

Isaac Regional Council

**UPPER NOGOA AND
MACKENZIE RIVER
CATCHMENTS
HYDRAULIC FLOOD STUDY**

July 2026



Upper Nogoia and Mackenzie River Catchments Hydraulic Flood Study

Final Flood Study Report

Prepared for:
Isaac Regional Council
PO Box 97 | Moranbah QLD 4744 | Australia

Prepared by:
Kellogg Brown & Root Pty Ltd
ABN 91 007 660 317
Level 1, 100 Brookes Street | Fortitude Valley QLD 4006 | Australia
GPO Box 633 | Brisbane QLD 4001 | Australia

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Acknowledgments

KBR acknowledges the Traditional Custodians throughout Australia and their continuing connection to land, water, culture and community, and pays respect to their Elders past and present.

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KBR derived the data in this report primarily from Isaac Regional Council and Central Highlands Regional Council supplied information. The passage of time, manifestation of latent conditions or impacts of future events may require further exploration at the site and subsequent data analysis, and re-evaluation of the findings, observations and conclusions expressed in this report.

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			Originated by	Checked by	Technical Approval	Project Approval
0	30/07/2026	Issued for Use	I Kim	J Eggleton	P Howell	I Kim
			 Digitally signed by Isaac Kim Date: 2026.07.30 14:37:20 +10'00'	 Digitally signed by J Eggleton DN: cn=J Eggleton, o=KBR, email=j.eggleton@kbr.com.au, c=au Date: 2026.07.30 14:37:20 +10'00'	 Digitally signed by P Howell DN: cn=P Howell, o=KBR, email=p.howell@kbr.com.au, c=au Date: 2026.07.30 14:37:20 +10'00'	 Digitally signed by Isaac Kim Date: 2026.07.30 14:42:01 +10'00'



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Glossary

4WD	Four Wheel Drive
ABS	Australia Bureau of Statistics
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ALS	Airborne Laser Scanning
ARF	Areal Reduction Factor
ARI	Average Recurrence Interval
ARR	Australia Rainfall and Runoff
AR6	6 th Assessment Report
ASRIS	Australian Soil Resource Information System
BOM	Bureau of Meteorology
CHRC	Central Highlands Regional Council
DCL	Dam Crest Level
DEM	Digital Elevation Model
DERM	Department of Environment and Resource Management
DRDMW	Department of Regional Development, Manufacturing, and Water
EAF	Elevation Adjustment Factor
ELVIS	Elevation and Depth Foundation Spatial Data
FEO	Flooded Exit Route Overland Escape
FER	Flooded Exit Route Rising Road
FERC	Flood Emergency Response Classification
FFA	Flood Frequency Analysis
FIE	Flooded Isolated Elevated
FIS	Flooded Isolated Submerged
FRMP	Flood Risk Management Program
FSL	Full Supply Level
GIS	Geographic Information System
GPU	Graphics Processing Unit
GSDM	Generalised Short Duration Method
GTSMR	Generalised Tropical Storm Method Revised
HPC	Heavily Parallelised Compute



HQ	Head Flow
HT	Head Time
IFD	Intensity Frequency Duration
IPCC	Intergovernmental Panel on Climate Change
IRC	Isaac Regional Council
KBR	Kellogg Brown and Root
LGA	Local Government Area
LiDAR	Light Detection and Ranging
MAF	Moisture Adjustment Factor
NIC	Not Flooded Indirect Consequence
PMF	Probable Maximum Flood
PMP	Probably Maximum Precipitation
QRA	Queensland Reconstruction Authority
QT	Flow Time
RCP	Reconciled Concentration Pathway
RoG	Rainfall on Grid
SGS	Sub Grid Sampling
SRTM	Shuttle Radar Topography Mission
SSP	Shared Socio-economic Pathway
TUFLOW	Two-Dimensional Unsteady Flow
USDA	United States Department of Agriculture
WMIP	Water Monitoring Information Portal



Executive Summary

Isaac Regional Council has engaged Kellogg Brown & Root to carry out the Upper Nogoia and Mackenzie River Catchments Hydraulic Flood Study. The Study provides an improved understanding of flood behaviour across the region and establishes a sound technical basis to support future planning, infrastructure decisions, and disaster management.

The Study has been completed in accordance with the Queensland Government Queensland Reconstruction Authority Flood Risk Management Program. The Study has been managed by Council, with both financial and technical support from the Queensland Reconstruction Authority. All hydrologic and hydraulic modelling principals were applied in accordance with the Australian Rainfall and Runoff guidelines (2019), including the Version 4.2 climate change update.

As part of this Study, KBR has developed a series of rainfall-on-grid TUFLOW models covering the wider Mackenzie River catchment up to the confluence with the Isaac River. These models were calibrated and validated to the historical events of January 2008 and December 2010. The Upper Nogoia River catchment model was additionally calibrated and validated to the January 2026 event. This process provided confidence for the modelling to be utilised for the purposes of defining the design event modelling over a range of theoretical flood magnitudes.

The Study places a particular focus on the key communities of Clermont and Middlemount, both of which play an important role in the regional economy. The study highlights the wide variance of flood behaviour across the region. The impacts of flooding across the study area have implications on emergency response, evacuation planning, and community safety as key access routes become frequently inundated and cut off.

Clermont has been modelled to experience widespread inundation during rare events. Flooding within Claremont is primarily driven by flows breaking out of Sandy Creek. Comparatively, Middlemount is modelled to be subject generally localised flooding, with flood waters largely contained within the banks of the watercourses adjacent to the town.

With Council's endorsement, the study will be placed on public exhibition. Following the completion of this study, the next step would be to undertake the Floodplain Risk Management Study and Plan, which will use the Flood Study as the foundation for investigating and developing flood risk management measures.



1 Introduction

Isaac Regional Council (herein referred to as Council) was formed in 2008 by the amalgamation of the former shires of Belyando, Broadsound, and Nebo. The responsibility of floodplain management and local land use planning across their former Local Government Areas (LGA) now falls upon Isaac Regional Council.

The Upper Nogoa and Mackenzie River Catchments Hydraulic Flood Study (herein referred to as the Study) is currently being prepared for Council to define the nature of flooding across the study area and to provide an improved understanding of flood behaviour and the associated flood risk under historical and existing floodplain conditions. Additionally, the Study addresses possible future variations in flood behaviour due to climate change.

This Study is currently being completed as a part of the Queensland Government Queensland Reconstruction Authority (QRA) Flood Risk Management Program (FRMP). The Study has been project managed by Council, with both financial and technical support from the QRA.

1.1 STUDY OBJECTIVES

The outcomes of this study are to fulfill the requirements of a Flood Study in accordance with QRA's Flood Risk Management Program. This study will form a foundation of Council's future works for planning relating to disaster management, essential infrastructure development assessments, and population growth within the study area.

The study objectives are as follows:

- Define the flood behaviour across a range of magnitudes within the study area to aid in Council's management of flood risks, and
- Form the basis for a subsequent floodplain risk management study where detailed assessment of flood mitigation options and floodplain risk management measures can be undertaken.

To achieve the above overarching objectives, this study includes the following components:

- Compilation and review of existing information pertinent to the study and acquisition of additional data, as required.
- Community consultation and participation to identify local flooding concerns, collect information on historical flood behaviour, advise on the outcomes of the flood study and flood behaviour predictions, and engage the community in the on-going flood risk management process.
- Development and calibration of appropriate hydrologic/hydraulic models.
- Determination of design flood conditions for a range of Annual Exceedance Probability (AEP) design events, including the 50%, 20%, 5%, 2%, 1%, 0.5%, and 0.2% AEP events as well as the Probable Maximum Flood (PMF) event. Design event modelling includes the consideration of the Australian Rainfall and Runoff (ARR) Version 4.2 guidelines (2024).
- Undertake sensitivity testing for a range of model parameters, as well as to assess the sensitivity of the catchments to the effects of climate change.
- Generate mapping of flood extent, velocity, depth and hazard for each of the defined flood events.



1.2 STUDY LOCALITY

Isaac Regional Council is located in Central Queensland, extending approximately 350 km inland from the Coral Sea coast. The region is bordered by the Mackay, Whitsunday, and Charters Towers Regional Councils to the north, and the Livingstone Shire and Rockhampton, Central Highlands, and Barcaldine Regional Councils to the south.

The immediate study area consists of the Upper Nogoa and Upper Mackenzie River catchments, encapsulating the townships of Clermont and Middlemount accordingly.

The Upper Nogoa River catchment borders the Central Regional Highlands Council border and includes the Blair Athol and Clermont coal mines as well as Theresa Creek Dam.

The Upper Mackenzie River catchment is further downstream and borders the Mackenzie River as the southern boundary up to the confluence with the Isaac River. Major features included within this catchment are the Capcoal Surface Operations, Aquila and Foxleigh coal mines, Bedford Weir, and Bingegang Weir. Fairbairn Dam and the town of Emerald are located further upstream of the study areas.

Land use across the region is dominated by rural industries (particularly cattle grazing), mining, and resource extraction. Smaller areas are dedicated to agriculture (particularly sorghum and wheat), and conservation. Urban areas and settlements are limited, clustered around the mining and service towns.

The study locality of the Upper Nogoa and Upper Mackenzie River catchments are depicted in Figure 1-1 and Figure 1-2 respectively.

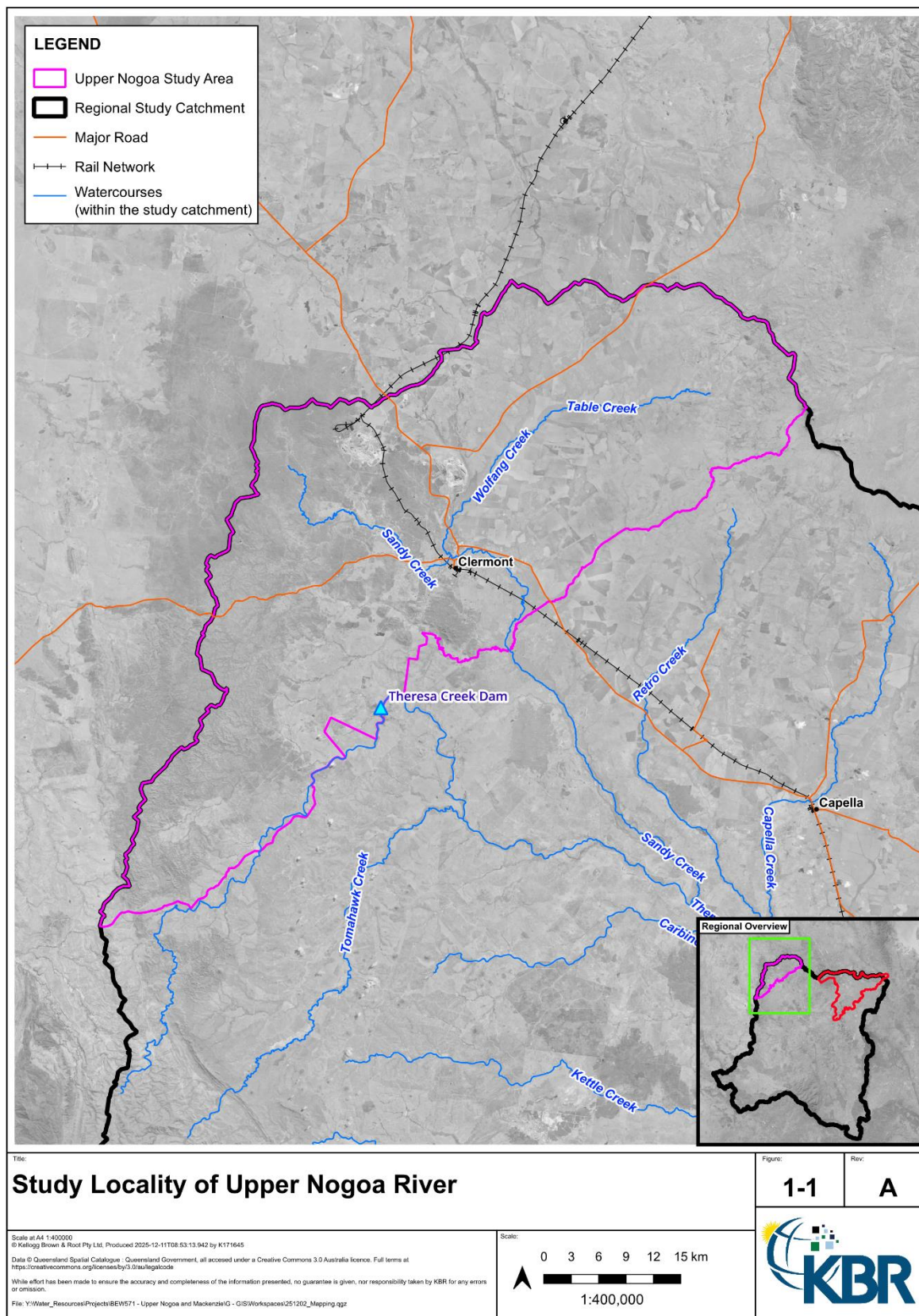


Figure 1-1 Study Locality of the Upper Nogoia River (Clermont) Model

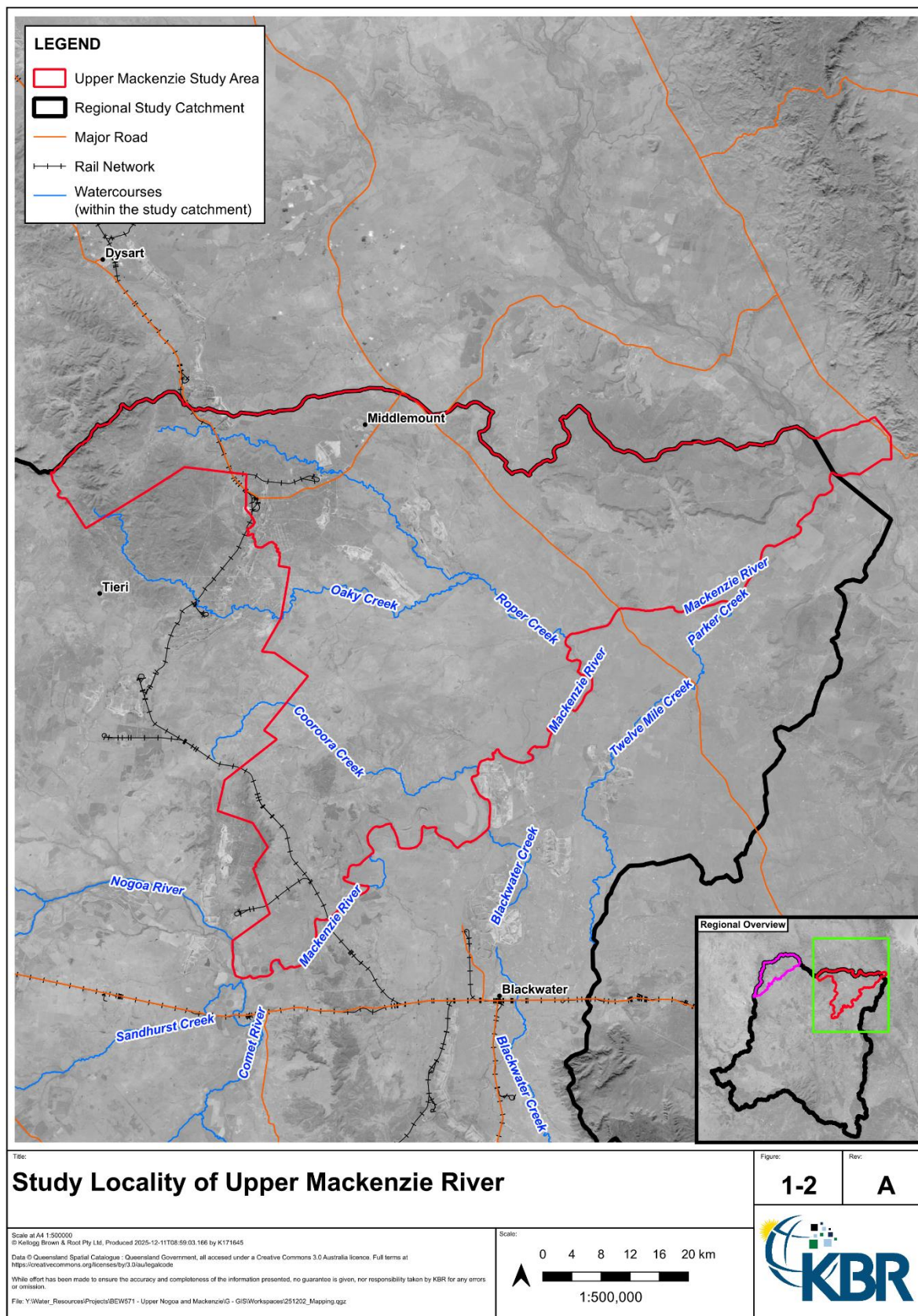


Figure 1-2 Study Locality of the Upper Mackenzie River (Middlemount) Model



1.3 POPULATION CHARACTERISTICS

The Australian Bureau of Statistics (ABS) according to the 2021 Census data estimated resident population of the town of Clermont and Middlesbrough to be 2,079 and 1,884 respectively. Understanding the socio-economic nature of communities can assist with ensuring that appropriate risk management measures are adopted. Information on categories including dwelling and tenure type, primary languages spoken, age of population, and the movement of people into and out of the area have been extracted from the 2021 Census data. These characteristics have been summarised in Table 1-1 and Table 1-2 for the townships of Clermont and Middlesbrough respectively.

In summary, the population of both towns has a lower proportion of persons in older age groups, with relatively low proportion requiring assistance with core activities. In particular, no persons above the age of 75 was recorded within the town of Middlesbrough, acknowledging the transient nature of the predominant mining population (refer to Section 1.4 for further information). Most persons (if not all) are competent English speakers with a low proportion of lone person dwellings across the two townships.

Table 1-1 Key Population Characteristics of Clermont (ABS, 2021)

Clermont Key Population Characteristics (Area Code LGA18050)	
	Population: 2,079 (2021)
	No. Private Dwellings: 1,229
	No. of Lone Person Dwellings: 264
	Property Tenure: • 20.4% owned with a mortgage • 23.0% owned outright • 49.7% rented
	Language: 87.3% only speak English at home No. Persons Requiring Assistance: 136 (8.7% of the population) <i>Relates to people with a profound or severe disability that are defined as those people needing help or assistance in one or more of the three core activity areas of self-care, mobility, and communication</i>
	No. Persons > 75: 140 (6.7% of the population) <i>Elderly people are less mobile and may not be able to respond as quickly to flood related emergencies alone</i> No. Single Parent Families: 82 (16.3% of the population) <i>Single parent families could be indicative of a low adult-to-child ratio leading to difficulty responding to flood related emergencies</i>

Information extracted from the Australian Bureau of Statistics: Clermont 2021 Census



Table 1-2 Key Population Characteristics of Middlemount (ABS, 2021)

Middlemount Key Population Characteristics (Area Code LGA18050)	
	Population: 1,884 (2021) No. Private Dwellings: 908 No. of Lone Person Dwellings: 114 Property Tenure: • 3.0% owned with a mortgage • 2.3% owned outright • 87.2% rented
	Language: 62.5% only speak English at home No. Persons Requiring Assistance: 53 (3.5% of the population) <i>Relates to people with a profound or severe disability that are defined as those people needing help or assistance in one or more of the three core activity areas of self-care, mobility, and communication</i>
	No. Persons > 75: 0 (0% of the population) <i>Elderly people are less mobile and may not be able to respond as quickly to flood related emergencies alone</i>
	No. Single Parent Families: 114 (26.2% of the population) <i>Single parent families could be indicative of a low adult-to-child ratio leading to difficulty responding to flood related emergencies</i>

Information extracted from the Australian Bureau of Statistics: Middlemount 2021 Census

1.4

ECONOMIC BASE

The top five (5) industries across the townships of Clermont and Middlemount are identified from the 2021 Census. The percentage of reported employment across the industries has been included and summarised as follows:

- Clermont:
 - Coal Mining (17.7%)
 - Beef Cattle Farming (Specialised) (14.4%)
 - Grain-Sheep or Grain-Beef Cattle Farming (4.0%)
 - Other Grain Growing (3.5%)
 - Hospitals (except Psychiatric Hospitals) (2.9%)
- Middlemount:
 - Coal Mining (50.3%)
 - Combined Primary and Secondary Education (5.7%)
 - Other Heavy Civil Engineering Construction (5.3%)
 - Labour Supply Services (3.4%)
 - Supermarket and Grocery Stores (2.3%)

The dominant industry providing employment is associated with coal mining across both townships. However, with Middlemount servicing several coal mines, the employment percentage of the industry within the Middlemount township exceeds 50% of the responses received. Clermont cattle farming produced the second highest occupation in Clermont.



2 Compilation and Review of Available Data

The review considers the data received from Council, Central Highlands Regional Council (CHRC), and information obtained from publicly available sources in the following categories:

- Previous studies and investigations,
- Existing hydrologic and hydraulic models,
- GIS data,
- Stormwater infrastructure,
- Rainfall data,
- Water level and streamflow data,
- Historical flood data, and
- Topographic data.

All data received and sourced by KBR is detailed as follows.

2.1 REVIEW OF PREVIOUS STUDIES AND INVESTIGATIONS

The Mackenzie River catchment, inclusive of its tributaries, has been subject to various flood risk management related studies. Various hydrologic and hydraulic models have been developed for the purposes of these studies. However, this study is the inaugural flood study covering the entirety of the Upper Nogoia and Upper Mackenzie River catchments.

