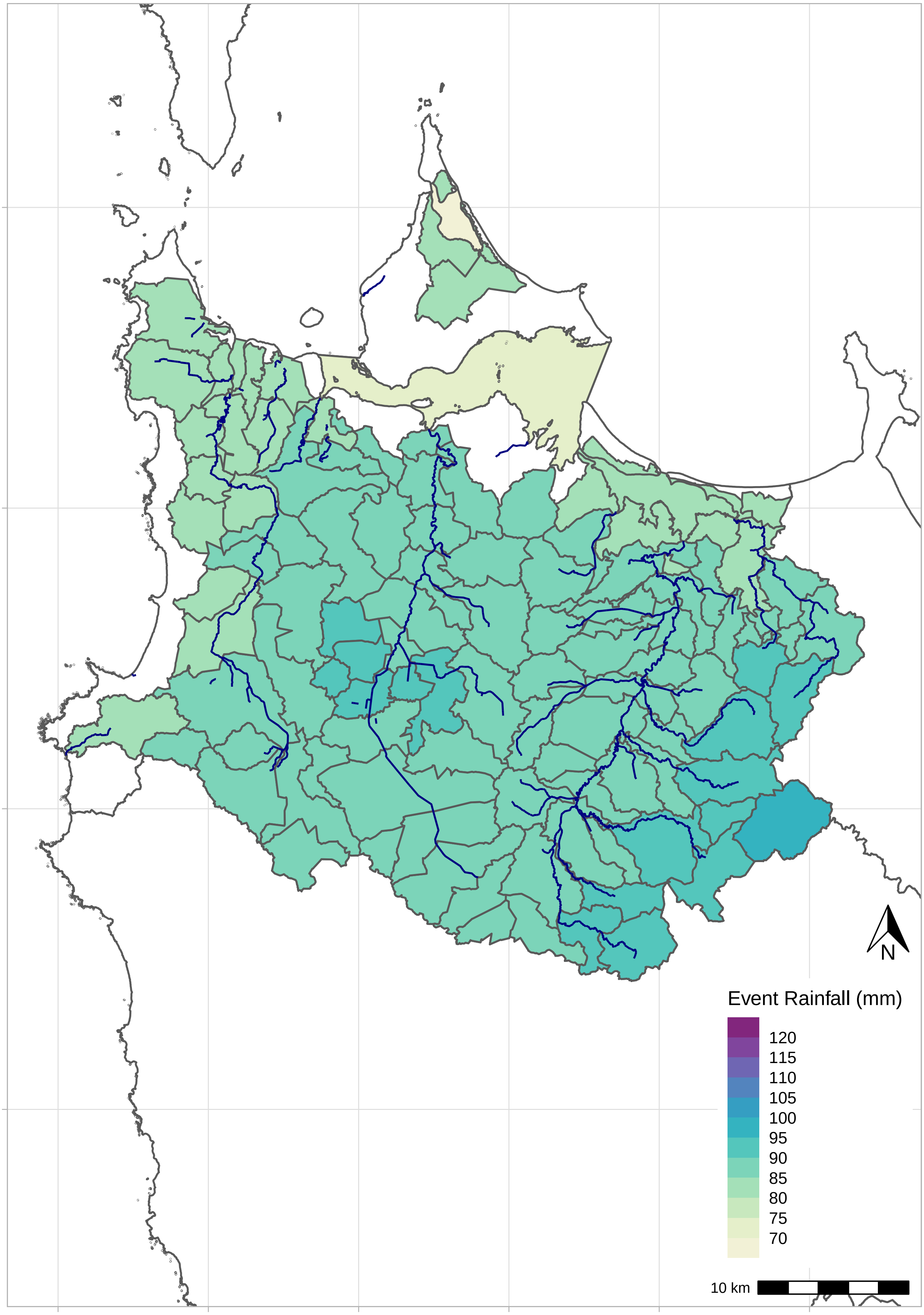
Appendix A

APPENDIX A. DESIGN EVENT DATA

FIGURE A1
DESIGN RAINFALL DEPTHS
1080MIN 2%AEP