A summary of the previous studies and their outcomes relevant to the study areas is presented in the following sections.

2.1.1 Central Highlands Regional Council Floodplain Management Study and Plan (KBR, 2014)

CHRC commissioned KBR to undertake a Floodplain Management Study and Plan for the Emerald, Gemfields Area, Capella, Tieri, Springsure, Rolleston, Comet, Duaringa, Bluff, Dingo, and Blackwater townships. The project involved the development of a series of calibrated hydrologic and hydraulic models, providing a detailed understanding of flooding and flood risk across the study area. The study involved a review of a range of structural and non-structural measures to manage flooding and outlines a plan to reduce the impact of flooding on the community.

As part of this study, three regional hydrologic models were developed to cover the wider study area:

- Model 1: Nogoia River and Comet River catchments up to their confluence.
- Model 2: Isaac River, Mackenzie River, and Connors River catchments.
- Model 3: Dawson River catchment to its confluence with the Mackenzie River.

The hydrologic modelling involved the following components:

- Detailed compilation and review of rainfall and stream gauge data (sourced from the Bureau of Meteorology, the former Department of Environment and Resource Management, and Central Highlands Regional Council).
- Catchment and sub-catchment delineation using the 2010 Shuttle Radar Topography Mission (SRTM) topographic dataset and the CatchmentSIM software.



- Development of XP-RAFTS hydrologic models.
- Calibration of the XP-RAFTS hydrologic models to the January 2008 and December 2010 historical events by comparing modelled flows against recorded gauged flows.
- Derivation of design flows (50%, 20%, 5%, 2%, 1%, and 0.2% AEP events as well as the Probable Maximum Flood event) to be injected into TUFLOW hydraulic models in accordance with the Australian Rainfall and Runoff 1987 guidelines.

A total of 12 localised TUFLOW hydraulic models were developed for individual townships with five (5) regional models covering the wider study area. While the township models were developed using LiDAR datasets, the regional models utilised the SRTM data with the report concluding that the regional models are indicative only and should not be relied upon for detailed assessment. Major hydraulic structures (i.e. bridges and culverts), informed through structural drawings and by site inspection, were built into the models. It should be noted that while components of this study and plan cover the wider Upper Nogoa and Mackenzie River catchments, no localised hydraulic modelling or analysis was undertaken for the Clermont and Middlemount study areas. As the hydrologic models encapsulate the study area, hydrologic inputs were reviewed and referenced in the development of models where applicable and appropriate.

2.1.2 Central Highlands Regional Council: Synthetic Rating Curve Report (KBR, 2016)

Following the completion of the Central Highlands Regional Council Floodplain Management Study and Plan, KBR was commissioned to develop model derived (synthetic) rating curves at 13 stream gauges within the CHRC LGA.

10 purpose-built TUFLOW hydraulic models were developed around 10 of the gauges utilising LiDAR data acquired between CHRC and the Queensland Government for the purpose of this project. Three (3) existing TUFLOW models completed as part of the previous Floodplain Management Study were relied upon. A total of 13 synthetic (model derived) rating curves were developed with the following rating curves relevant to this study:

- (1) Craigmore ALERT (130209A)
- (2) Comet Weir ALERT (130504B)
- (3) Duckponds TM (130219A)
- (4) Gregory Highway ALERT (130206A)

The synthetic rating curves represent results from the TUFLOW hydraulic models at the gauge locations using parameters that are considered the most appropriate for each site. The updated rating curves were presented to key stakeholders (Bureau of Meteorology, the former Department of Environment and Resource Management, the Department of Energy and Water Supply, SunWater and Central Highlands Regional Council) over two (2) sessions, allowing for the endorsement of the approach and review of the outputs.

2.1.3 Central Highlands Flood Plain Management Plan Regional Models – Flood Modelling Update Report (KBR, 2018)

As part of the previous Central Highlands Regional Council Floodplain Management Study and Plan, KBR developed five (5) regional TUFLOW hydraulic models. These models were built using SRTM data with significant vertical inaccuracies.

Since the completion of the previous study, the following topographic datasets of higher quality were made available:

- Surat Basin 15 m Digital Elevation Model (DEM), and
- Bowen Basin 20 m DEM.



As such, KBR was commissioned by CHRC to undertake a review and update of the previous regional scale hydraulic model for the Upper Mackenzie River catchment as well as develop new regional scale hydraulic models for the Upper Comet, Medway Creek, and Borilla Creek catchments.

The regional scale hydraulic models were similarly calibrated to the January 2008 and December 2010 events. Model calibration was undertaken by comparing model results to surveyed flood debris levels provided by CHRC. Due to the scale of the models and topographic inputs, a wide variance in levels was noted in comparison to the recorded information.

All design event modelling (2%, 1%, and 0.2% AEP events) completed for this study was in accordance with the Australian Rainfall and Runoff 1987 guidelines.

2.1.4 Central Highlands Regional Council Flood Study Update: Nogoia River Flood Frequency Analysis and ARR16 Update (KBR, 2019)

Following the release of Australian Rainfall and Runoff 2016 guidelines, KBR was commissioned by CHRC to upgrade the existing XP-RAFTS hydrologic model developed for the Central Highlands Regional Council Flood Plain Management Study and Plan. The update involved the following scope of work:

- Review of the existing Nogoia River XP-RAFTS hydrologic model,
- Update of the Craigmore ALERT gauge Flood Frequency Analysis (FFA),
- Review and refinement of the historical event-based model calibration to the 2008 and 2010 events,
- Update of the design event hydrologic modelling to ARR 2016,
- Review of the updated hydrologic model outputs against the updated Craigmore ALERT FFA, and
- Undertake a sensitivity assessment of the spatial rainfall patterns from significant historic storms.

An assessment of the Fairbairn dam storage levels was also undertaken as a part of this study. An analysis of the monthly water levels and discharge data for the Fairbairn Dam was provided by SunWater. The assessment concluded that there was no direct correlation with the storage levels preceding a major storm event and that the initial dam level could be either low or full at the onset of a major flood event. As such, it was concluded that the dam level be modelled at Full Supply Level for the design flood assessment, consistent with findings from the previous study.

The study concludes with the need to consider the spatial variation of rainfall over a large catchment. A singular point extract of design event rainfall may not be sufficient to represent the different conditions for the entire catchment. Additionally, consideration of areal temporal patterns or a historical temporal pattern may be necessary for larger catchments.

2.1.5 Central Highlands Regional Council Flood Study Update: Borilla, Serpentine and Sandy Creek – Rating Curve Report (KBR, 2019)

Following the procurement of additional high-resolution LiDAR, KBR was commissioned by CHRC to undertake detailed rating curve analyses for a further three stream gauges. The scope of works is in line with the methodology detailed in Section 2.1.2 of this report.

Three (3) new TUFLOW hydraulic models were built for the development of synthetic (model derived) rating curves at the following gauges:

- Borilla Creek ALERT (535175)
- Sandy Creek ALERT (535103)



- Serpentine Alert (535154)

Similar to the previous study, a registered surveyor was engaged by CHRC to survey the gauge cross section of the three (3) aforementioned gauges. The synthetic rating curves represent results from the TUFLOW hydraulic models at the gauge locations using parameters that are considered the most appropriate for each site.

The study concludes with the recommendation that the Sandy Creek ALERT gauge be moved further up the Wolfgang Creek system to a location that is not impacted by the breakout flow at the current location. The study notes that the current locality is suitable for measuring in channel flows (< 10 m in depth), however above this rate, the change in flow is significant for small variations in flow depth.

2.1.6 **Nogoa Mackenzie Water Supply Scheme Resource Operations License (Queensland Government, 2019)**

Infrastructure details for the Nogoa Mackenzie Water Supply Scheme were included as Attachment 1 within the Operations License. This includes key structural details on the Fairbairn Dam, Selma Weir, Bedford Weir, Bingegang Weir, and Tartrus Weir. The relevant information was summarised and presented in Table 2-1.

Table 2-1 Summary of Water Infrastructure

Description	Fairbairn Dam	Bedford Weir	Bingegang Weir
Type	Earth fill dam	Mass concrete weir with fabridam	Mass concrete weir
Full Supply Level	204.23 m AHD	124.00 m AHD	102.90 m AHD
Fixed Crest Level	204.23 m AHD	122.80 m AHD	102.90 m AHD
Full Supply Volume	1,301,000 ML	22,900 ML	8,060 ML
Spillway Level	204.23 m AHD	122.80 m AHD	102.90 m AHD
Spillway Width	167.64 m	185.90 m	107.30 m

2.1.7 **Isaac Regional Council Isaac River Flood Study (KBR, 2021)**

KBR was commissioned by Isaac Regional Council to undertake the Isaac River Flood Study to define the existing flood behaviour within the Isaac River catchment. The scope of works involved the compilation and review of existing information pertinent to the study, the development and calibration of a combined hydrologic/hydraulic TUFLOW rainfall-on-grid model, the determination of design flood conditions for the 5%, 2%, 1%, 0.5%, and 0.1% AEP events as well as the PMF event, and the subsequent mapping of flood hazard.

The TUFLOW model was appropriately calibrated to the March 2017 (Tropical Cyclone Debbie) event with modelled outcomes compared against recorded stream gauge data and surveyed floor marks.

While the extents of the Isaac River catchment are outside of the study area for this study, the Isaac River joins the Mackenzie River at the downstream end of the study area. If necessary, the Isaac River flows modelled from this study will be incorporated as an inflow into the regional hydraulic model.

2.1.8 **Isaac Regional Council Clermont, Moranbah and Nebo Flood Model and Hazard Mapping 2022: Clermont Update Flood Study (GHD, 2023)**

GHD was commissioned by Isaac Regional Council to create new hydrologic and hydraulic models for the townships of Clermont, Moranbah, and Nebo in line with the Australian Rainfall and Runoff



Version 4.1 guidelines (2019). The updated models are reflective of Level 3 flood models and include simulation of the 50%, 20%, 5%, 2%, 1%, and 0.2% AEP events as well as the PMF event.

A new XP-RAFTS hydrologic model was developed for the Sandy Creek and Wolfgang Creek catchments. Modelled design flows were validated against a Flood Frequency Analysis conducted at the Sandy Creek at Clermont gauge (130207A). While no historical event-based calibration was undertaken as a part of this study, the modelled design flows aligned with the flows estimated through the FFA.

The modelled Sandy Creek and Wolfgang Creek flows were injected into a newly developed TUFLOW hydraulic model.

2.1.9 Isaac Regional Council Clermont, Moranbah and Nebo Flood Model and Hazard Mapping 2022: Variation 3: Extension Clermont TUFLOW Model Area (GHD, 2025)

During the update of Isaac Regional Council's planning scheme, it was identified that the hydraulic model extent of the Clermont, Moranbah and Nebo Flood Model and Hazard Mapping 2022 study did not sufficiently cover a number of rural residential zoned lots and rural residential investigation areas. GHD was engaged by Council to extend the hydraulic model upstream of the town of Clermont.

No updates to the XP-RAFTS hydrologic model were made for the town of Clermont and the hydraulic model updates were in accordance with the methodologies previously adopted.

2.1.10 Emergency Action Plan – Fairbairn Dam (ID 0269) (SunWater, 2025)

The report details the Emergency Action Plan for the Fairbairn Dam in accordance with the Water Supply (Safety and Reliability) Act 2008. While the emergency action plan does not have direct relevance to this study, key structural details, dam characteristics, and previous historical event behaviour has been detailed within the report. The relevant information has been summarised in Table 2-2.

Table 2-2 Summary of Fairbairn Dam (ID 0269) (SunWater, 2025)

Description	Value
Dam Type	Zoned, rock-filled embankment dam with a central clay core.
Purpose	The main source of supply for the Nogoa Mackenzie Water Supply Scheme. The dam is operated in conjunction with Selma, Bedford, Bingegang, and Tartrus Weirs to regulate supplies along the Mackenzie River and downstream to Springton Creek junction.
Storage Capacity	1,301,000 ML to Full Supply Level (FSL)
Catchment Area	16,320 km ²
Spillway Length	167.64 m
Spillway Elevation	204.23 m AHD
Embankment Length	823 m
Embankment Crest Level	218.86 m AHD
Outlet Type	Right bank outlet – Intake tower with outlets into the Nogoa River and the Weemah Channel (1,200 ML/day) Left bank outlet – Dual inlet with a combined outlet into the Selma Channel (690 ML/day)
December 2010 Peak Spillway Discharge	4,300 m ³ /s (approximately)



Description	Value
December 2010 Peak Reservoir Level	209.80 m AHD

2.1.11 Theresa Creek Dam Emergency Action Plan (Isaac Regional Council, 2025)

The report details the Emergency Action Plan for the Theresa Creek Dam in accordance with the Water Supply (Safety and Reliability) Act 2008. While the emergency action plan does not have direct relevance to this study, key structural details, dam characteristics, and previous historical event behaviour has been detailed within the report. The relevant information has been summarised in Table 2-3 and illustrated in Figure 2-1.

Table 2-3 Summary of Theresa Creek Dam Characteristics

Description	Value
Dam Type	Concrete gravity ogee crested primary overflow, flanking reinforced concrete, earth filled terrace overflow and homogeneous non-overflow embankments to abutments.
Purpose	Formerly water supply for the Blair Athol Coal Project development. Currently used for town water supply and recreation.
Storage Capacity	9,200 ML to Full Supply Level (FSL) 22,000 ML to Dam Crest Level (DCL)
Catchment Area	738 km ²
Central Spillway Length	225 m
Central Spillway Elevation	271.0 m AHD
Right Concrete Terraced Section Length	150 m
Left Concrete Terraced Section Length	55 m
Left/Right Concrete Terrace Crest Elevation	272.5 m AHD
Flanking Earthfill Embankment Length	434 m
Flanking Earthfill Embankment Crest Elevation	276.4 m AHD
Outlet Type	660 mm fixed dispersion cone valve
Outlet Invert Level	259.7 m AHD (approximately)
17 January 2008 Peak Spillway Discharge	1,450 m ³ /s
17 January 2008 Peak Reservoir Level	272.96 m AHD
25 November 2021 Peak Spillway Discharge	1,150 m ³ /s
25 November 2021 Peak Reservoir Level	272.76 m AHD

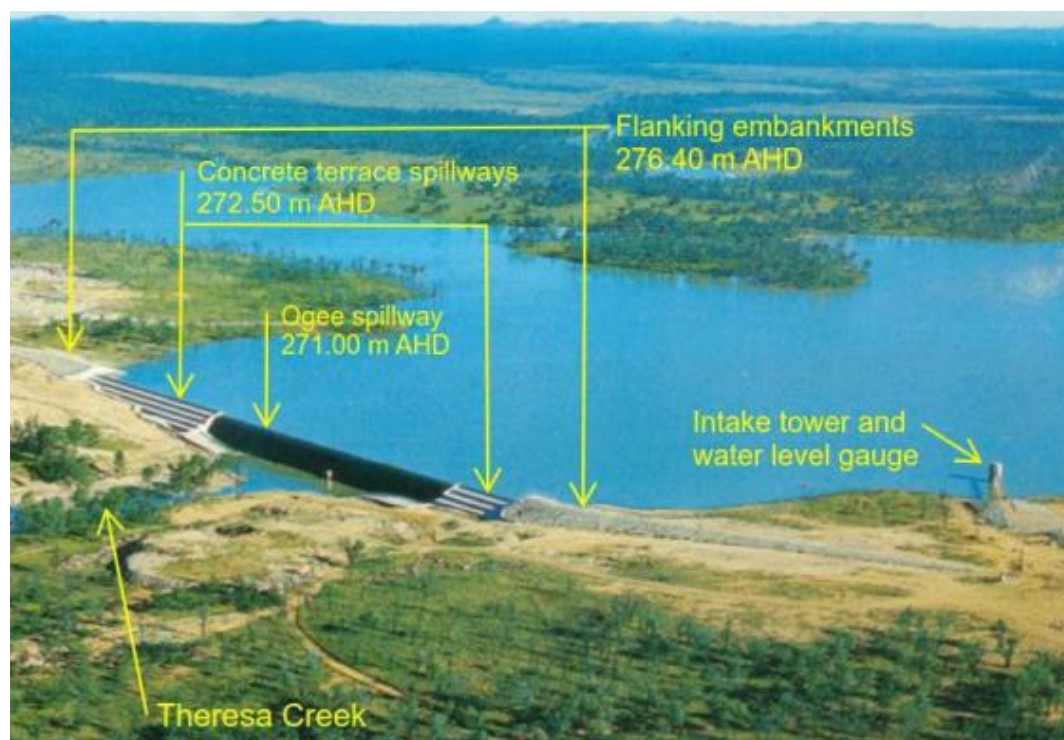


Figure 2-1 Theresa Creek Dam Schematisation (Photograph Taken After Construction in 1982)

2.2 EXISTING HYDROLOGIC AND HYDRAULIC MODELS

The existing hydrologic and hydraulic models relevant to the study area were provided by Council and CHRC at the outset of the study. A summary of the models received, and their intended uses are presented in Table 2-4. It is noted that the existing hydraulic models do not sufficiently cover the entirety of the study area.

Table 2-4 Summary and Intended Application of Relevant Existing Models

Dataset	Provider	Contents	Application
Nogoa River and Comet River XP-RAFTS model (KBR, 2014)	CHRC	Regional hydrologic and hydraulic models developed for the Central Highlands Regional Council Floodplain Management Study and Plan.	Sub-catchment delineation and model inputs (e.g. fraction imperviousness, spatial distribution, and temporal patterns) were reviewed and used to inform model inputs.
Isaac River, Mackenzie River, and Connor River XP-RAFTS model (KBR, 2014)	CHRC		While localised hydraulic models have been developed, no models are noted to cover the Clermont and Middelmount townships. Relevant model inputs (e.g. cross-drainage structures and hydraulic roughness delineation) were extracted and used where appropriate and relevant.
Comet Regional TUFLOW model (KBR, 2014)	CHRC		
Theresa and Retreat Creeks Regional TUFLOW model (KBR, 2014)	CHRC		
Upper Mackenzie Regional TUFLOW model (KBR, 2014)	CHRC		
Upper Nogoa Regional TUFLOW model (KBR, 2014)	CHRC		
Isaac River TUFLOW model (KBR, 2021)	Council	Whole of catchment combined hydrologic/hydraulic rainfall-	If necessary, modelled design flows for the Isaac River will be injected as an upstream



Dataset	Provider	Contents	Application
		on-grid model developed for the Isaac River Flood Study.	inflow into the hydraulic model.
Clermont XP-RAFTS model (GHD, 2022)	Council	Hydrologic and hydraulic models developed for the urban areas of Clermont and Nebo, as well as the urban areas of Moranbah extending to the Peak Down Highway, including Hazard mapping.	The hydraulic model has been superseded by the updated 2025 model. The FFA developed will be used for model validation purposes.
Clermont TUFLOW model (GHD, 2022)	Council		
Clermont extended TUFLOW model (GHD, 2025)	Council	Updated hydraulic model following the 2023 GHD study.	Relevant model inputs (e.g. cross-drainage structures, hydraulic roughness delineation) were extracted and used where appropriate and relevant.

2.3 GIS DATA

The GIS data provided by Isaac Regional Council, Central Highlands Regional Council, and the Queensland Government as well as datasets sourced from publicly available government sources is detailed in Table 2-5. A description of each dataset and its application to the study have also been included.

Table 2-5 Summary and Intended Application of GIS Data Provided/Sourced

Dataset	Provider	Contents	Format	Application
2017 Fitzroy NRM land use mapping	Queensland Government Open Data Portal	Geodatabase containing the surface land use distribution.	gdb	Used to inform hydraulic roughness and impervious ratios
Public Google Maps; QLD Globe Imagery; Council online mapping	Google; Queensland Spatial Catalogue – Qspatial; Council	Publicly available aerial imagery	wms/ IntraMaps	Used to provide aerial information and support model schematisation at the time of model development
Queensland public GIS dataset	Spatial Catalogue – Qspatial	General cadastral and spatial information in QLD	gdb	Used to support model schematisation in general
Council online mapping	Council	General cadastral and spatial information in Isaac Regional Council LGA	IntraMaps	Used to support model schematisation in general
CHRC Flood Heights	CHRC	Historical flood levels mainly in the vicinity of Theresa Creek, Retreat Creek, and Emerald	shp	Used to support model calibration in historical events

2.4 TOPOGRAPHIC DATA

The various topographic datasets sourced for the wider study area have been detailed in Table 2-6. The resolution and quality of the datasets vary from high resolution LiDAR to coarser resolution photogrammetry.



Table 2-6 Summary and Intended Application of Topography Data Provided/Sourced

Dataset	Provider	Contents	Format	Application
2012 Bowen Basin 20 m resolution photogrammetry	Council	Captured and produced by Fugro Spatial Solutions with a vertical accuracy of ± 0.7 m and a horizontal accuracy of ± 1.7 m.	xyz	Superseded by the 2017 Bowen Basin dataset
2017 Bowen Basin 10 m resolution photogrammetry	CHRC	Captured and produced by AEROMETREX. Accuracy is unknown.	tif	Used to establish the base topography of the regional hydraulic model
Unknown Surat Basin 15 m resolution photogrammetry	CHRC	Dataset has been supplied to the Queensland Government Department of Resources. The author and accuracy of the dataset is unknown.	Unknown	Superseded by the 2020 Surat Basin dataset
2020 Surat Basin 10 m resolution photogrammetry	CHRC	Dataset has been supplied to the Queensland Government Department of Resources. The author and accuracy of the dataset is unknown.	ige	Used to establish the base topography of the regional hydraulic model
2013 Fugro ROAMES Power Network Survey (Clermont) 0.5 m resolution LiDAR	ELVIS	Captured and produced by Fugro Spatial Solutions with a vertical accuracy of ± 0.15 m and horizontal accuracy of ± 0.50 m.	tif	Used to establish the base topography of the local hydraulic model
2018 Powerline Corridor 0.5 m resolution LiDAR	ELVIS	Captured and produced by Fugro Spatial Solutions with a vertical accuracy of ± 0.15 m and horizontal accuracy of ± 0.50 m.	tif	Used to establish the base topography of the local hydraulic model
2011 Clermont 1 m resolution LiDAR	ELVIS	Elevation data sourced from the Queensland Government Department of Natural Resources and Mines, Manufacturing and Regional and Rural Development (DNRMMRRD) with a vertical accuracy of ± 0.15 m and horizontal accuracy of ± 0.45 m.	tif	Used to validate the recently captured 2025 LiDAR dataset
2025 Clermont 0.5 m resolution LiDAR	Council	Captured by RPS Consulting AAP Pty Ltd on behalf of the DNRMMRRD with a vertical accuracy of ± 0.2 m and horizontal accuracy of ± 0.6 m.	tif	Used to establish the base topography of the local hydraulic model
2014 Middlemount 1 m resolution LiDAR	ELVIS	Elevation data sourced from the DNRMMRRD with a vertical accuracy of ± 0.15 m and horizontal accuracy of ± 0.40 m.	tif	Used to validate the recently captured 2025 LiDAR dataset
2025 Middlemount 0.5 m resolution LiDAR	Council	Captured by RPS Consulting AAP Pty Ltd on behalf of the DNRMMRRD with a vertical accuracy of ± 0.2 m and horizontal accuracy of ± 0.6 m.	tif	Used to establish the base topography of the local hydraulic model



Dataset	Provider	Contents	Format	Application
2011 SRTM-derived 1 Second Digital Elevation Models Version 1.0	Commonwealth of Australia (Geoscience Australia)	The DEMs were derived from the SRTM data acquired by NASA in February 2000 and were publicly released under Creative Commons licensing from November 2011 in ESRI Grid format.	tif	Used for the rest of the hydraulic model area where the photogrammetry and high-resolution LiDAR have insufficient coverage

The combination of elevation datasets from multiple sources can often present significant challenges. While careful consideration is typically required on how best to preferentially select, modify, and/or merge these datasets in areas of overlap, the review of the various topographic datasets indicates that there is good alignment outside of the SRTM. KBR has layered the datasets in the order of resolution and accuracy with the appropriate offsets applied during the model development stage of this study (refer to Section 5.4.2 for further information).

As the provided LiDAR reports the highest threshold of accuracy between data sources, each dataset has been compared against the LiDAR in areas of overlap. Due to the high resolution of the datasets, the LiDAR data is able to appropriately capture detailed hydraulic features such as road and levee crests, and culvert headwalls.

The photogrammetry datasets cover the majority of the wider catchment extent and is able to effectively capture the broad characteristics of the catchment and large, define features (e.g. major dam embankments and weirs). However, the coarse resolution of the dataset results in the inability to accurately represent hydraulic features that are smaller than the respective cell sizes (i.e. 10 or 20 m).

A small portion of the Upper Nogoia catchment (along part of the western boundary) is not covered by either the photogrammetry or LiDAR. As such, for this area, the SRTM dataset was used to supplement the other topographic data sources. While the SRTM is of a much lower resolution and quality, manual adjustments to the datum of the dataset were required to ensure a smooth transition and interface with the photogrammetry datasets.

While the photogrammetry datasets are able to appropriately capture the alignment, width, and extent of major watercourses, the LiDAR is able to more accurately capture the low points of the rivers and creeks. However, due to the method of data capture employed across all survey approaches scanning from top down, a degree of uncertainty is to be anticipated in capturing the true low points/inverts of permanent water bodies and watercourses even within the LiDAR datasets.

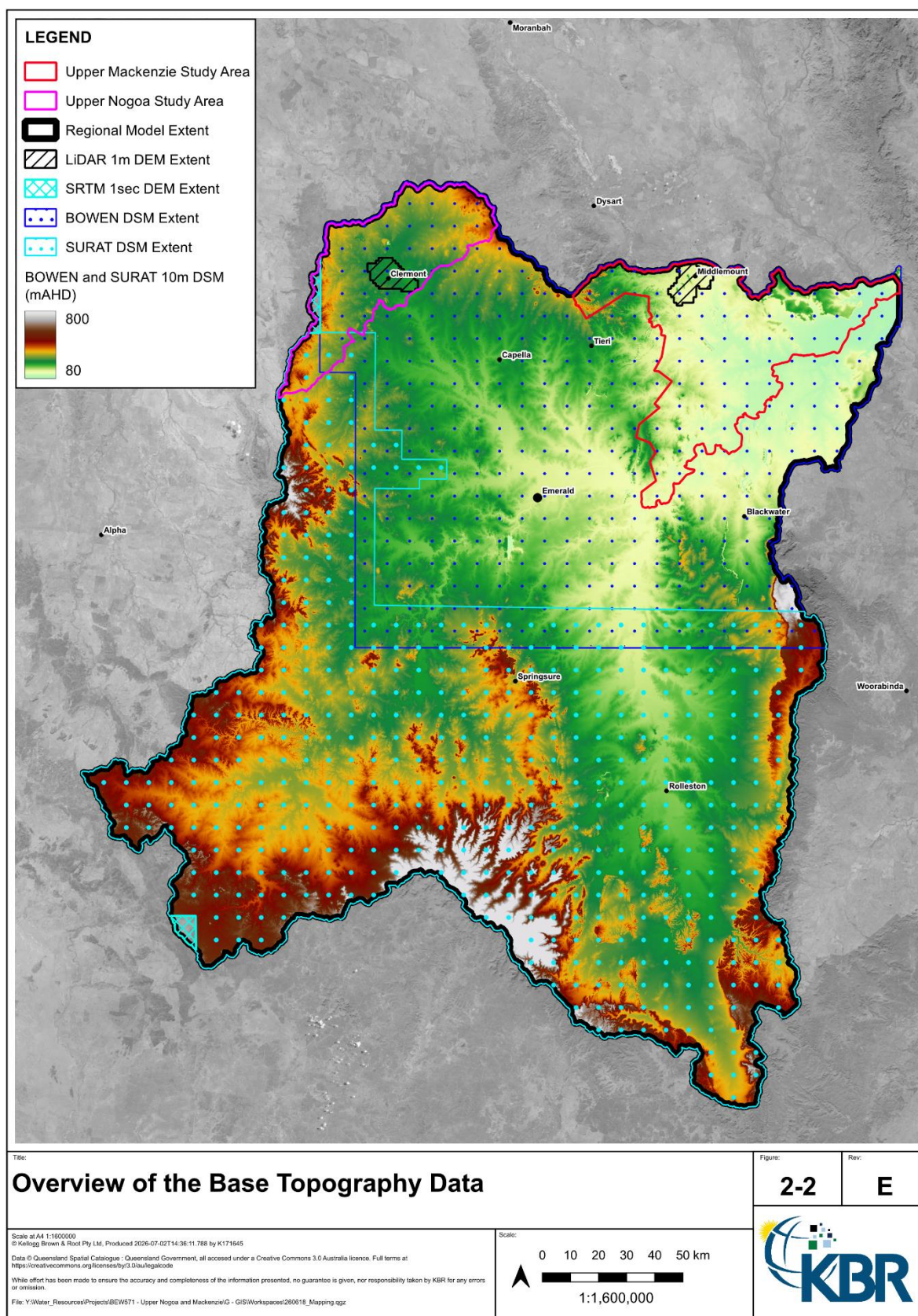


Figure 2-2 Overview of the Base Topography Data



2.5 HYDRAULIC STRUCTURES

Various hydraulic structure datasets were sourced from local and state government agencies. During the data review process, missing attributes were commonly encountered due to incomplete source data. This has led to the establishment of several assumptions in a data infilling process using a variety of aerial imagery, Streetview, and interrogation of topographic datasets. A summary of the hydraulic structure datasets is presented in Table 2-7.

Table 2-7 Summary of Sourced Hydraulic Structure Data

Dataset	Provider	Contents	Format	Application
Memorandum for Structures in Floodplain –GHD Clermont TUFLOW Model Extension	Council	Information including dimensions, plans, council IntraMap and photos for hydraulic structures and stormwater networks, mainly to the west of Clermont town centre only	pdf	Used to inform development of the local hydraulic model for the Clermont area
Culverts	Council	Information for culverts within the Isaac Regional Council LGA including locations and dimensions.	shp	Used to inform development of the local hydraulic models where applicable
BIS (Bridge Information System) database	QLD TMR	Selected structures within the study area including bridges, culverts, minor culverts	shp	Used to inform development of the local hydraulic models where applicable
State_controlled_roads_culverts	Queensland Spatial Catalogue – Qspatial	Registered culvert locations and sizes in the state	gdb	Used to inform development of the local and regional hydraulic models where applicable
Hydraulic Structures across railway	Queensland Rail	Bridges, culverts, and minor drainage across railway for chainage 78.00km - 119.00km, mainly around Clermont	kml, pdf, xlsx	Used to inform development of the local and regional hydraulic models where applicable
Rail_bridges_and_overpasses	Queensland Spatial Catalogue – Qspatial	Registered bridge locations and lengths in the state	gdb	Used to inform development of the local and regional hydraulic models where applicable



Example railway and road hydraulic structures taken on site are presented below in Figure 2-3.



Figure 2-3 Hydraulic Structure Photographs Taken on Site

2.6 RAINFALL GAUGE DATA

Historic rainfall information is a vital dataset that plays a key role in the calibration and validation process of hydrologic and hydraulic models. It is primarily used to define the magnitude, and spatial and temporal distribution of rainfall for historical rainfall events.

Rainfall data was acquired from several sources, including the Australian Government Bureau of Meteorology (BoM) Water Data Online portal, BoM Climate Data online portal, Queensland Government Water Monitoring Information Portal (WMIP), and information directly sourced from Central Highlands Regional Council, the Queensland Government Department of Regional Development, Manufacturing and Water (DRDMW), and SunWater.

Rainfall gauges are typically categorised into daily or sub-daily/pluviographic gauges, correlated with the frequency of recording. Approximately 61 pluviographic rainfall gauges and nine (9) daily rainfall gauges were identified within the wider regional catchment. A summary of the acquired rainfall gauge information is presented in Table 2-8 and Figure 2-4.

Table 2-8 Summary of Rainfall Gauge Information

Gauge ID	Gauge Name	Gauge Owner	2008 Rainfall (mm) (15/01/2008 to 30/01/2008)	2010 Rainfall (mm) (18/12/2010 to 06/01/2011)
035001	Anakie Richardson St	BoM Daily	521	223
035021	Comet Post Office	BoM Daily	72	237
035016	Capella Post Office	BoM Daily	223	159
035289	Mt Playfair	BoM Daily	274	N/A
035051	Orion	BoM Daily	163	173
035053	Peakvale	BoM Daily	499	238
035063	Somerby	BoM Daily	54	289
035194	Wyseby	BoM Daily	170	486
035019	Clermont Post Office (Sirius St)	BoM Daily	240	159
035264	Emerald Airport	BoM Sub-daily	131	N/A



Gauge ID	Gauge Name	Gauge Owner	2008 Rainfall (mm) (15/01/2008 to 30/01/2008)	2010 Rainfall (mm) (18/12/2010 to 06/01/2011)
035065	Springsure (Dame St)	BoM Sub-daily	325	N/A
035059	Rolleston (Warrijo St)	BoM Sub-daily	93	N/A
535039	Raymond	BoM Sub-daily	293	361
535033	Bogantungan	BoM Sub-daily	713	N/A
535035	Emerald	BoM Sub-daily	172	114
035292	Ducabrook	BoM Sub-daily	N/A	226
535082	Billaboo	BoM Sub-daily	N/A	263
035293	Heathwood	BoM Sub-daily	N/A	400
035294	Kulumur Range	BoM Sub-daily	N/A	205
035146	Emerald Radar	BoM Sub-daily	N/A	127
535074	Florence Vale	BoM Sub-daily	N/A	161
035185	Capella (Rowe's Hill)	BoM Sub-daily	N/A	203
535091	Humboldt	BoM Sub-daily	N/A	243
535092	Avocet	BoM Sub-daily	N/A	196
035186	Blackdown Tablelands	BoM Sub-daily	N/A	119
534022	Middlemount	BoM Sub-daily	N/A	248
535037	Mantuan Downs	CHRC Sub-daily	338	N/A
535038	Wharton Creek	CHRC Sub-daily	234	410
535101	Fairbairn Dam	CHRC Sub-daily	326	159
535042	Springsure	CHRC Sub-daily	293	N/A
535083	Glen Rock	CHRC Sub-daily	N/A	409
535085	Echo Hills	CHRC Sub-daily	N/A	351
535081	Green Valley	CHRC Sub-daily	N/A	224
535106	Upper Van Dyke	CHRC Sub-daily	N/A	402
535040	Penjobe	CHRC Sub-daily	N/A	470
535086	Upper Claude	CHRC Sub-daily	N/A	293
535100	Sapphire	CHRC Sub-daily	N/A	166
535077	Rubyvale	CHRC Sub-daily	N/A	79
535084	Middle Ridge	CHRC Sub-daily	N/A	171
535103	Sandy Creek Bridge	CHRC Sub-daily	N/A	116
534025	West Wolfgang Creek	CHRC Sub-daily	N/A	115
535075	Roddas Lookout	CHRC Sub-daily	N/A	313
535018	Gregory	DRDM&W Sub-daily	274	N/A
535019	Amah	DRDM&W Sub-daily	271	N/A
535020	Wyuna	DRDM&W Sub-daily	152	N/A
535027	CTFN	DRDM&W Sub-daily	221	N/A
535029	CTFS	DRDM&W Sub-daily	277	N/A
535042	RTCS	DRDM&W Sub-daily	301	N/A



Gauge ID	Gauge Name	Gauge Owner	2008 Rainfall (mm) (15/01/2008 to 30/01/2008)	2010 Rainfall (mm) (18/12/2010 to 06/01/2011)
535044	Wyoming	DRDM&W Sub-daily	246	N/A
535045	The Glen	DRDM&W Sub-daily	234	N/A
535047	Gordon Road	DRDM&W Sub-daily	223	N/A
535048	Larundel	DRDM&W Sub-daily	119	N/A
535049	Lara	DRDM&W Sub-daily	179	N/A
535050	Coates	DRDM&W Sub-daily	137	N/A
535073	Graze	DRDM&W Sub-daily	272	N/A
130207A	Clermont	DRDM&W Sub-daily	155	136
130209A	Craigmore	DRDM&W Sub-daily	304	194
130210A	Valeria	DRDM&W Sub-daily	290	130
130219A	Duckponds	DRDM&W Sub-daily	92	176
130113A	Rileys Crossing	DRDM&W Sub-daily	66	211
535057	Cowley	DRDM&W Sub-daily	126	N/A
130502	Lake Brown	DRDM&W Sub-daily	126	351
130504	Comet Weir	DRDM&W Sub-daily	73	246
130510	Springsure Creek Junction	DRDM&W Sub-daily	110	137
130509	Rewan	DRDM&W Sub-daily	206	405
130206A	Gregory Hwy	DRDM&W Sub-daily	N/A	111
130105A	Coolmaringa	DRDM&W Sub-daily	82	300
130401A	Yatton	DRDM&W Sub-daily	241	262
130111A	Bedford Weir	SunWater Sub-daily	N/A	222
130110A	Bingegang Weir	SunWater Sub-daily	N/A	325

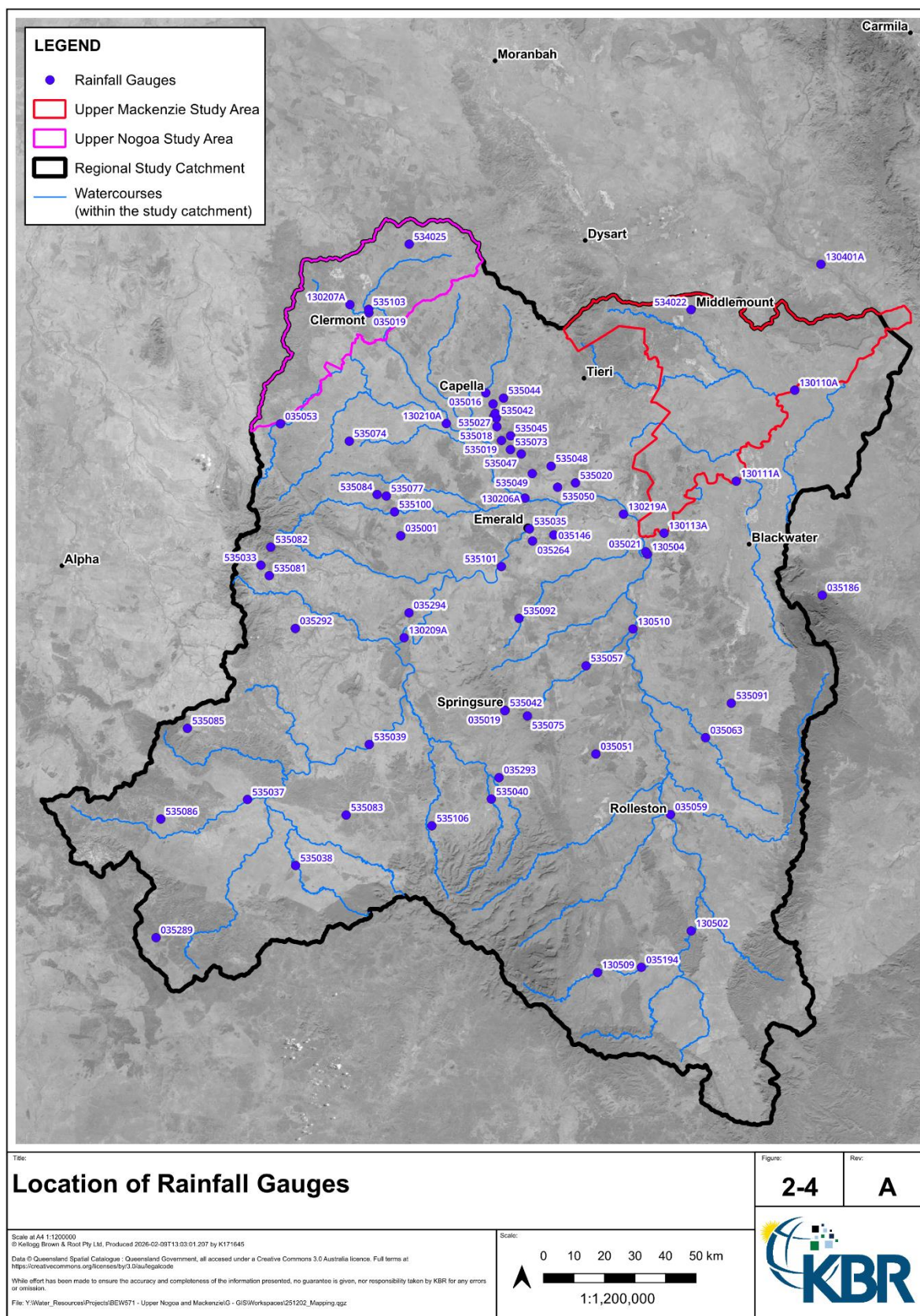


Figure 2-4 Location of Rainfall Gauges



2.7 STREAM GAUGE DATA

Stream gauges have been located on major watercourses and tributaries across the wider study area. While extensive analysis of the existing stream gauges and their flow-level gauging relationship has been undertaken as part of previous studies, the recorded flows were pivotal in facilitating the following two components of this study:

- Verification of the model's ability to reproduce recorded historical flow rates as part of model calibration and validation, and
- Flood frequency analysis for validation of design flow rates.

Stream gauge data was acquired from several sources, including the BoM Water Data Online portal and WMIP. The stream gauges within the study area have been summarised in Table 2-9 and shown in Figure 2-5.

Table 2-9 Summary of Stream Gauge Information

Gauge ID	Gauge Name	Gauge Owner	Site Commenced	Site Finished
535103	Sandy Creek Bridge TM	BoM	28/07/2010	Ongoing
130207A	Sandy Creek at Clermont	DRDMW	21/01/1965	Ongoing
130210A	Theresa Creek at Valeria	DRDMW	9/08/1971	Ongoing
130206A	Theresa Creek at Gregory Highway	DRDMW	10/01/1956	Ongoing
130209A	Nogoa River at Craigmore	DRDMW	10/02/1972	Ongoing
130216A	Nogoa River at Fairbairn Dam HW	SunWater	14/12/1973	01/07/2002
130219A	Nogoa River at Duck Ponds	DRDMW	2/04/1993	Ongoing
130510A	Comet River at Springsure Creek Junction	DRDMW	1/06/2007	Ongoing
130504B	Comet River at Comet Weir	DRDMW	12/06/2002	Ongoing
130113A	Mackenzie River at Rileys Crossing	DRDMW	13/10/2004	Ongoing
130111A	Mackenzie River at Bedford Weir TW	SunWater	28/06/1997	01/07/2002
130106A	Mackenzie River at Bingegang	DRDMW	13/08/1971	Ongoing
130110A	Mackenzie River at Bingegang Weir TW	SunWater	28/08/1993	01/07/2002

While the distribution of the gauges across the wider catchment allows for calibration of select historical events, the incomplete records and missing years of data limited the feasibility of flood frequency analyses for the majority of the gauges identified above. In addition, the gaugings available are mostly limited to low flow, in-channel flood behaviour and are sparse across the available gauges. The rating curves and gaugings associated with the key gauges of importance during the model calibration and validation stage of the study have been detailed in Section 6. A photograph taken on site of the Sandy Creek Bridge TM gauge has been included as Figure 2-6.