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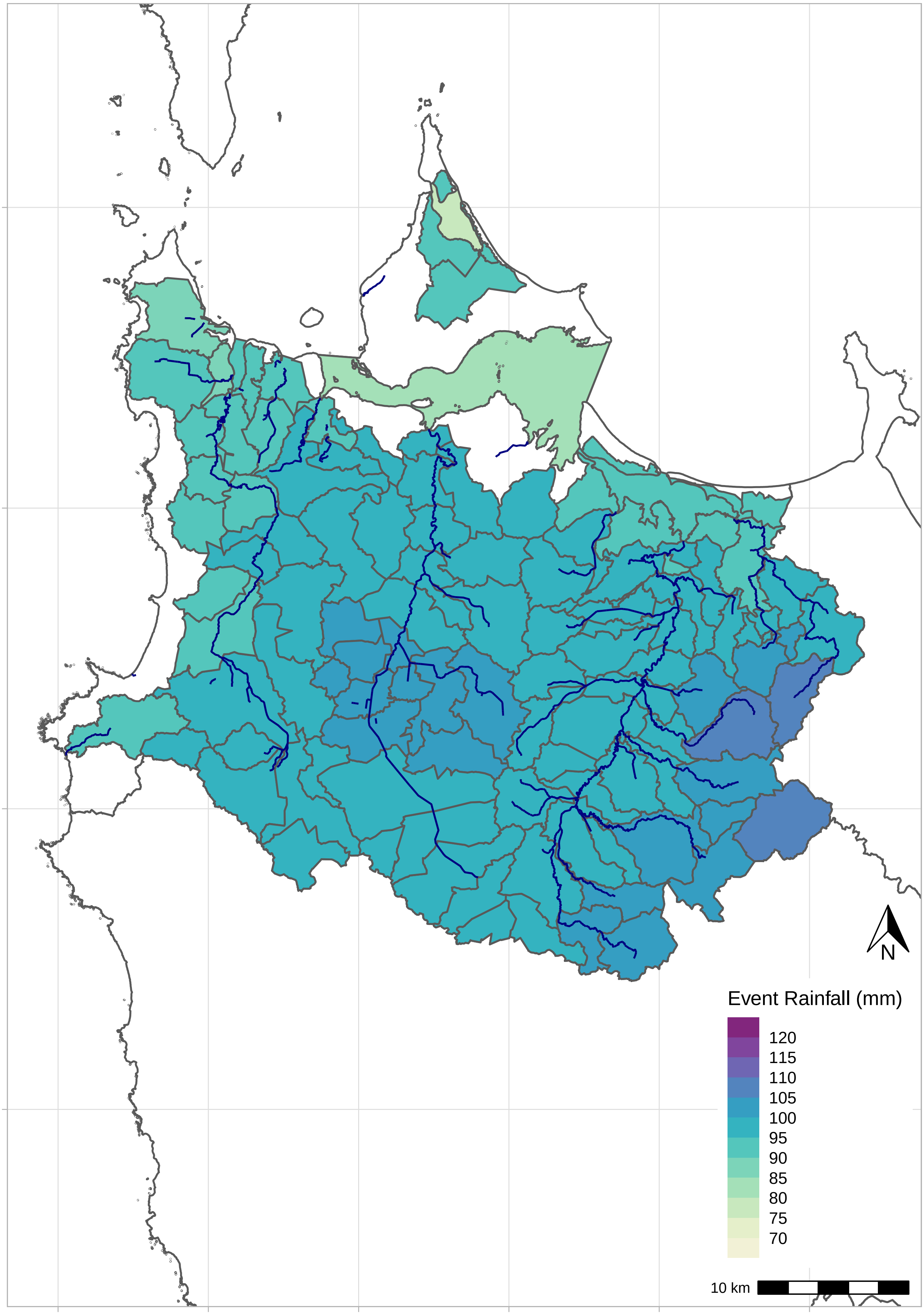
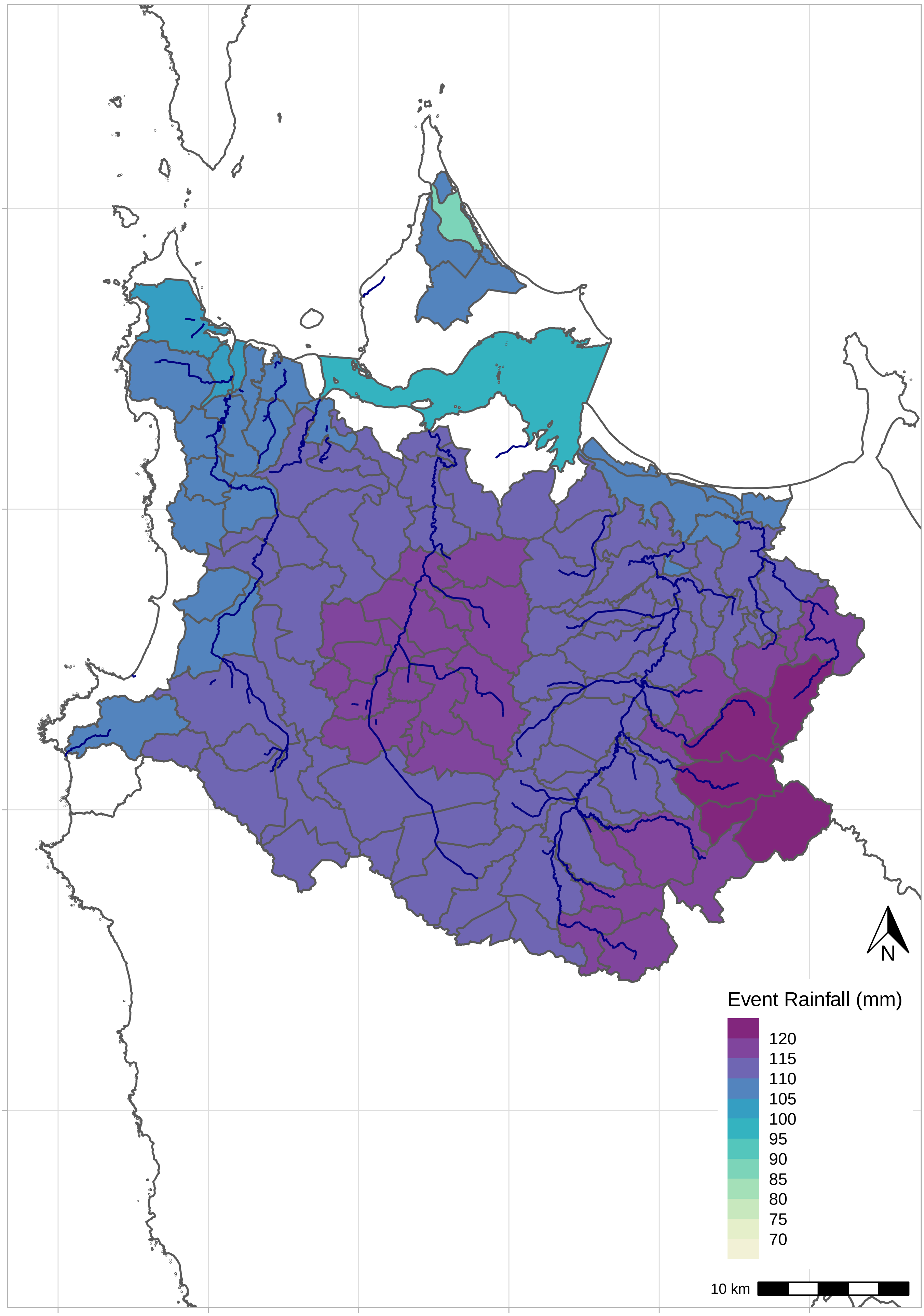
J:/Jobs/120038/Hydrology/Statewide/Design_Events/Welcome-Duck/Welcome-Duckv3_changeCL_zero_rain_small_arfs/Report_Figures/FigureA1_10802pAEP_same_scale.pdf

FIGURE A2
DESIGN RAINFALL DEPTHS
1080MIN 1%AEP



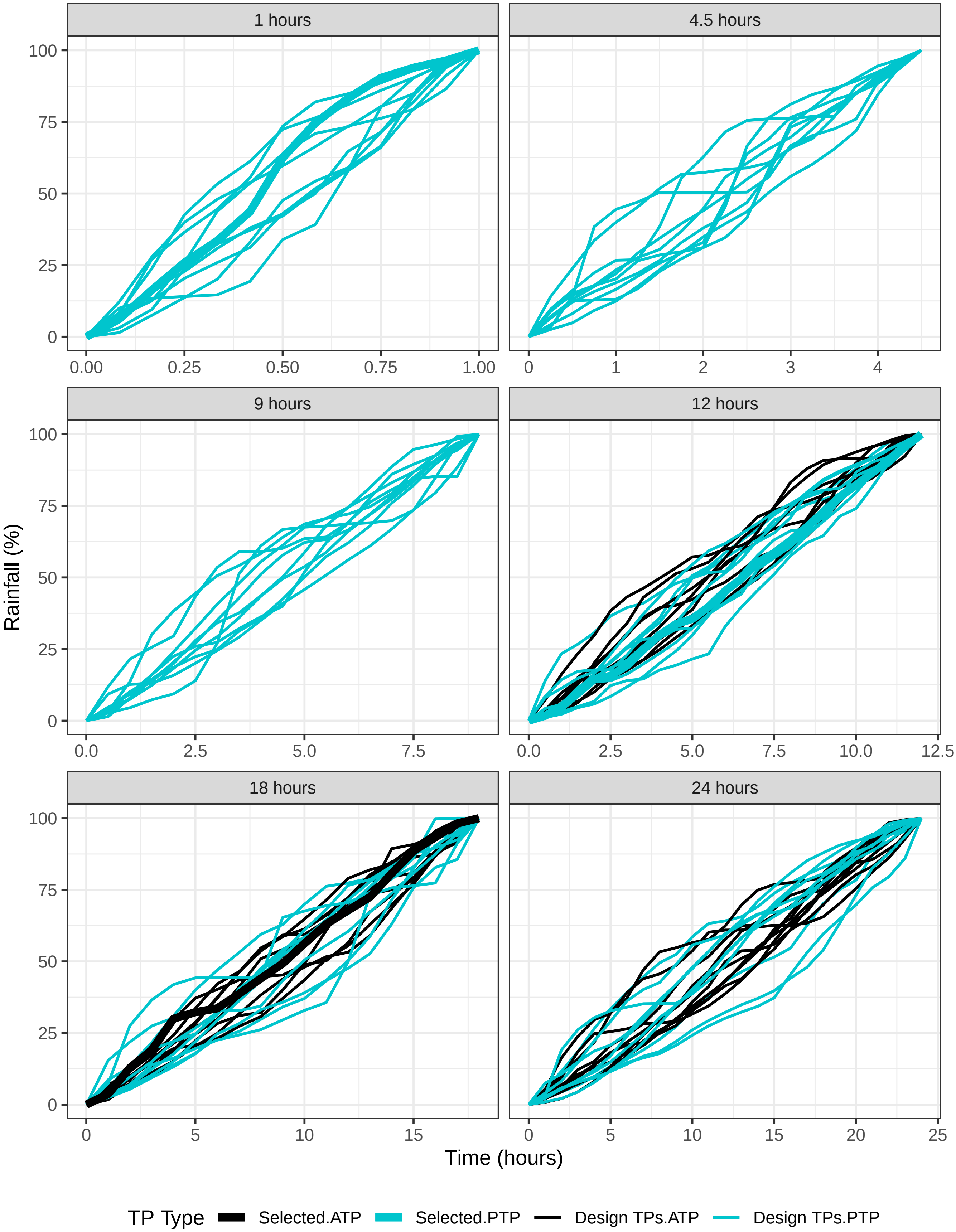
created by J:/Jobs/120038/Hydrology/Statewide/Design_Events/Welcome-Duck/Welcome-Duck_7_Design_Report_Plots.R
J:/Jobs/120038/Hydrology/Statewide/Design_Events/Welcome-Duck/Welcome-Duckv3_changeCL_zero_rain_small_arfs/Report_Figures/FigureA2_10801pAEP_same_scale.pdf

FIGURE A3
DESIGN RAINFALL DEPTHS
1080MIN 0.5%AEP



created by J:/Jobs/120038/Hydrology/Statewide/Design_Events/Welcome-Duck/Welcome-Duck_7_Design_Report_Plots.R
J:/Jobs/120038/Hydrology/Statewide/Design_Events/Welcome-Duck/Welcome-Duckv3_changeCL_zero_rain_small_arfs/Report_Figures/FigureA3_10801in200AEP_same_scale.pdf