The Central Highlands Regional Council Floodplain Management Study and Plan (KBR, 2014) states that the gauges on the Comet River lacked "reliable records as well as potential inaccuracies in stage-discharge ratings at higher stage flows". In addition, synthetic rating curve development is acknowledged at select gauges as described in Section 2.1. KBR has considered the appropriateness of the modelled results to the best rating curve information available at key gauges.

The application of the streamflow gauges for calibration and validation is discussed further in Section 7.4 and Section 7.5.

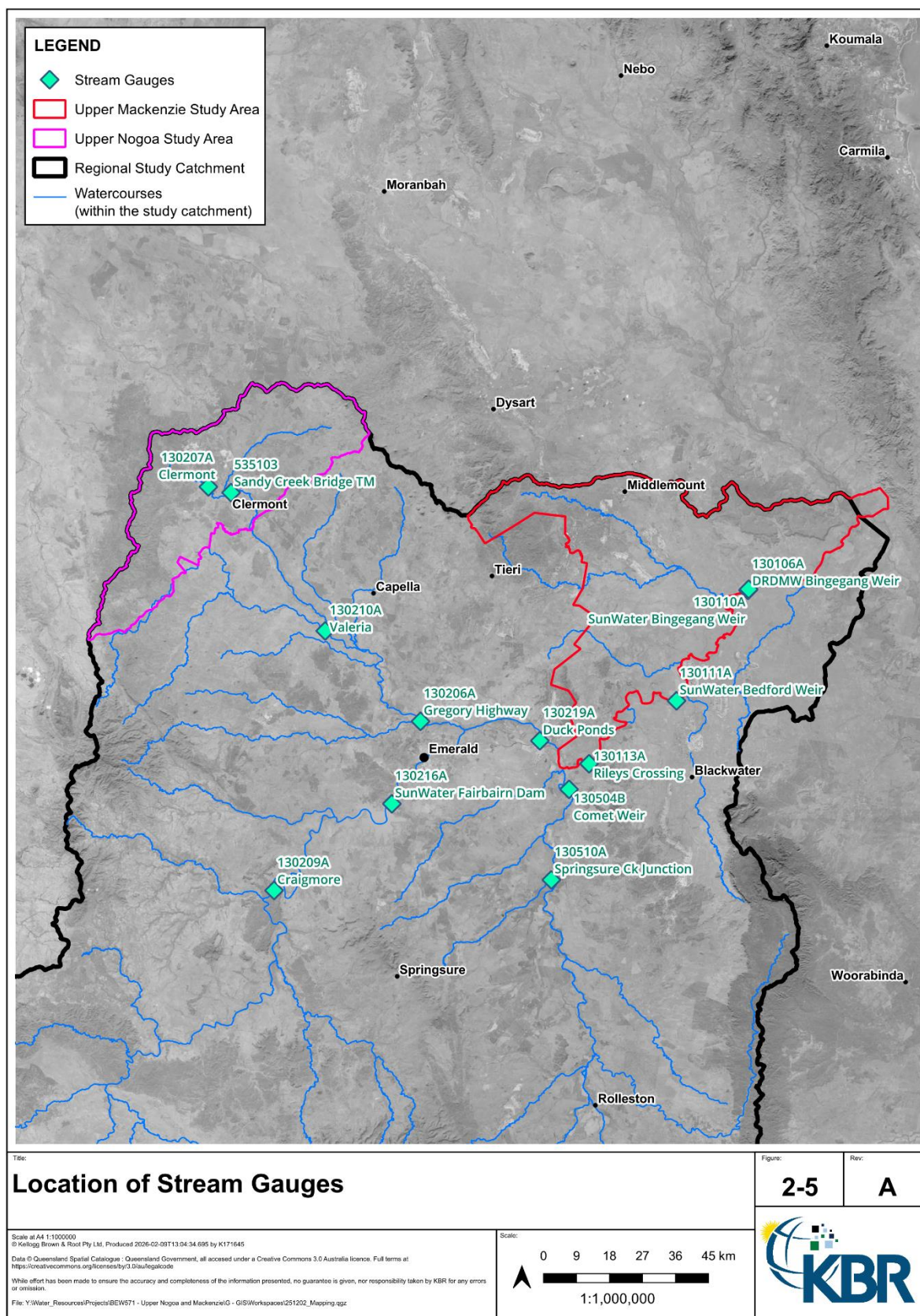


Figure 2-5 Location of Stream Gauges



Figure 2-6 Sandy Creek Bridge TM Gauging Station

2.8 HISTORICAL FLOOD DATA

Historical flood information has been requested as part of the initial community consultation exercise (refer to Section 3 for further information). In particular, it is acknowledged that the township of Clermont has experienced several major flood events, with one of the worst recorded flood disasters in Australia in terms of loss of life. The severity of the historical flooding has led to the relocation of the township after the December 1916 flood to higher ground.

Recent recorded debris markers post the January 2026 flood event and an estimated flood extent for the same event were provided by Council and is detailed in Section 7.4.3.



3 Community Consultation and Engagement

Community consultation is an integral component of floodplain management and provides several benefits contributing to the success and reliability of a flood mapping study. Community consultation and engagement aim to raise awareness of the program and provide the community with an opportunity to provide data that can be used to inform the outcomes of the Study.

It is understood that many community members have been residing within the study area for extended periods of time and have experienced notable rainfall and flood events. The input from the community is acknowledged to be a valuable source of real-lived experience and can contribute to enhancing the robustness of the model calibration process.

Community consultation serves several purposes, including but not limited to:

- To inform the community of the process for floodplain risk management within their location,
- To inform the community of the progress of defining and mitigating flood risk within the catchment,
- To enable the community to provide key information into the undertaking of flood studies and floodplain risk management studies and plans, and
- To provide the community ownership over the floodplain risk management strategies and mitigation options.

A consultation process is currently underway as a part of this Study. The following elements have been completed to date:

- Consultation throughout the study with governmental bodies including Council and the Queensland Reconstruction Authority,
- Community consultation via a commencement of flood study letter, community questionnaire, webpage, and media release.

With Council's endorsement, the study will be placed on public exhibition. During this time, the report will be publicly available, allowing the community to provide feedback on the Study and associated outcomes.

3.1 INITIAL COMMUNITY CONSULTATION

A request for flood information letter was mailed out to 76 and 216 rural households in the Upper Mackenzie and Upper Nogoia catchments respectively on the 14th of November 2025. The letter included an overview of the Study and instructions on how the community can support the Study.

In conjunction, Council has established a dedicated page on their Speak Up section of their website, with the contents of the letter and further details on the stages of the study for the community to access digitally. A Frequently Asked Questions sheet and instructions on how to record a flood marker were prepared by Council and included in the webpage.

Similarly, a flood survey was prepared and made available via Council's webpage. The focus of the survey was to gather relevant flood information from the community, including photographs of flooding, observed or recorded flood depths, descriptions of flood behaviour, or private rainfall data within the study locality.

Copies of the community consultation material are included in Appendix A of this report. The outcomes of the initial community consultation exercise will be presented upon completion of the consultation period.



4 Site Investigation

Prior to the site investigation, a preliminary TUFLOW Rain-on-Grid (RoG) model was developed to assist in the identification of key locations subject to inundation. A site investigation was subsequently conducted following the study inception and completion of the initial data compilation and review. The site visit was conducted between the 25th and 27th of November 2025 and included the following:

- Ground truthing of hydraulic cross-drainage structure dimensions by comparing measured sizes against information provided by the various providers.
- Investigation of key hydraulic control structures including the Theresa Creek Dam, Bedford Weir, and Bingegang Weir.
- Walkover of the Clermont and Middelmount townships.
- Walkover of known flooding locations informed by Council and previous studies.
- Meeting with Isaac Regional Council Councillor residing within the study area.

4.1 HYDRAULIC STRUCTURES

To consolidate the information received across the various data providers, the site investigation was utilised as an opportunity to ground truth the hydraulic structure dimensions on hand by measuring assets across various localities. KBR and Council measured cross-drainage structures spanning Council roads, state roads, and the railway. While the locality of the geo-referenced asset database required refinement, the dimensions presented within the datasets was of high quality and accuracy as confirmed on site.



Figure 4-1 QLD TMR 8 x 1.2 m x 1.2 m Measured Box Culverts



Figure 4-2 QLD TMR 4 x 1.8 m Diameter Circular Measured Culverts



Figure 4-3 Queensland Rail 5 x 3.0 m x 3.2 m Measured Box Culverts

4.2 STREAM GAUGE LOCATIONS

The coarseness of the topographic information and absence of high quality aerial imagery made it difficult to gain an appreciation and deeper understanding of the terrain immediate to the streamflow gauging stations. An improved understanding of the location, terrain, and topographic features within the vicinity of the gauge is a critical component in the successful calibration of



hydrologic and hydraulic models. As such, the following gauges were identified for further investigation on site:

- 535103 – Sandy Creek Bridge TM
- 130207A – Sandy Creek at Clermont
- 130113A – Mackenzie River at Rileys Crossing
- 130111A – Mackenzie River at Bedford Weir TW
- 130110A – Mackenzie River at Bingegang Weir TW

While the Sandy Creek at Clermont and Mackenzie River at Rileys Crossing gauges were unable to be accessed due to being on private property, the following observations were noted on site:

- The Sandy Creek Bridge TM gauging station is located on the upstream side of the bridge, approximately 55 m perpendicular to the Clermont Connection Road (refer to Figure 4-4).
- The Mackenzie River at Bedford Weir TW gauging station is located on the downstream side of the weir adjacent to the Blackwater Cooroorah Road (refer to Figure 4-5). Multiple depth indicators are placed adjacent to the roadway directly downstream of the weir. The road is a single laneway road and was moderately trafficked during a midday weekday.
- The Mackenzie River at Bingegang Weir TW gauging station is located on the upstream side of the weir (refer to Figure 4-6). Several depth indicators are placed in close proximity of the weir all the way down to the reservoir.



Figure 4-4 Sandy Creek Bridge



Figure 4-5 Bedford Weir (from downstream point of view)



Figure 4-6 Bingegang Weir



5 Model Development

5.1 MODELLING SOFTWARE

TUFLOW is a hydraulic modelling platform used for simulating depth-averaged, one and two-dimensional free-surface flows from fluvial and tidal flooding. TUFLOW Heavily Parallelised Computing (HPC) utilises the power of parallel processing capabilities of Graphics Processing Units (GPUs) to significantly reduce model simulation times.

The use of a 2D modelling platform enables the complex interaction between rivers, creeks, and floodplains; the converging and diverging of flows through structures; and the interaction between surface and sub-surface flows to be simulated within a single model.

Specific to this study, the distinct advantage of TUFLOW is the ability to spatially represent rainfall and hydrologic losses in a computationally efficient manner. The latest TUFLOW release (2025.2.2) at the time of model development has been utilised for this study.

Due to the size of the required modelling extent and the need to spatially represent the townships of Clermont and Middelmount at a higher resolution, the following two features of the TUFLOW software were relied upon:

- TUFLOW Quadtree (QPC) allows for variable cell sizes within a single model, and
- TUFLOW Sub-Grid-Sampling (SGS) allows computations to be performed optimally using higher resolution terrain data than the TUFLOW grid cell size adopted.

5.2 MODELLING METHODOLOGY

Modelling undertaken to assess a catchment's flood behaviour is typically considered in two distinct components:

- The hydrologic model – simulates the catchment rainfall-runoff response to generate inflows for inclusion into the hydraulic model, and
- The hydraulic model – simulates the flow behaviour of the overland flow paths, creeks, and waterways, producing flood inundation extents, depths, and velocities. Hydraulic modelling allows for a detailed understanding of the flood behaviour across the catchment.

The hydrologic modelling component can either be undertaken using a standalone hydrologic model (e.g. XP-RAFTS) or included within the hydraulic model when adopting a Direct Rainfall/Rainfall-on-Grid (RoG) approach. A RoG approach evenly distributes rainfall across the model domain.

Hydrologic modelling was previously undertaken for various studies across the Isaac Regional Council and Central Highlands Regional Council LGA's. However, the previously adopted XP-RAFTS software has been discontinued since 2018.

The use of TUFLOW as a combined hydrologic and hydraulic model will provide model longevity for future development and remove the complexity of multi-software modelling. The advantages of using the RoG approach in TUFLOW include:

- 2D mapping of modelled outcomes across the entire catchment area,
- The ability to capture cross-catchment flows as rainfall is applied across the whole modelled area, and



- The catchment delineation process is simplified compared to that for a node/link hydrological model as direct rainfall is applied within the whole regional catchment extent.

5.2.1 Multi-Model Approach

To define the flood behaviour for the study area, the adoption of a RoG approach requires the modelling of the entire contributing catchment (including the Mackenzie River and its tributaries) up to the confluence with the Isaac River. As the townships of Clermont and Middelmount are the focal points of the study, higher resolution flood mapping was required at these locations. Due to the size of the required modelling for the entire contributing catchment, the modelling was broken up into the following separate models:

- Coarse scale Regional TUFLOW RoG model covering the entire Mackenzie River catchment up to the confluence with the Isaac River (herein referred to as the Regional model).
- Higher resolution Local TUFLOW RoG model covering the Upper Mackenzie River catchment. Flow hydrographs for the Mackenzie River have been extracted from the Regional model for inclusion as an upstream boundary into this localised model.
- Higher resolution Local TUFLOW RoG model covering the Upper Nogoia River catchment. As the Upper Nogoia River catchment is at the top of the catchment with no upstream inflow, there was no need to extract flow hydrographs from the Regional model.

While three (3) separate models were developed for the purposes of this study, where appropriate, hydrologic and hydraulic parameters and inputs were shared and consistent across the models.

5.3 HYDROLOGIC PARAMETISATION

While the need for a standalone hydrologic model is negated with the adoption of a RoG approach, hydrologic inputs and parameters are still required to be defined (i.e. rainfall and losses). The basis of the hydrologic parameterisation is detailed subsequently.

5.3.1 Sub-Catchments Delineation

The contributing catchment to the Mackenzie River was delineated into several smaller sub-catchments. The delineation of sub-catchments is required to represent the significant variation within the larger Mackenzie River system. The delineation was undertaken primarily using the available topographic information and in consideration of the spatial and temporal variation in rainfall (noticed during the historical event modelling process).

The applied rainfall catchments are presented in Figure 5-1.

5.3.2 Rainfall Data

Rainfall data is the primary input to a TUFLOW RoG model which simulates the catchments response to rainfall. The applied rainfall is defined by:

- Rainfall depth – the total depth of rainfall across the catchment over a defined time period,
- Temporal pattern – the distribution of the rainfall depth at a selected time interval over the duration of the rainfall event, and
- Spatial distribution – the spatial distribution of rainfall depth and temporal patterns across the catchment.

The rainfall inputs for the historical events are presented in Section 7.3.



5.3.3 Loss Model and Parameters

Losses within the TUFLOW models were accounted for through the infiltration functionality of TUFLOW. The application of losses through the infiltration mechanism allows for the continual removal of runoff from the model, mimicking the real-life behaviour during flood events.

Both Initial Loss/Continuing Loss and Green-Ampt loss models were tested as part of the iterative model calibration process. The application of the Green-Ampt loss model produced better alignment with the gauged information, as such was the adopted loss model.

The 1991 Digital Atlas of Australian Soils was sourced from CSIRO's Australian Soil Resource Information System (ASRIS) and is a classification scheme that is represented as a series of GIS shapefiles spanning Australia. Each shapefile consists of a soil type with accompanying explanatory notes, including descriptions of the underlying soil and geological landscape.

This dataset was reclassified in accordance with the United States Department of Agriculture (USDA) soils classification matrix for application of the Green-Ampt loss model within TUFLOW. Soil types and standard parameters are built into the TUFLOW software package and have been utilised in lieu of physical soil testing.

The USDA soil parameters built into the TUFLOW software have been detailed in Table 5-1 with the spatial distribution illustrated in Figure 5-2.

Table 5-1 USDA Soil Type Parameters for the Green-Ampt Loss Model

ID	Type	Suction (mm)	Hydraulic Conductivity (mm/hr)	Porosity (fraction)
1	Clay	316.3	0.3	0.385
2	Silty Clay	292.2	0.5	0.423
3	Sandy Clay	239.0	0.6	0.321
4	Clay Loam	208.8	1.0	0.309
5	Silty Clay Loam	273.0	1.0	0.432
6	Sandy Clay Loam	218.5	1.5	0.330
7	Silt Loam	166.8	3.4	0.486
8	Loam	88.9	7.6	0.434
9	Sandy Loam	110.1	10.9	0.412
10	Loamy Sand	61.3	29.9	0.401
11	Sand	49.5	117.8	0.417