FIGURE A4
DESIGN AREAL TEMPORAL PATTERNS
DURATIONS FROM 1 TO 18 HOURS



created by J:/Jobs/120038/Hydrology/Statewide/Design_Events/Welcome-Duck/Welcome-Duck_7_Design_Report_Plots.R

Appendix B

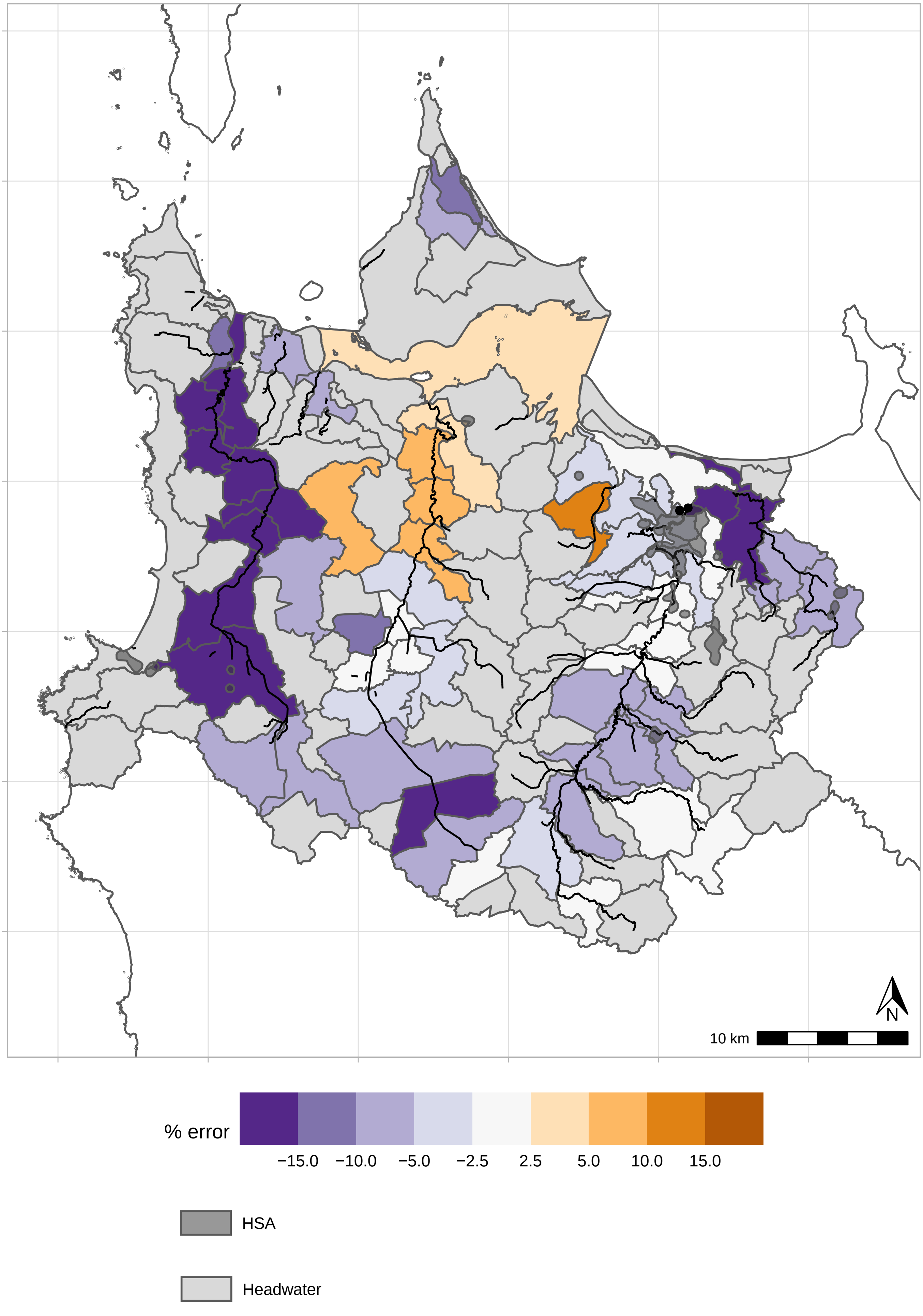
APPENDIX B. DESIGN PEAK ERRORS

Figure B1

Welcome−Duck Catchment

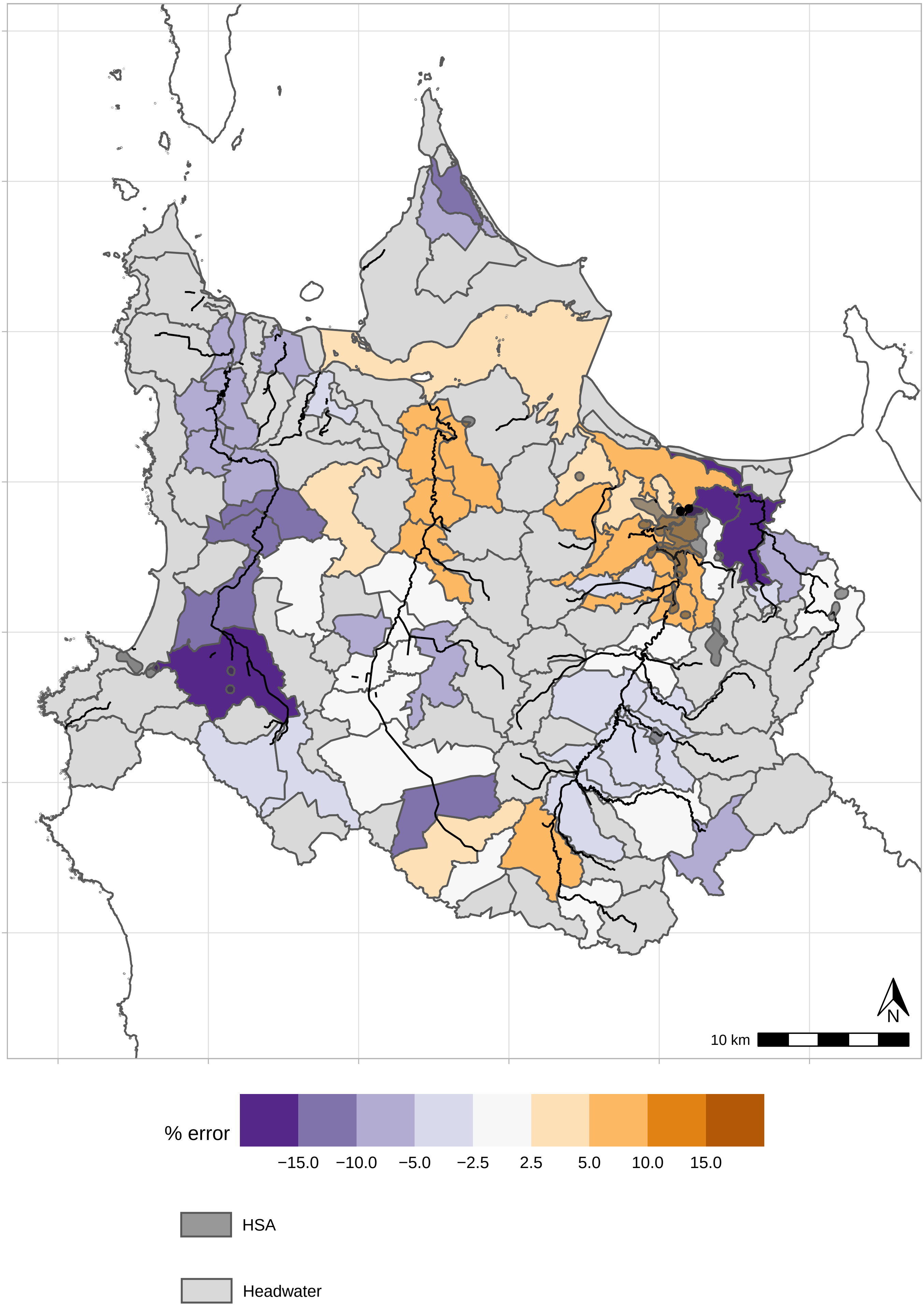
Percentage error in peak flows using selected runs

2pAEP



created by J:/Jobs/120038/Hydrology/Statewide/Design_Events/Welcome-Duck/Welcome-Duck_7_Design_Report_Plots.R

Figure B2
Welcome−Duck Catchment
Percentage error in peak flows using selected runs
1pAEP