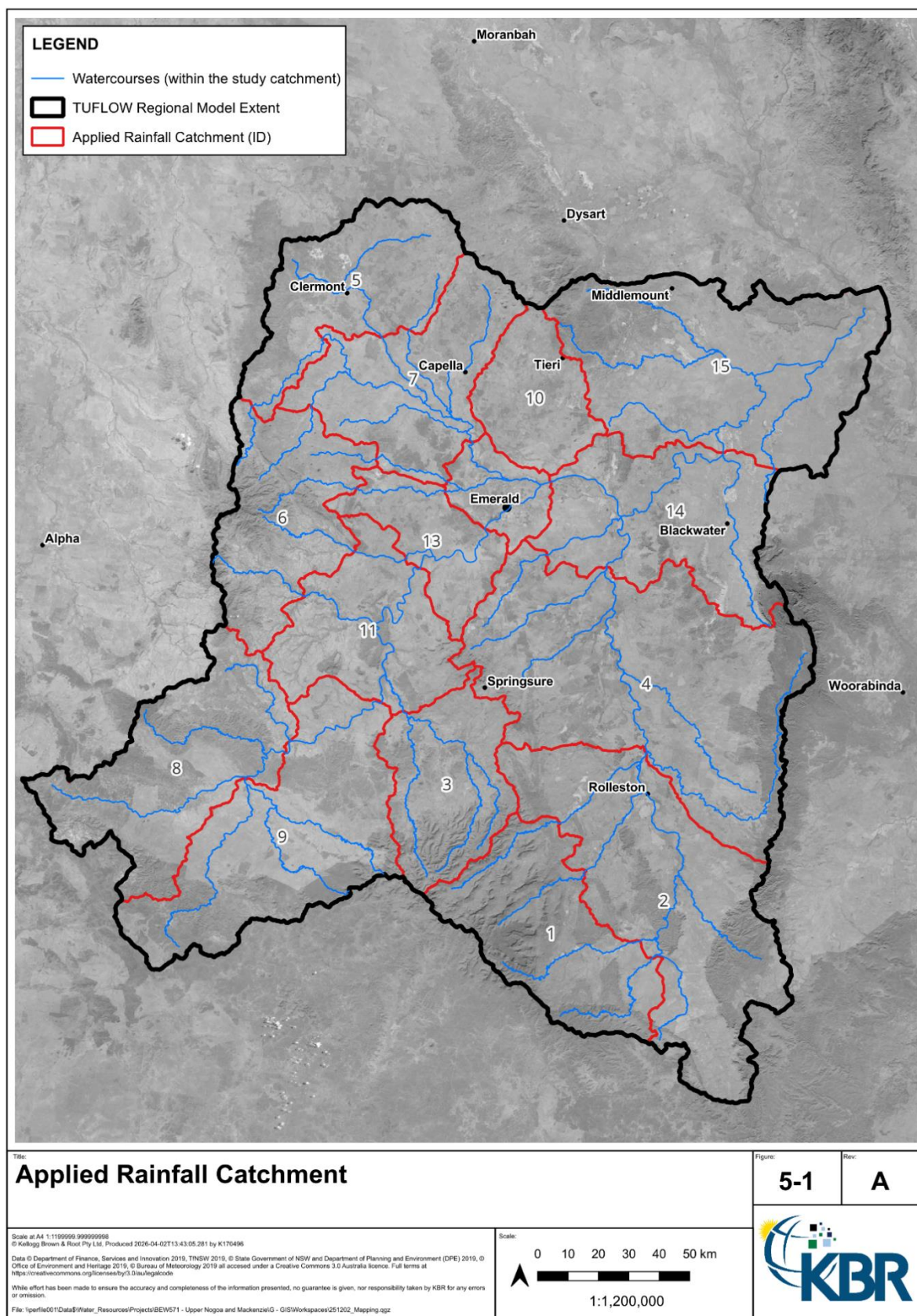


Figure 5-1 Applied Rainfall Catchments

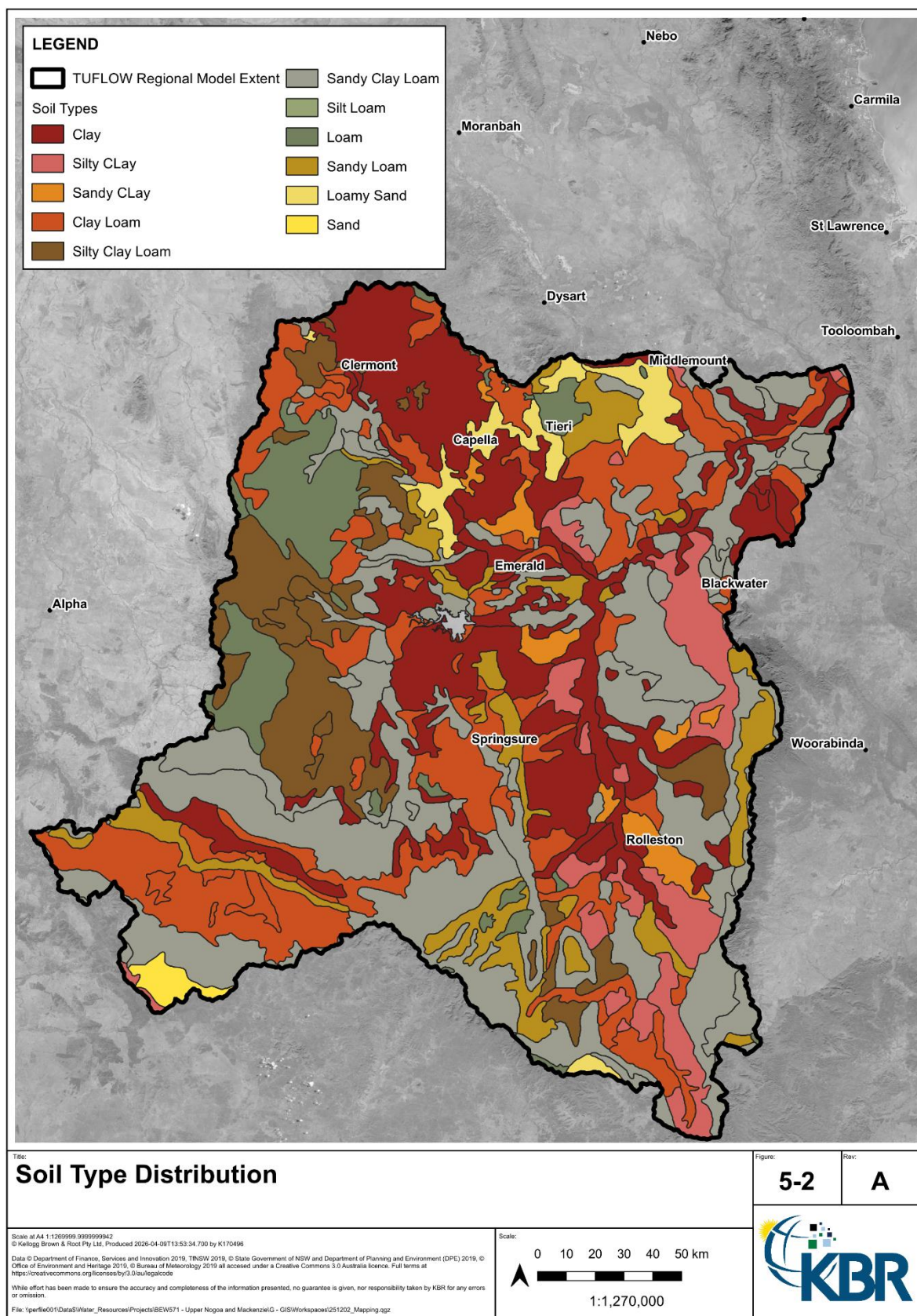


Figure 5-2 Soil Type Distribution



5.4 HYDRAULIC MODEL DEVELOPMENT

The development of a TUFLOW model generally follows the procedure below:

- Model Domain – Delineation of the region which the TUFLOW model will cover.
- Model Cell Size – Establishment of the model cell and sub-cell size resolutions.
- Manning's 'n' – Delineation of the surface roughness/Manning's 'n' zones using available information such as land use, vegetation cover, geology, and aerial imagery where available and the establishment of the Manning's 'n' values to be applied to the various zones delineated.
- Topography – Preparation of the underlying DEM using a range of topographic datasets with the incorporation or reinforcement of the physical features of the floodplain, such as the top of levees, spillways, and embankments.
- Hydraulic structures – Inclusion of the hydraulic structure assets, such as culverts and bridges.
- Boundary Conditions – Delineation of inflow and outflow boundaries where necessary.
- Reporting – Delineation of reporting points, lines, and/or regions for the extraction of hydraulic time series outputs such as flow, level, or velocity.

5.4.1 Model Domain

As described in Section 5.2, the Mackenzie River catchment up to the confluence with the Isaac River is covered in entirety by the extent of the regional model domain. The local Upper Nogoia and Upper Mackenzie models cover the upper catchments up to the Isaac Regional Council LGA.

Within the Regional TUFLOW model, a 60 m horizontal grid cell size resolution was adopted with an approximate 10 m sub-grid-sampling distance. The adopted configuration optimises the model resolution while maintaining model run time efficiency.

The Local TUFLOW models adopt a 16 m horizontal grid cell size resolution for the broader model area beyond the extents of the townships of Clermont and Middelmount (with 8 m sub-grid-sampling distance). A 4 m horizontal grid cell size resolution (with 1 m sub-grid-sampling distance) within and around the townships of Clermont and Middelmount. Similar to the regional model, sub-grid-sampling has been enabled, maximising the resolution of the underlying topographic datasets.

The adopted model domains are depicted in Figure 5-3.

5.4.2 Model Topography

As described in Table 2-6, various topographic datasets were sourced for building the underlying model topography. The Surat and Bowen Basins photogrammetry datasets were adopted to represent the underlying topography across all models. There were two minor locations in the far upper catchment which required supplementary information due to lack of coverage by the photogrammetry datasets. In these areas, the SRTM satellite derived dataset was utilised with appropriate vertical offsets applied.

For the townships of Clermont and Middelmount, the high-resolution LiDAR datasets were superimposed over the photogrammetry datasets. The 2025 LiDAR supersedes both the 2011 and 2014 LiDAR datasets, therefore only the 2025 LiDAR was utilised.

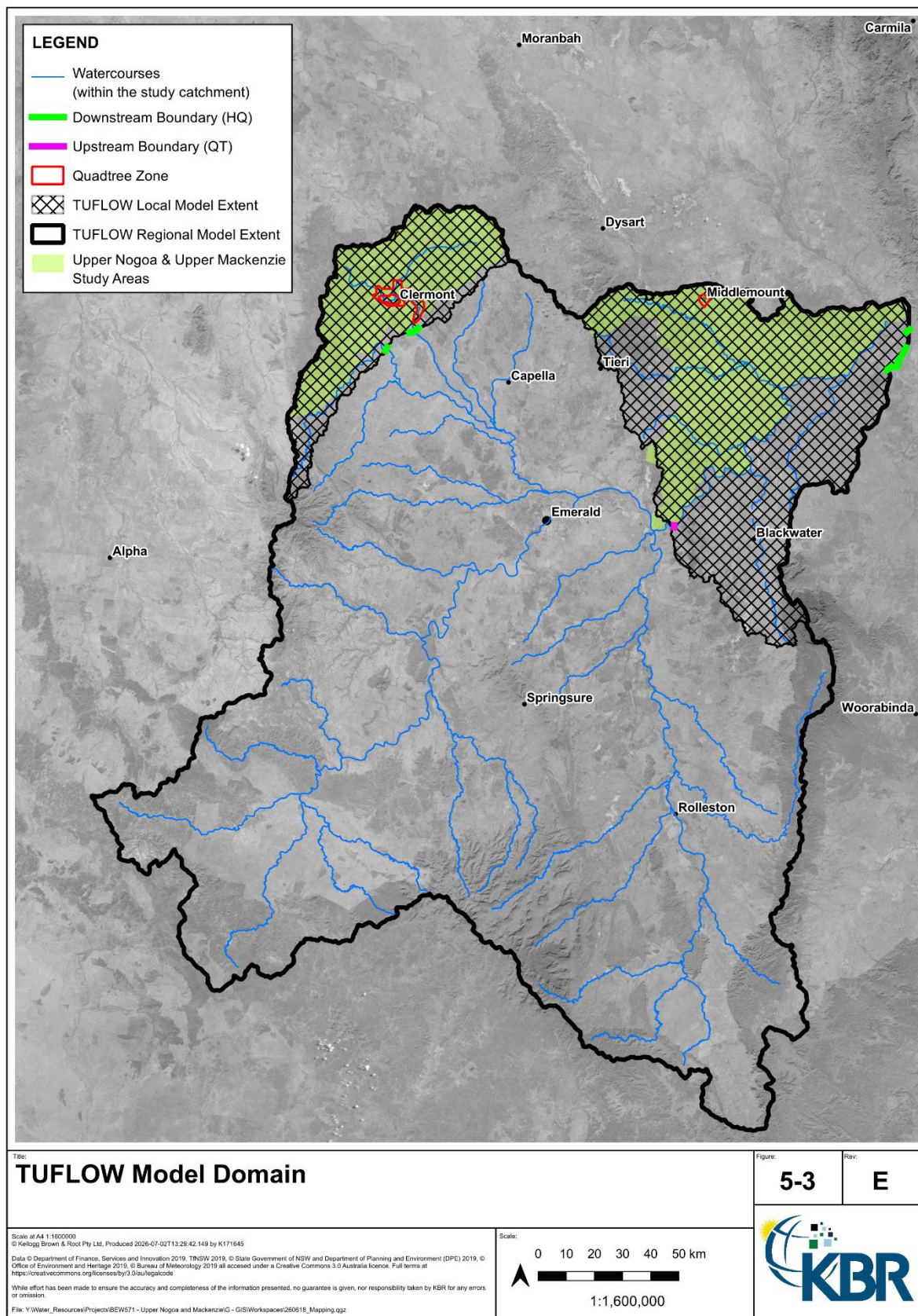


Figure 5-3 TUFLOW Model Domains



5.4.3 Hydraulic Roughness

Hydraulic roughness represents flow resistance offered by various surface materials. In the context of the TUFLOW model, hydraulic roughness is spatially distributed to describe the variability in flow resistance across the model extent.

Hydraulic roughness zones were delineated through a combination of the following methods:

- Review of existing hydraulic roughness layers developed as part of the hydraulic models,
- Review of publicly available Queensland Government QSpatial datasets including property cadastres and land use types, and
- Manual interrogation of aerial imagery and topography.

The applied Manning's 'n' values were initially collated from existing studies with comparisons made to applied values on adjacent and nearby catchments (i.e. Isaac River) and commonly adopted industry values. As part of the model calibration and validation process, the applied parameters were iteratively adjusted.

The adopted hydraulic roughness delineation is displayed in Figure 5-4 and Figure 5-5 for the Upper Nogoa River (Clermont) and Upper Mackenzie River (Middlemount) Local TUFLOW models respectively. The applied Manning's 'n' values are presented in Table 5-2.

Table 5-2 Hydraulic Roughness Distribution and Applied Manning's 'n' Values

Hydraulic Roughness Surface Type	Manning's 'n' Value
Open Space	0.040
Cropping	0.070
Dense Vegetation	0.115
Riparian Corridor	0.050
Water Body	0.025
Mine	0.040
Residential/Commercial/Industrial	0.120
Roads	0.020

5.4.4 Representation of Buildings

As described in Section 4, a detailed walkthrough of the townships of Clermont and Middlemount was completed at the outset of the study. As part of the site investigation, it was noted that most buildings were on raised foundations (i.e. on piers above ground). In the event of a storm event, flood waters would be able to pass underneath the building floor largely unobstructed.

As such, buildings have been represented implicitly within the higher Manning's 'n' value applied to residential/commercial/industrial areas. This approach allows for the generalised impeding of floodwaters as it passes through areas with constructed buildings and is appropriate for the resolution and scale of modelling employed.

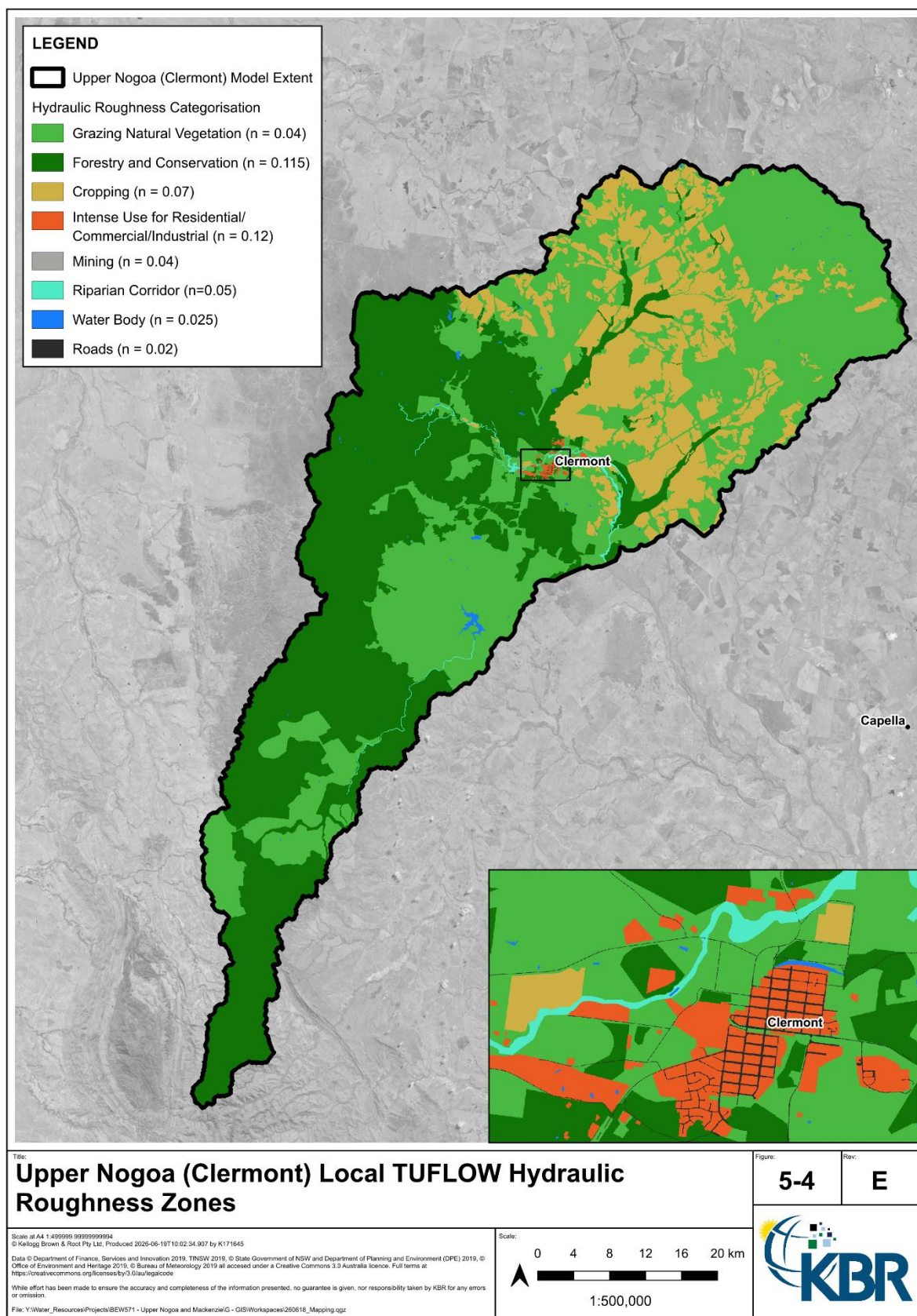


Figure 5-4 Upper Nogoia River (Clermont) Local TUFLOW Hydraulic Roughness Zones

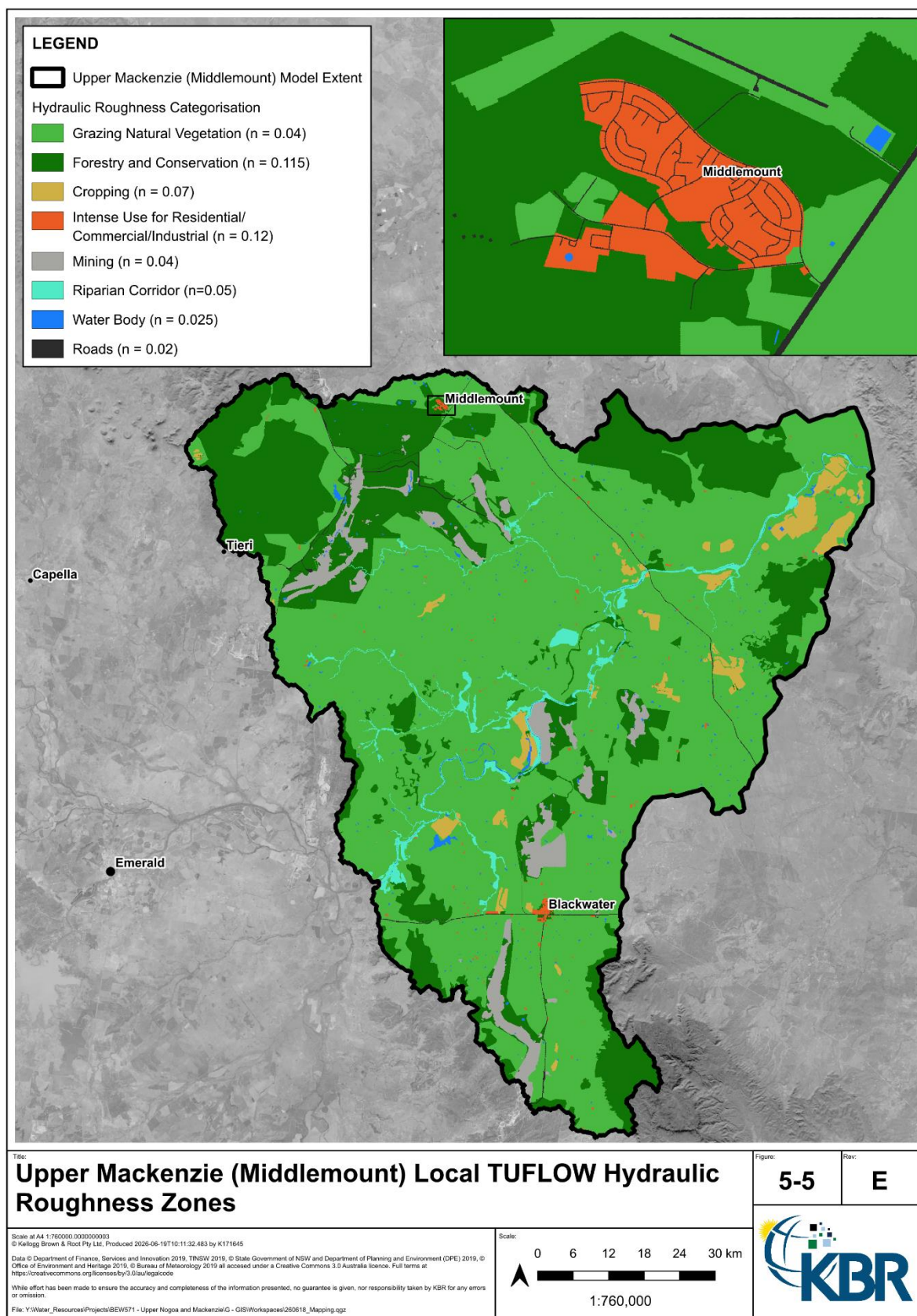


Figure 5-5 Upper Mackenzie River (Middlemount) Local TUFLOW Hydraulic Roughness Zones



5.4.5 Representation of Bridges

Bridges are represented through the application of a layered flow constriction shape. This method applies depth-averaged form loss coefficients and blockages to the transfer of flow between cells across three (3) layers of a bridge structure:

- Beneath the bridge deck,
- The bridge deck, and
- Above the bridge deck (i.e. rails).

Bridges have been modelled using TUFLOW's latest 'bg' functionality which applies a combined form loss co-efficient for the bridge deck and above the bridge deck (in comparison to previous layered flow constrictions where different form loss co-efficients can be applied to the bridge deck and above the bridge deck). The combined form loss co-efficient is automatically calculated within the TUFLOW software. For the area beneath the bridge deck, existing modelling parameters were utilised where available. For newly modelled bridges, form loss co-efficients were calculated in accordance with the Hydraulics of Bridge Waterways guidelines (Bradley J. N., 1978).

All bridges modelled are displayed in Figure 5-6 and Figure 5-7 for the Upper Nogoa River (Clermont) and Upper Mackenzie River (Middlemount) Local TUFLOW models respectively. A summary of the modelled culverts is presented in Table 5-3.

Table 5-3 Summary of Modelled Bridges

Model	Number of Bridges
Upper Nogoa River (Clermont)	5
Upper Mackenzie River (Middlemount)	8

It is noted that most bridges are located outside of the townships of Clermont and Middlemount and are unlikely to materially influence the flood behaviour at the townships. However, the bridge located on the Clermont Connection Road intersecting Sandy Creek, north of the town, is identified to be a key bridge. The previously applied parameters for this bridge in preceding studies were reviewed carefully and verified on site prior to its inclusion within the TUFLOW model.

5.4.6 Representation of Culverts

Culvert datasets for major road and rail were sourced from various local and state government operators at the outset of the study (refer to Table 2-7 for further information). As detailed in Section 4.1, several key structures were verified as part of the site investigation.

While the initial extent of data capture extended beyond the immediate townships of Clermont and Middlemount, only the structures within the extent of the higher resolution LiDAR were included into the Local TUFLOW models. This is largely due to the coarser resolution of the 10-20 m datasets unable to accurately represent key controls (i.e. minor road embankments less than 10 m in width). The potential lack of appropriate representation of roads outside of the LiDAR extent is acknowledged to be a limitation of the modelling, should it be considered for the purposes of flood emergency management and evacuation route assessment.

During the model development stage of the study, all provided culvert information was reviewed against aerial imagery, Streetview, and topographic information. It should be noted that the majority of the culverts required a degree of relocation to a more appropriate location as the provided datasets were often indicative only. All culverts were missing invert levels and lengths in the provided datasets. These attributes were approximated based on LiDAR, aerial imagery, and Streetview. For the Upper Nogoa River and Upper Mackenzie River models, 35 and 4 culverts had missing dimensions respectively. The missing attributes were assumed based on nearby culverts, aerial imagery, and Streetview where available.



A total of 84 culverts were modelled in the Upper Nogoa River (Clermont) model with 28 modelled in the Upper Mackenzie River (Middlemount) model. All culverts have been modelled within the 1D domain using the TUFLOW 1D ESTRY engine and dynamically linked to the 2D domain.

The modelled culverts are presented in Figure 5-6 and Figure 5-7 for the Upper Nogoa River (Clermont) and Upper Mackenzie River (Middlemount) Local TUFLOW models respectively.

5.4.7 Representation of Major Hydraulic Structures

As part of the initial data collation and review, hydraulic details including weir crest levels, length, and orientation were sourced for Theresa Creek Dam and Fairbairn Dam (refer to Section 2 for further information). Recorded initial water level conditions at Fairbairn Dam for the 2008 and 2010 historical events were sourced from SunWater and implemented accordingly for the purposes of model calibration. For all other events, the initial water level was set to the enforced spillway crest level (that is, the full supply level was assumed to be at the spillway crest).

Spillway details were collated for Bedford Weir and Mackenzie Weir from the Queensland Government WMIP. While information for the abutments adjacent to the spillway were not publicly available, these details were approximated during the site investigation and modelled accordingly. The watercourse thalweg of the Mackenzie River was enforced between Bedford Weir and Mackenzie Weir with known gauge zero values at both weirs.

All hydraulic details were enforced manually over the topographic data within the TUFLOW model and displayed in Figure 5-6 and Figure 5-7 for the Upper Nogoa River (Clermont) and Upper Mackenzie River (Middlemount) Local TUFLOW models respectively. The modelled structural details are presented in Table 5-4.

Table 5-4 Modelled Hydraulic Structure Details

Name	Spillway Level	Spillway Length	Abutment Level
Fairbairn Dam	204.23 m AHD	168 m	218.86 m AHD
Theresa Creek Dam	271.00 m AHD	225 m	272.50 m AHD
Bedford Weir	122.80 m AHD	183 m	125.30 m AHD
Bingegang Weir	102.90 m AHD	107 m	105.40 m AHD



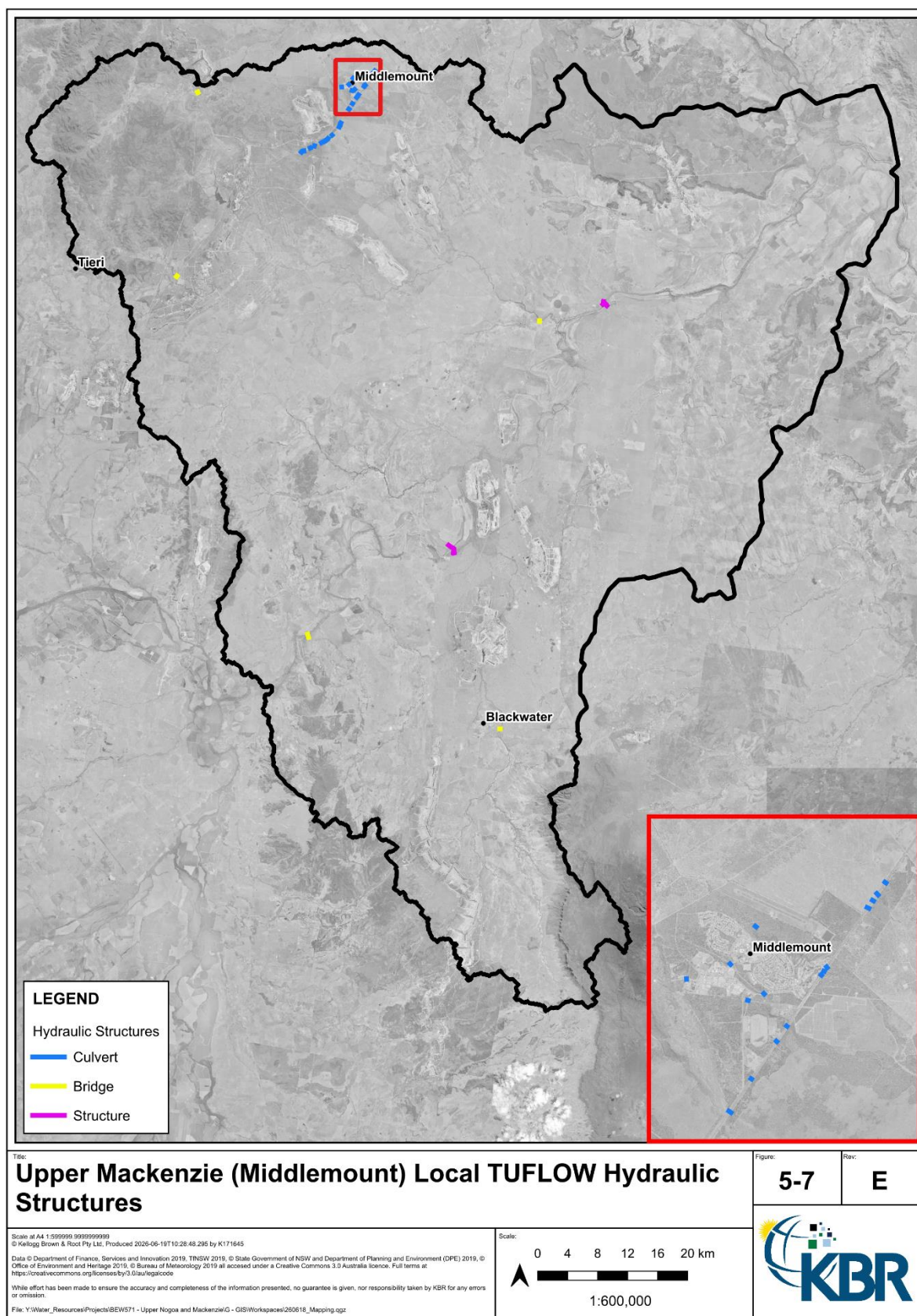


Figure 5-7 Upper Mackenzie River (Middlemount) Local TUFLOW Hydraulic Structures



5.4.8 Upstream Boundary

As described in Section 5.2, the Regional Mackenzie River model was utilised to simulate the catchment's response to rainfall-runoff for the wider catchment. Flow-Time (QT) hydrographs were extracted from the regional model and adopted as a QT upstream boundary for the Upper Mackenzie River (Middlemount) Local TUFLOW model. The boundary was modelled downstream of the confluence with the Comet and Nogo River.

For the purposes of model calibration, an upstream inflow boundary was applied for the Isaac River, informed by gauged records at the Isaac River at Yatton stream gauge (130401A). For the purposes of design event modelling, no upstream inflow was applied as agreed upon with Council.

As the Upper Nogo River (Clermont) Local TUFLOW model covers the top of the catchment, no upstream boundary was required.

The application of the upstream boundary is presented in Figure 5-3.

5.4.9 Downstream Boundary

Downstream boundary conditions for all models adopt Head-Flow (HQ) boundaries where watercourses intersect the model boundary (i.e. Nogo River and Mackenzie River). HQ boundaries are automatically generated based on the assigned slope factor, derived from the underlying topography. HQ boundaries are free flowing and continuously allow water to exit the model unlike Head-Time (HT) boundaries that apply a fixed condition.

It is acknowledged that a HT boundary is anticipated to better represent the hydraulic complexities downstream of Bingegang Weir. As described in detail in Section 7.5, the model calibration process demonstrated the inability of the HQ boundary to replicate the backwater effects caused by the confluence of the Isaac River with the Mackenzie River to form the Dawson River. More accurate representation of the downstream boundary was not feasible due to the lack of gauged information in the Dawson River nor significant extension of the model to appropriately represent the confluence and lower Dawson River, which is outside of the scope for this study.

The application of the downstream boundaries is presented in Figure 5-3.



6 Stage-Discharge Rating Curve Analyses

A rating curve is a defined relationship between stage (depth) and discharge (flow). At gauges rating curves are adopted to convert water levels into flows. Rating curves are defined by factors such as the watercourse's geometry and surface roughness as well as any local hydraulic controls (i.e. dams or weirs). Rating curves will be unique depending on the location and can be highly sensitive to topographical changes over time. In some circumstance rating curves can also be highly sensitive to hydraulic conditions such as backwatering affects, or tidal conditions.

KBR completed a detailed review of the stage-discharge rating curve relationship at the following key stream gauges:

- Sandy Creek at Clermont (130207A),
- Mackenzie River at Rileys Crossing (130113A),
- Mackenzie River at Bedford Weir (130111A), and
- Mackenzie River at Bingegang Weir (130110A).

A key focus of the rating curve analyses was to ensure that where appropriate, the modelled stage-discharge relationship was reflective of the observed data. Additionally, it is important that the modelling is reflective of the recorded spot gaugings (recorded stage/flow points).

6.1.1 Sandy Creek at Clermont (130207A) Stream Gauge Stage-Discharge Rating Curve

A comparison of the Queensland Government WMIP published stage discharge rating curve against the modelled rating curve is presented in Figure 6-1. It is noted that no high-flow gaugings were recorded at this location with the maximum gauging recorded at a depth of 2.41 m with a corresponding flow of 56 m³/s. Comparatively, the highest recorded depth at the gauge was 8.25 m, significantly larger than the gaugings.

The modelled results mirror the published rating curve up to a stage of approximately 5 m with all gaugings matched. Slightly lower levels are produced at higher flows in comparison to the WMIP rating curve. The model is considered to have strong alignment with both the gaugings and WMIP adopted rating curve.

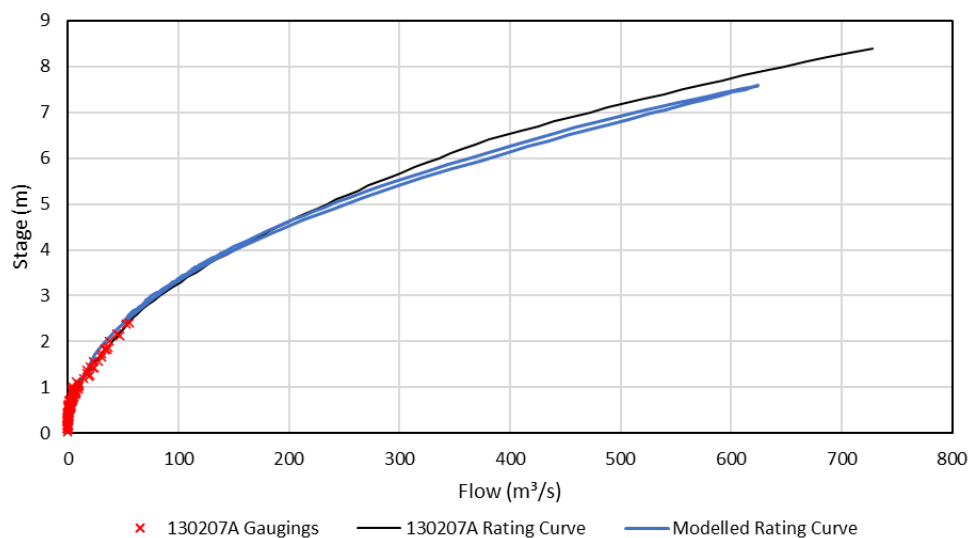


Figure 6-1 Stage-Discharge Rating Curve Comparison at Sandy Creek at Clermont (130207A)



6.1.2 Mackenzie River at Rileys Crossing (130113A) Stream Gauge Stage-Discharge Rating Curve

The Mackenzie River at Rileys Crossing (130113A) stream gauge is strategically located downstream of the major confluence of the Mackenzie River, Nogo River, and the Comet River. A comparison of the Queensland Government WMIP published stage-discharge rating curve against the modelled rating curve is presented in Figure 6-2.

The hydraulic behaviour of the Mackenzie River within the Isaac Regional Council LGA is complex with the presence of two large concrete dam spillways. In addition, the Mackenzie River at the downstream end of the study area boundary intersects the Isaac River, which conveys a significant volume of runoff. While outside of the scope of work for this study, the influence of the Isaac River in combination with the constrained nature of the Mackenzie River downstream of the confluence may result in a notable backwatering effect.

As described in Section 4.2, due to the gauge being located on private property, the precise location of the gauge could not be identified. Additionally, a review of the various topographic datasets at the outset of the study (refer to Section 2.4 for further information) indicated that differences up to 5 m were observed within watercourses between LiDAR and photogrammetry datasets in areas of overlap. As such, while the out of bank stage-discharge relationship has been replicated, uncertainty is noted at the lower flow regime. Minimal hysteresis is modelled with the published rating curve threading the modelled rising and falling limbs, noting the peak gauging recorded was 20.44 m and 3,854 m³/s for stage and flow respectively.

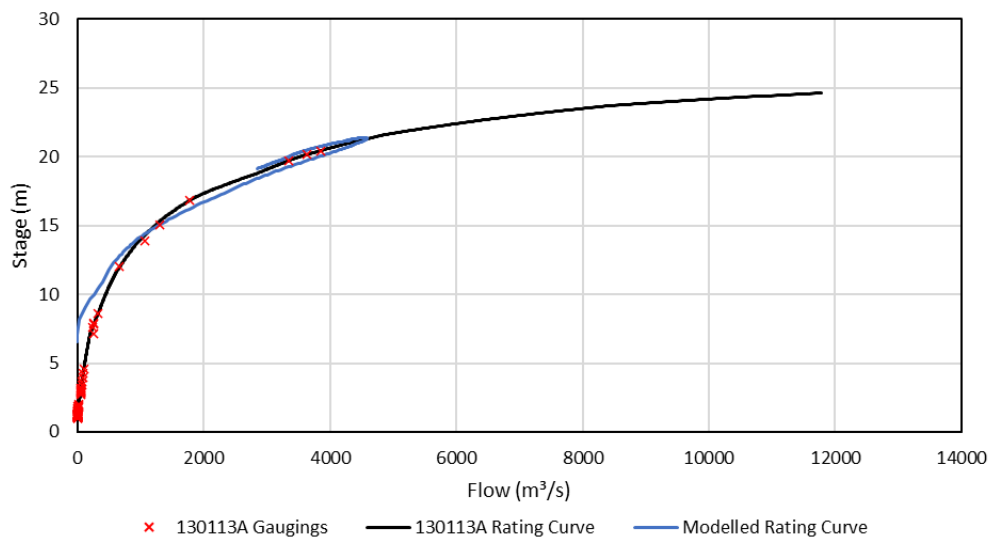


Figure 6-2 Stage-Discharge Rating Curve Comparison at Mackenzie River at Rileys Crossing (130113A)

6.1.3 Mackenzie River at Bedford Weir (130111A) Stream Gauge Stage-Discharge Rating Curve

The Mackenzie River at Bedford Weir (130111A) stream gauge is located on the downstream side of the weir. A comparison of the Queensland Government WMIP published stage-discharge rating curve against the modelled rating curve is presented in Figure 6-3.

The topographic representation of the gauge location is limited and has been assumed from the Bowen topographic dataset. As such, the following manual enforcements have been applied:

- Enforcement of the spillway crest,
- Enforcement of the raised abutments and embankments adjacent to the spillway (locality and elevations were assumed based on aerial imagery, topographic datasets, and physical site inspection), and



- Enforcement of the Mackenzie River thalweg between Bedford Weir and Bingegang Weir (refer to Section 5.4.7 for further information).

As the stage-discharge relationship at the gauge can be highly sensitive to the cross-sectional topographic representation, a degree of uncertainty is acknowledged. However, as presented in Figure 6-3, the falling limb of the modelled rating curve mirrors the published information. The peak gauging recorded was 18.72 m and 3,070 m³/s for stage and flow respectively.

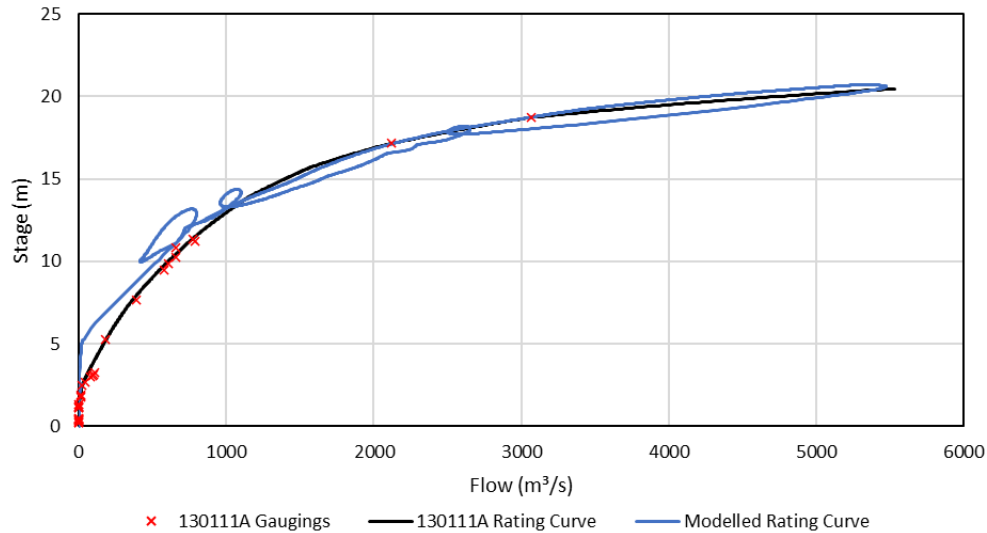


Figure 6-3 Stage-Discharge Rating Curve Comparison at Mackenzie River at Bedford Weir (130111A)

6.1.4 Mackenzie River at Bingegang Weir (130110A) Stream Gauge Stage-Discharge Rating Curve

The Mackenzie River at Bingegang Weir (130110A) stream gauge is located on the upstream side of the weir. A comparison of the Queensland Government WMIP published stage-discharge rating curve against the modelled rating curve is presented in Figure 6-4.

Similar to the Bedford Weir, the topographic representation of the gauge is limited and has been assumed from the Bowen topographic dataset. The following manual enforcements have been applied:

- Enforcement of the spillway crest,
- Enforcement of the raised abutments and embankments adjacent to the spillway (locality and elevations were assumed based on aerial imagery, topographic datasets, and physical site inspection),
- Enforcement of the Bingegang Weir Access Road (locality and elevations were assumed based on aerial imagery, topographic datasets, and physical site inspection), and
- Enforcement of the Mackenzie River thalweg between Bedford Weir and Bingegang Weir (refer to Section 5.4.7 for further information).

The modelled results closely align with the published rating curve up to a stage of approximately 10 m with all lower flow gaugings matched. However, the modelled rating curve and WMIP rating curve diverge from this point, with the model over-estimating flow for equivalent stage based on two (2) gaugings in 2008 (15.61 m | 2,680 m³/s and 17.01 m | 3,710 m³/s). These high flow gaugings were recorded during the same 2008 event on the falling limb of the event.

The discrepancy between the modelled and observed high flow gaugings can be attributed to the inability of reproducing the backwatering effect at the downstream end of the model beyond the confluence of the Isaac River with the Mackenzie River during the 2008 event.



In addition to the two (2) 2008 high flow gaugings being on the falling limb, the modelled flood extents for the 2008 and 2010 historical events were compared to historical satellite long band imagery over the same storm duration. The satellite imagery validates the 2008 gaugings and similarly indicates that the modelled peak flood levels are approximately 4 m lower than what was recorded.

As described in Section 5.4.9, a free flow HQ boundary has been applied in lieu of available gauged information at the downstream end of the model. The application of the HQ boundary type allows water to continuously exit the model. This is in contrast to what the historical event information indicates, where floodwaters can backwater up the Mackenzie River. While the flood behaviour below a stage of 10 m can be relied upon, higher flow results downstream of Bedford Weir cannot be relied upon.

As discussed in Section 5.4.9, more accurate representation of the downstream boundary was not feasible due to the lack of gauged information or significant extension of the model to suitably represent the downstream confluence, which is outside of the scope for this study. As such, the accurate representation of flood behaviour downstream of Bedford Weir, particularly during events of coincident flooding is considered a limitation of this study.

Further discussion on the outcomes of the model calibration at Bingegang Weir is included in Section 7.5.