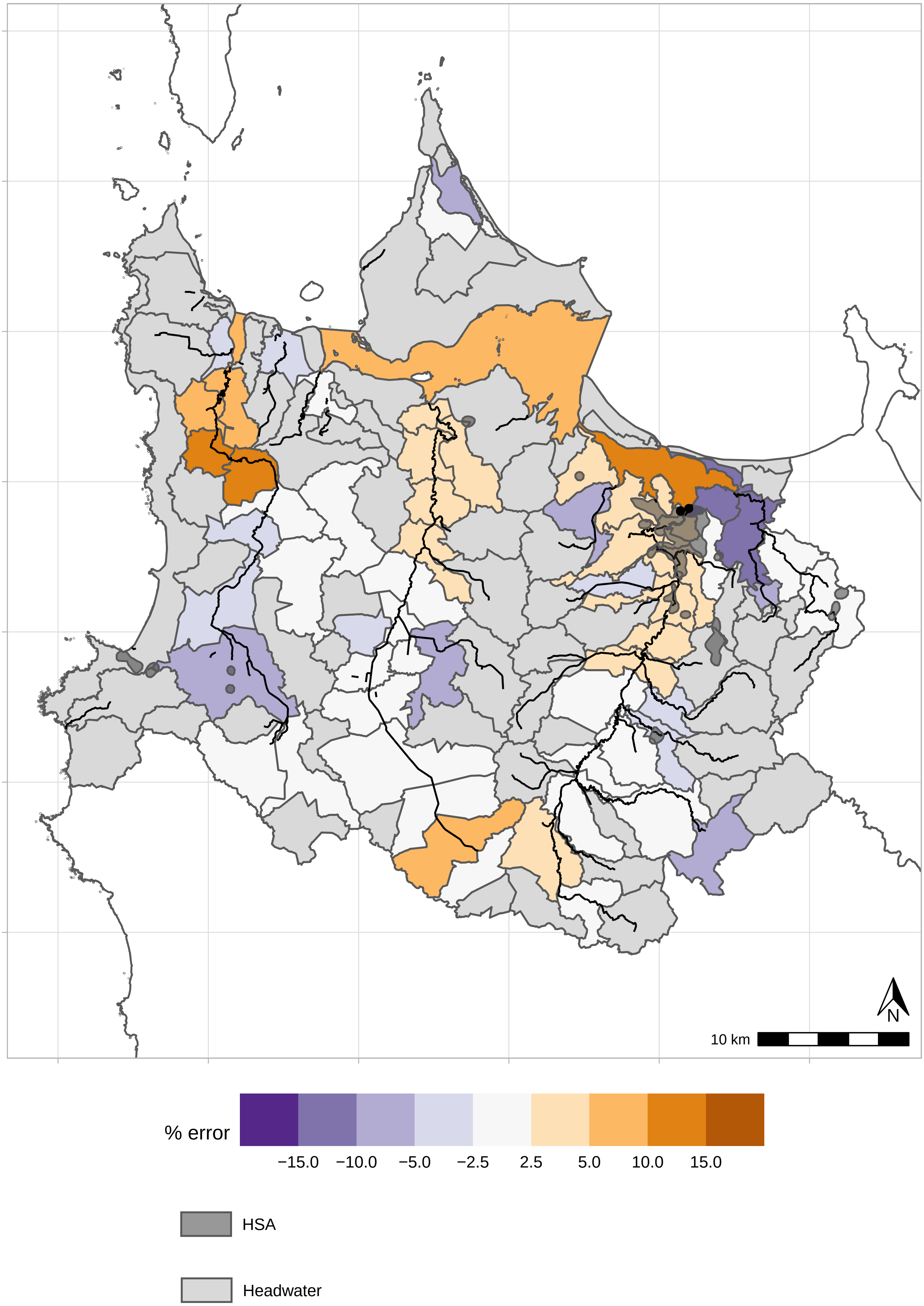
created by J:/Jobs/120038/Hydrology/Statewide/Design_Events/Welcome−Duck/Welcome−Duck_7_Design_Report_Plots.R

Figure B3

Welcome−Duck Catchment

Percentage error in peak flows using selected runs

0.5pAEP



created by J:/Jobs/120038/Hydrology/Statewide/Design_Events/Welcome−Duck/Welcome−Duck_7_Design_Report_Plots.R