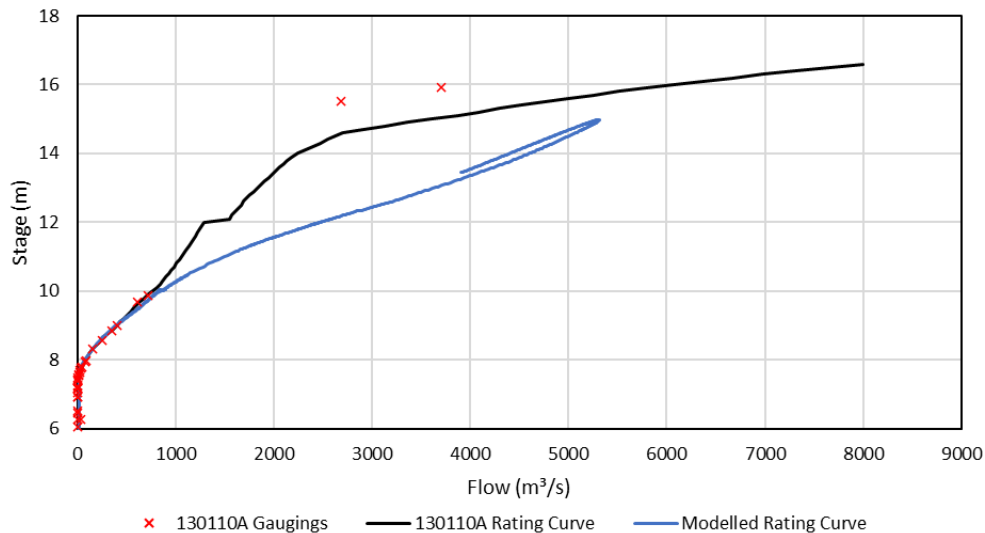


Figure 6-4 Stage-Discharge Rating Curve Comparison at the Mackenzie River at Bingegang Weir (130110A)



7 Model Calibration and Validation

The calibration of hydrologic and hydraulic models is a key component of any flood modelling. The outcomes of the calibration and validation process provide increased confidence in the model's ability to replicate historical flood behaviours and the subsequent forecasting of design events. Model calibration is largely dependent on the availability and quality of historical flood information. The aim of the calibration process is to determine the model parameters and schematisation to be confidently utilised during the design event modelling stage of the study.

7.1 SELECTION OF CALIBRATION AND VALIDATION EVENTS

The Mackenzie River catchment has experienced several historical flooding events in recent decades. As part of previous studies completed on behalf of CHRC and Council (refer to Section 2.1 for further information), a significant amount of information has been collated for the January 2008 and December 2010 historical events. KBR has undertaken an extensive review of all relevant information and has concluded both events are appropriate for the purposes of a historical event-based model calibration exercise. The recorded data from the relevant rainfall and stream gauges is detailed in Section 2.6 and Section 2.7 respectively.

In addition, it was noted that a significant rainfall event occurred within the Upper Nogoia catchment during January 2026. Accordingly, the January 2026 event was identified as an additional calibration event for the Upper Nogoia River (Clermont) TUFLOW model.

A summary of the selected historical events is presented in Table 7-1.

Table 7-1 Proposed Calibration Points

Event	Start Time	End Time	Purpose
January 2008	15/01/2008 15:25	20/01/2008 12:00	Validation
December 2010	18/12/2010 14:30	31/12/2010 06:00	Calibration
January 2026	11/01/2026 01:00	16/01/2026 08:00	Calibration

7.2 ADOPTED METHODOLOGY

Due to the availability of stream gauges across the wider Mackenzie River catchment, modelled results were compared against the recorded level and flow information. For the modelling of the January 2026 event, further validation was undertaken against post event recorded historical flood depths provided by Council.

As part of an iterative process, calibration and validation of the model was completed in accordance with the following methodology:

- (1) Assessment of relevant daily and sub-daily total event rainfall,
- (2) Assessment of pluviographic historic temporal patterns,
- (3) Selection of appropriate historic temporal patterns for each rainfall zone,
- (4) Application of total event rainfall to historic temporal pattern for each rainfall zone,
- (5) Simulation of historical events through the TUFLOW model,
- (6) Iterative adjustment of model parameters to achieve convergence with stream gauging records, and
- (7) Validation of modelled results against recorded flood depths.



7.3 HISTORICAL STORM DEVELOPMENT

As described in Section 5.3.1, large spatial and temporal variability across the wider Mackenzie River catchment was identified. As each pluviographic record consisted of inconsistent recording intervals, appropriate rainfall records were consolidated to 15-minute intervals. The converted rainfall hyetographs were assigned to each of the rainfall sub-catchments (refer to Figure 5-1). Where necessary, the converted rainfall hyetographs were scaled up if a notable discrepancy was observed against nearby records of total rainfall depths for the same time series (refer to Section 7.3.1 and Section 7.3.2 for further information).

7.3.1 January 2008 Rainfall Data

The January 2008 flood event resulted from widespread rainfall across the Mackenzie River catchment. Significant rainfall depths were recorded across multiple gauges upstream of Lake Maraboon and within the Nogo River catchment. Lesser rainfall was recorded along the eastern portion of the wider catchment (i.e. the Comet River and its tributaries). The event spanned approximately five (5) days with the applied rainfall depths presented in Table 7-2. The temporal distribution is illustrated in Figure 7-1, with the spatially distributed applied total rainfall depth presented in Figure 7-2.

Table 7-2 Applied Total Rainfall 15/01/2008 15:25 – 20/01/2008 12:00

ID	Location	Gauge Name	Gauge ID	Recorded Rainfall (mm)	Applied Rainfall (mm)
1	Carnarvon Creek	Carnarvon Creek at Rewan	130509A	202	202
2	Brown River	Brown River at Lake Brown	130502B	89	89
3	Wealwandangie	Springsure TM	535042	218	218
4	Arcturus/Togara	Comet River at Springsure Creek Junction	130510A	94	94
5	Clermont	Theresa Creek at Valeria	130210A	289	289
6	Bogantungan	Bogantungan TM	535033	644	644
7	Valeria	Theresa Creek at Valeria	130210A	289	289
8	Claude River	Mantuan Downs TM	535037	240	338
9	Upper Nogo River	Mantuan Downs TM	535037	240	240
10	Crinum Creek	Emerald TM	535035	134	207
11	Craigmore	Nogo River at Craigmore	130209A	304	304
12	Lake Maraboon	Emerald TM	535035	134	367
13	Emerald	Emerald TM	535035	134	207
14	Comet	Comet River at Comet Weir	130504B	83	83
15	Lower Mackenzie River	Comet River at Comet Weir	130504B	67	161

Due to the size of the wider Mackenzie River catchment and its tributaries, a large degree of spatial variation was observed during the review of the various rainfall gauged datasets. Where appropriate, the recorded rainfall depths over time were implemented directly within the TUFLOW models. However, where the accuracy of the records was deemed questionable, nearby gauges were relied upon to supplement any data gaps. In some instances, gauges with more appropriate temporal distributions were scaled based on nearby rainfall records.



The following five (5) sub-catchments required localised adjustments to the applied rainfall:

- The rainfall record at Valeria was used for the Sandy Creek catchment as the rainfall record at Sandy Creek did not reflect the significant flows recorded at the Sandy Creek at Clermont (130207A) stream gauge.
- The rainfall record at Mantuan Downs TM was scaled for the Claude River catchment with rainfall recorded for the Bogantungan TM gauge.
- The rainfall record at Emerald TM was used for the Emerald/Crinum Creek catchment and scaled using nearby rainfall totals.
- The rainfall record at Emerald TM was scaled for the Lake Maraboon region using the recorded rainfall total at the Fairbairn Dam TM gauge.
- The rainfall record at Comet Weir was scaled for the lower Mackenzie Region using the recorded rainfall total at the St Lawrence gauge.

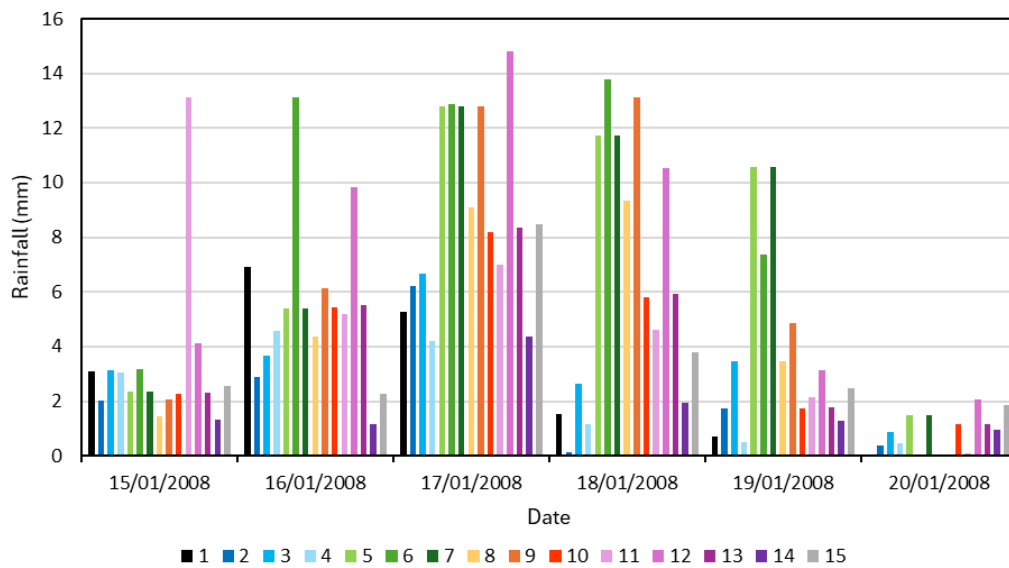


Figure 7-1 January 2008 Rainfall Temporal Distribution

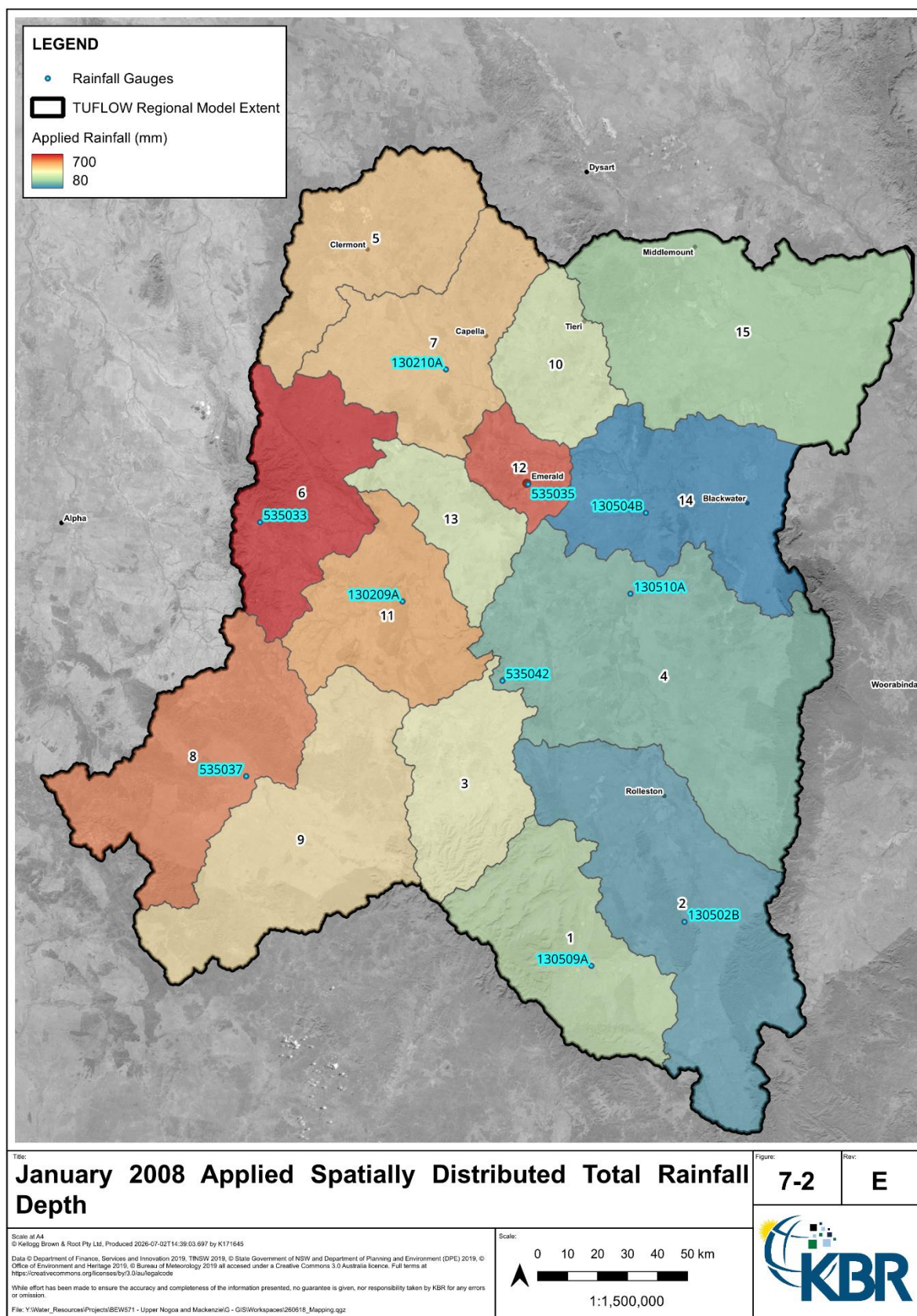


Figure 7-2 January 2008 Applied Spatially Distributed Total Rainfall Depth



7.3.2 December 2010 Rainfall Data

The December 2010 flood event was a notable flood event across the Upper Mackenzie River catchment. As reported by the Bureau of Meteorology in their Flood Summary for the Nogoia River at Emerald – December 2010 and January 2011 (BoM, 2011) report, rainfall intensities were estimated to be between a 2% to 1% AEP event. Contextually, the township of Emerald is approximately 50 km west of the Mackenzie River at Rileys Crossing stream gauge.

Significant rainfall depths were recorded on the Upper Comet River and Upper Nogoia River catchments. Lesser rainfall was recorded in the Teresa Creek and Sandy Creek catchments. The event spanned approximately 13 days with the applied rainfall depths presented in Table 7-3. It is noted that several rainfall and stream gauges were established in 2010, allowing for increased confidence in the modelling of the December 2010 historical event. The temporal distribution is illustrated in Figure 7-3 with the spatially distributed applied total rainfall depth presented in Figure 7-4.

Table 7-3 Applied Total Rainfall 18/12/2010 14:30 – 31/12/2010 06:00

ID	Location	Gauge Name	Gauge ID	Recorded Rainfall (mm)	Applied Rainfall (mm)
1	Carnarvon Creek	Carnarvon Creek at Rewan	130509A	405	405
2	Brown River	Brown River at Lake Brown	130502B	351	351
3	Wealwandangie	Penjobe TM	535040	470	470
4	Arcturus/Togara	Comet River at Springsure Creek Junction	130510A	137	137
5	Clermont	Sandy Creek at Clermont	130207A	89	134
6	Bogantungan	Green Valley AL	535929	220	220
7	Valeria	Theresa Creek at Valeria	130210A	130	183
8	Claude River	Mantuan Downs TM	535037	403	403
9	Upper Nogoia River	Mantuan Downs TM	535037	235	235
10	Crinum Creek	Fairbairn Dam AL	535924	159	198
11	Craigmore	Nogoia River at Craigmore	130209A	304	304
12	Lake Maraboon	Fairbairn Dam AL	535924	159	202
13	Emerald	Fairbairn Dam AL	535924	159	159
14	Comet	Comet River at Comet Weir	130504B	233	233
15	Lower Mackenzie River	Comet River at Comet Weir	130504B	233	264

From 2010, additional rainfall gauges have been established across the wider Mackenzie River catchment, allowing for increased confidence in the historical information underpinning the modelling of the December 2010 event. As described in Section 7.3.1, scaling of rainfall records was required in select instances where uncertainty associated with the gauge was noted.

The following six (6) sub-catchments required localised adjustments to the applied rainfall:

- The rainfall record at Sandy Creek at Clermont was scaled up using nearby rainfall totals.
- The rainfall record at Valeria was scaled using nearby rainfall totals.
- The rainfall record at Mantuan Downs TM was scaled for the Claude River catchment with rainfall recorded for the Bogantungan TM gauge.



- The rainfall record at Fairbairn Dam AL was used for the Crinum Creek catchment and scaled using nearby rainfall totals.
- The rainfall record at Fairbairn Dam AL was scaled for the Lake Maraboon region using nearby rainfall totals.
- The rainfall record at Comet Weir was scaled for the lower Mackenzie Region using the recorded rainfall total at the St Lawrence gauge.

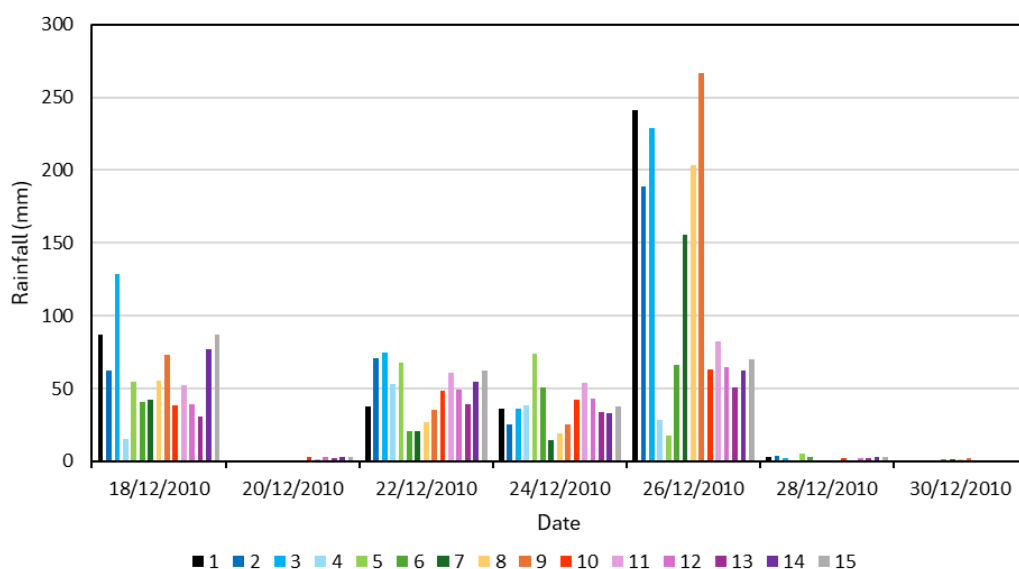


Figure 7-3 December 2010 Rainfall Temporal Distribution

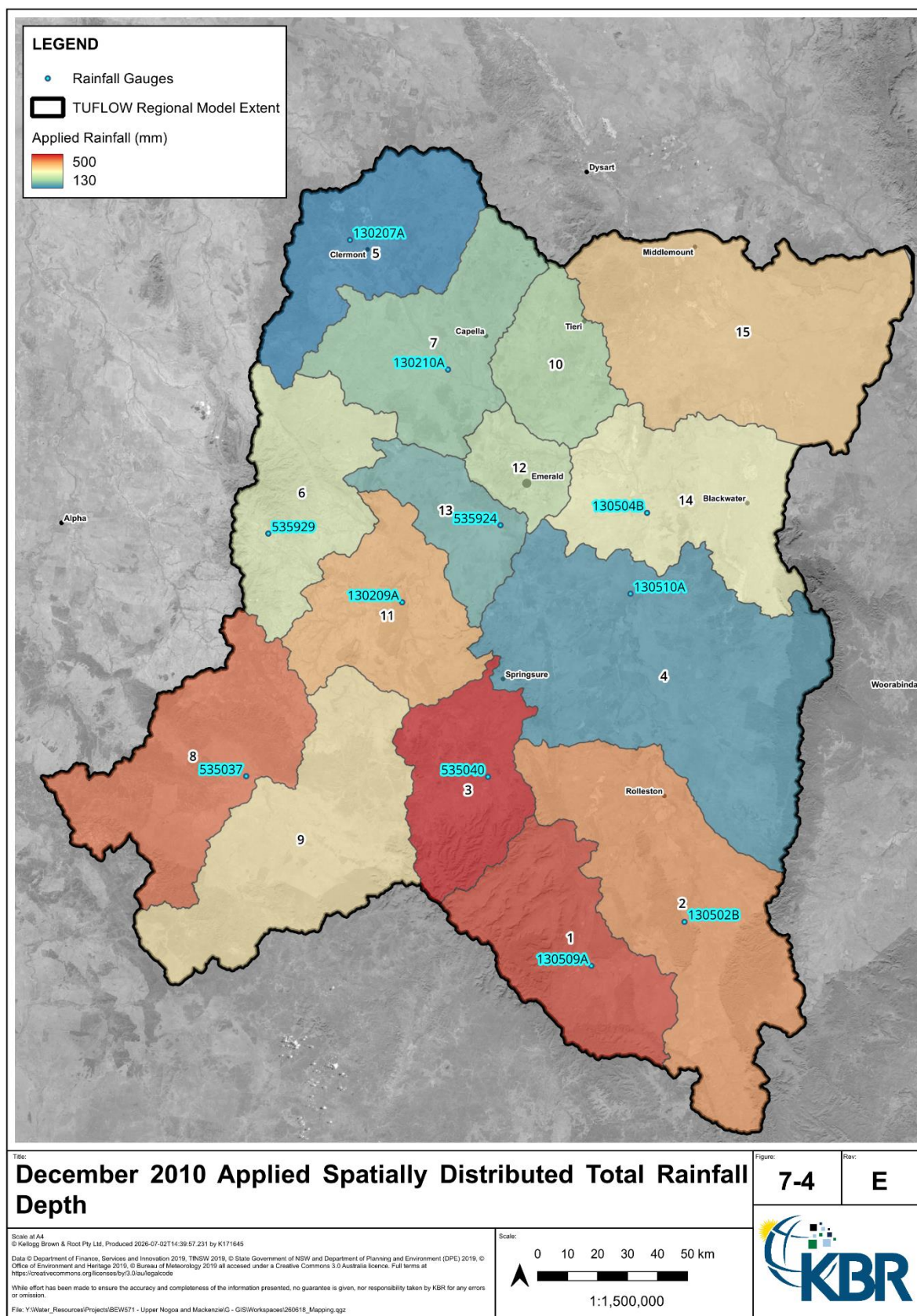


Figure 7-4 December 2010 Applied Spatially Distributed Total Rainfall Depth



7.3.3 January 2026 Rainfall Data

The January 2026 event was modelled for the Upper Nogoa River (Clermont) Local TUFLOW model only. Significant rainfall depths impacted the Clermont township, illustrated through a photograph presented in Figure 7-5. The event spanned approximately five (5) days for the main burst with a smaller second burst recorded thereafter. For the purposes of model calibration, KBR has modelled the main storm burst over the five-day duration. Over the various rainfall gauges within the vicinity of the Sandy Creek catchment, the total rainfall depths over the five-day duration ranged from 194 mm to 288 mm (218 mm to 409 mm for the entire double burst event). The catchment average rainfall of 229 mm for the main five-day burst was applied to the temporal pattern extracted from the Sandy Creek Bridge TM (535103) pluviograph.

The applied storm is presented in Figure 7-6.



Figure 7-5 Aerial Photograph of Clermont Taken by the Bush Heli-Services

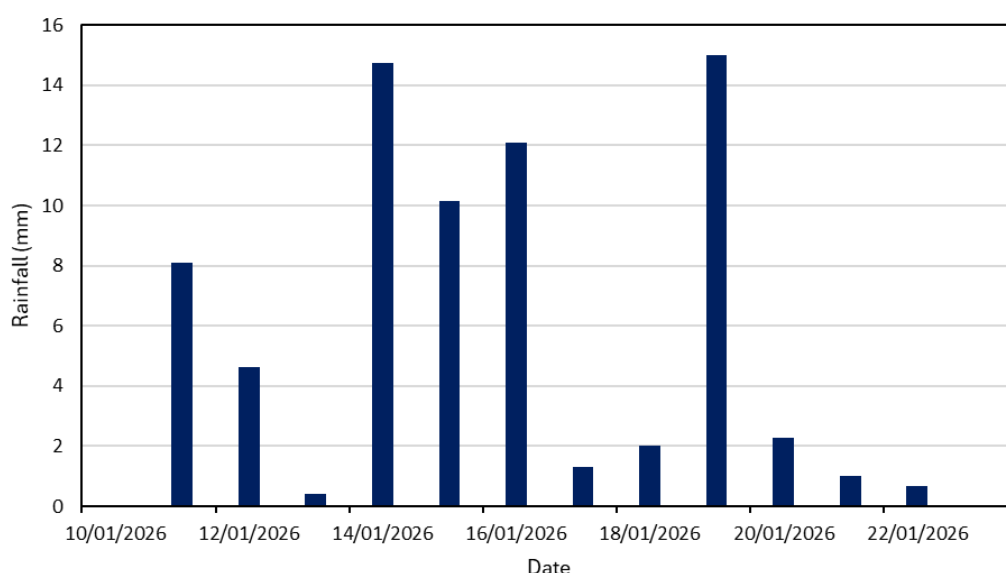


Figure 7-6 January 2026 Rainfall Temporal Distribution at the Sandy Creek Bridge TM Gauge (535103)



7.4 UPPER NOGOA RIVER (CLERMONT) CALIBRATION AND VALIDATION OUTCOMES

The calibration and validation of the Upper Nogoia River (Clermont) Local TUFLOW model was undertaken primarily against the recorded data at the Sandy Creek at Clermont (130207A) stream gauge. Further model validation was completed against post-event collated information provided by Council and community members for the January 2026 event. The approach to model calibration and validation for the Upper Nogoia River is summarised as follows:

- December 2010 model calibration,
- January 2026 model calibration,
- January 2026 additional model validation, and
- January 2008 model validation.

7.4.1 December 2010 Model Calibration Outcomes

The recorded stage series at the Sandy Creek at Clermont (130207A) gauge indicates a single peak event with a peak stage and flow of 2.89 m and 77 m³/s recorded accordingly. Comparatively, modelled peak stage and flows were 3.11 m and 77 m³/s respectively, representing a difference of 0.22 m (7.6%) and 0 m³/s (0.0%) respectively. Stage and flow hydrographs are presented in Figure 7-7 and Figure 7-8 respectively.

The modelling of the December 2010 event indicates strong alignment with the observed results at the gauge. In addition, the shape of the stage and flow hydrographs are in correlation, indicating appropriate temporal distribution of the applied rainfall over the main storm burst.

The gauge record indicates that Sandy Creek was not dry at the start of the modelled storm (i.e. 18th of December 2010 2:30 pm). No baseflow is included within the model and is dry at the start of the model simulation. The baseflow within the observed gauge record is relatively minor with 0-10 m³/s. Inclusion of the baseflow would likely result in minor increase in the simulated peak flow however is not expected to sufficiently change outcomes of the calibration.

The modelled peak flood depth output is presented in Figure 7-9.

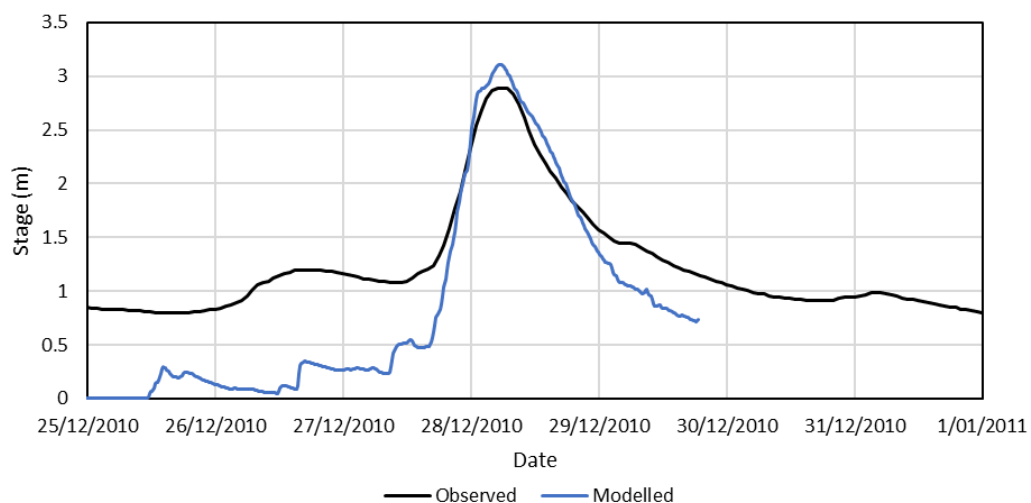


Figure 7-7 December 2010 Observed vs Modelled Stage Results at Clermont (130207A)

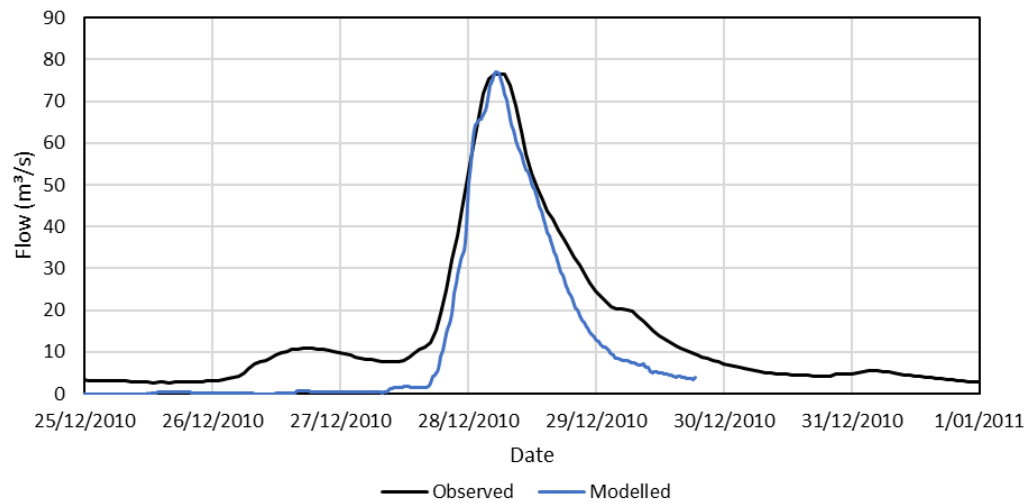


Figure 7-8 December 2010 Observed vs Modelled Flow Results at Clermont (130207A)

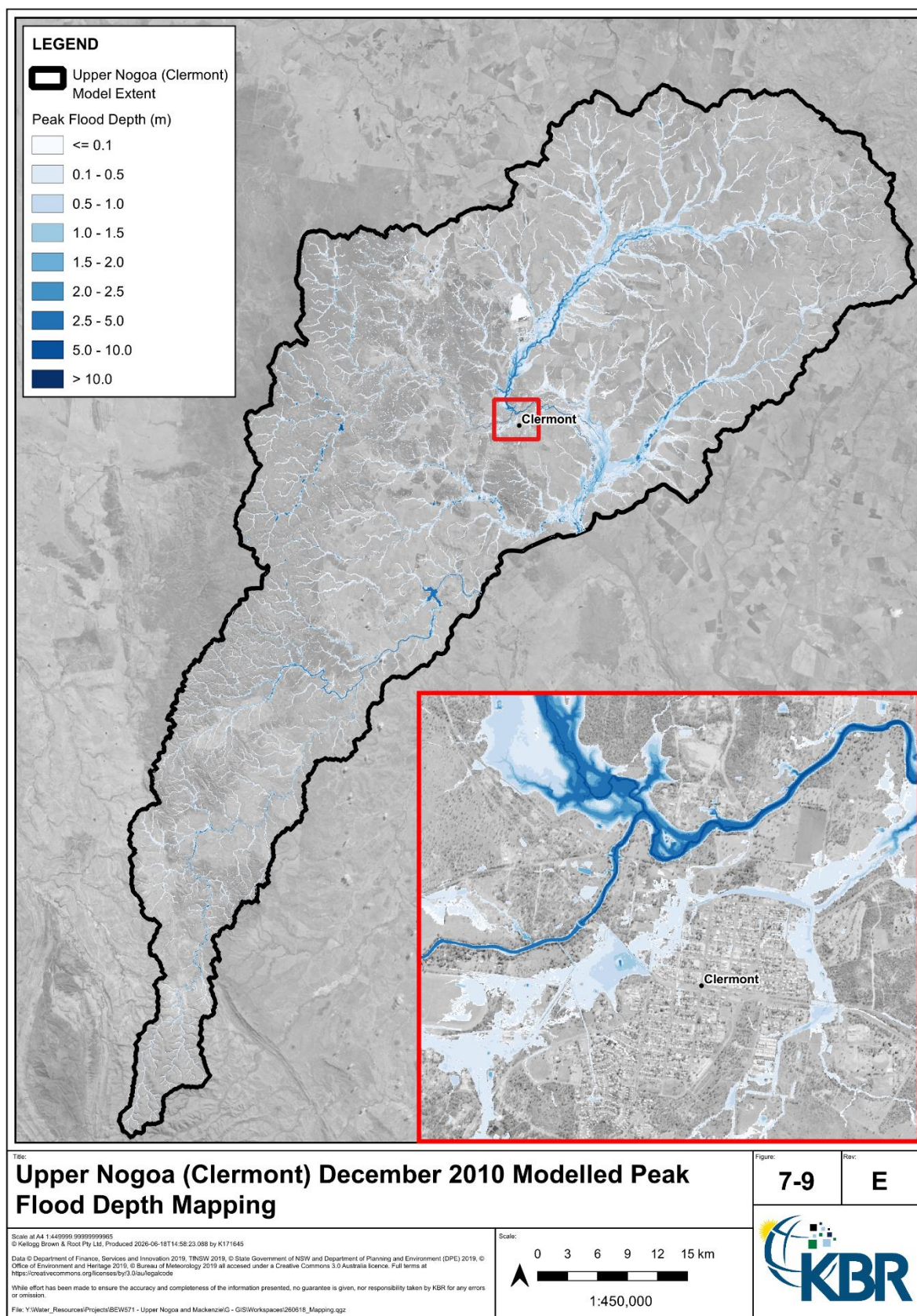


Figure 7-9 Upper Nogoia River (Clermont) December 2010 Modelled Peak Flood Depth Mapping



7.4.2 January 2026 Model Calibration Outcomes

The January 2026 event was a significant storm for the Sandy Creek catchment (inclusive of the Wolfgang Creek catchment), recording a large volume of rainfall over a short period of time. As described in Section 7.3.3, the rainfall records demonstrate a twin peak event. However, due to the first peak being the largest and most critical of the two peaks, only the first peak was modelled. A peak stage and flow of 7.07 m and 483 m³/s was recorded accordingly. Comparatively, modelled peak stage and flows were 6.83 m and 479 m³/s respectively, representing a difference of 3.4% and 0.8% respectively. Stage and flow hydrographs are presented in Figure 7-10 and Figure 7-11 respectively.

A strong correlation in results is noted between the recorded and modelled results at the Sandy Creek at Clermont (130207A) gauge in magnitude and shape.

The modelled peak flood depth output is presented in Figure 7-12.

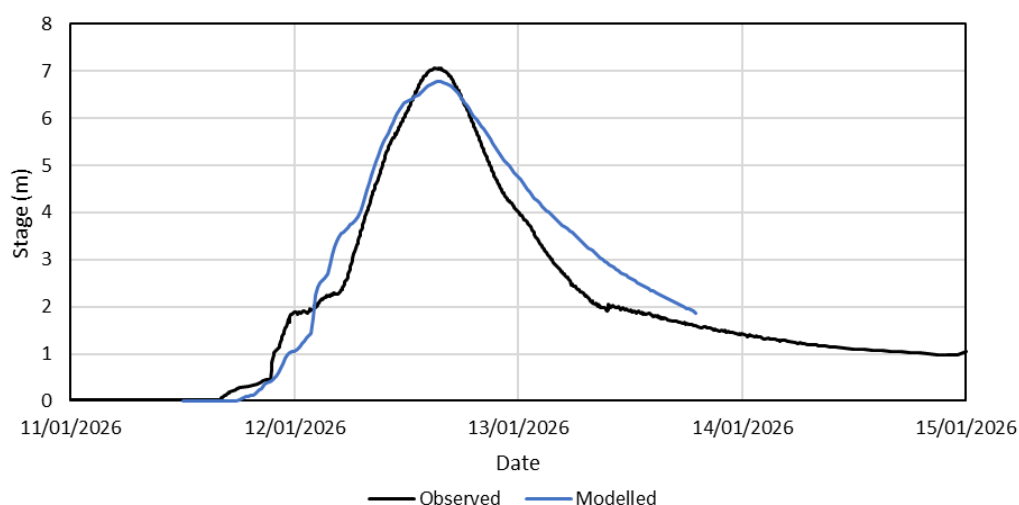


Figure 7-10 January 2026 Observed vs Modelled Stage Results at Clermont (130207A)

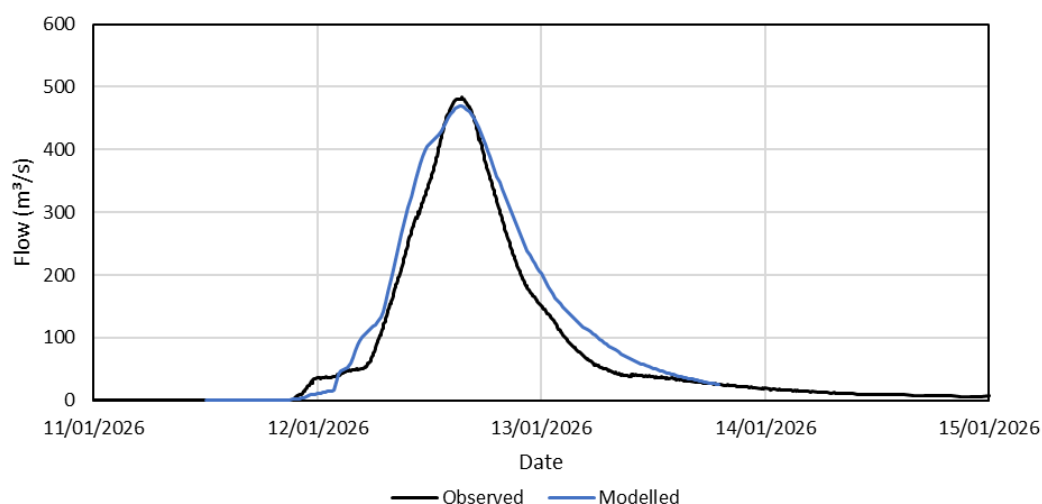


Figure 7-11 January 2026 Observed vs Modelled Flow Results at Clermont (130207A)

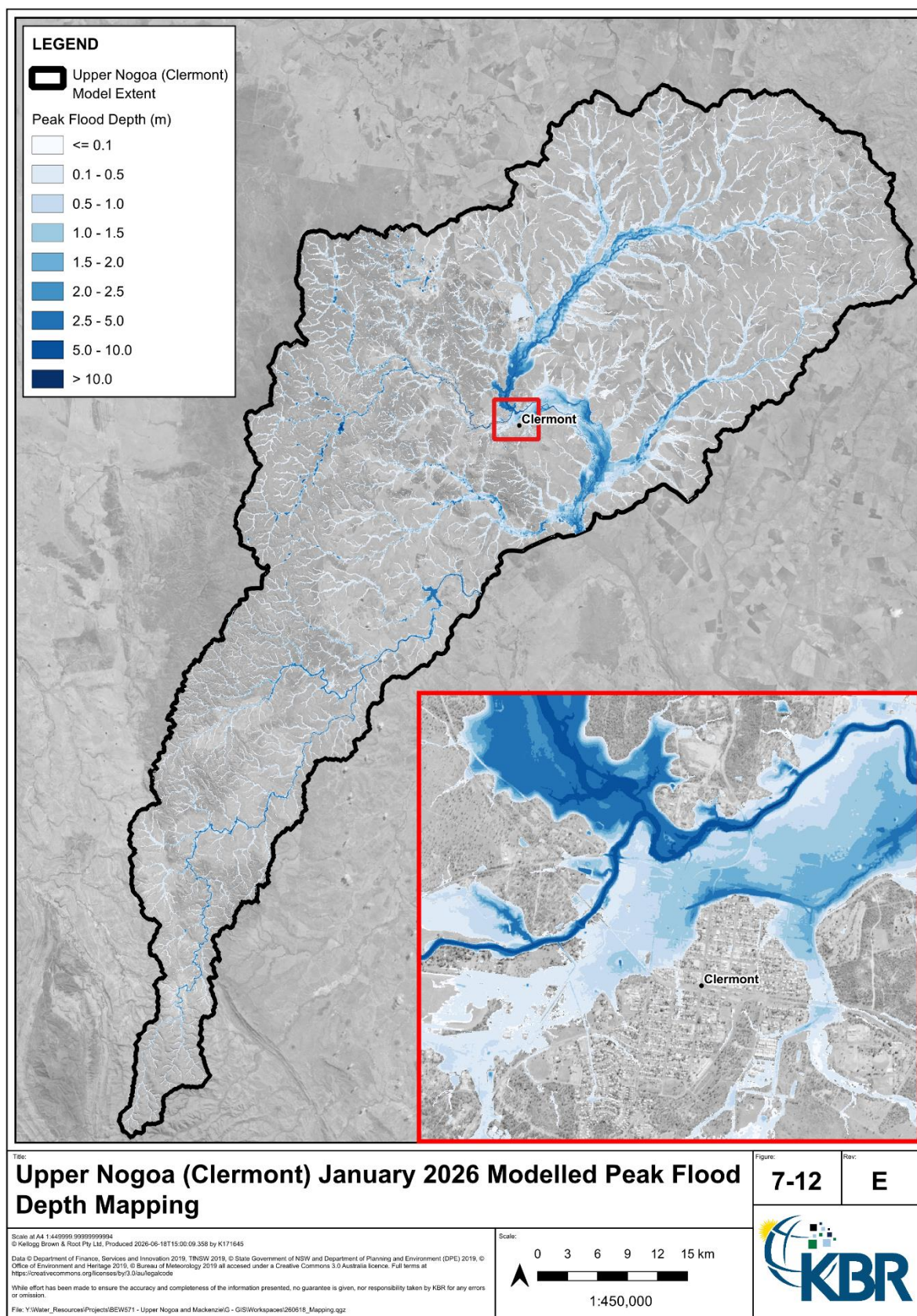


Figure 7-12 Upper Nogoia River (Clermont) January 2026 Modelled Peak Flood Depth Mapping



7.4.3 January 2026 Model Validation Outcomes Against Additional Information

Further validation of the 2026 modelled results was undertaken by comparing the modelled peak flood depth results to the post event debris markers recorded by Council. A total of 10 locations with approximate depths were recorded across the township of Clermont and summarised in Table 7-4. The spatial distribution of the flood marker locations has been presented in Figure 7-12. The comparison in results indicated that nine (9) locations were within a ± 0.03 m tolerance, with the remaining location indicating a + 0.07 m difference.

Table 7-4 January 2026 Recorded Flood Marker Depths

ID	Location	Recorded (m)	Modelled (m)	Difference (m)
1	Clermont Weir	0.43	0.46	+0.03
2	Mimosa Street	1.22	1.22	-
3	Bottom Hoods Lagoon	2.00	2.03	+0.03
4	Clermont Alpha Road	1.53	1.54	+0.01
5	Drummond Street	1.34	1.41	+0.07
6	Hoods Lagoon	1.82	1.79	-0.03
7	Cheeseborough Road	1.58	1.57	-0.01
8	Lagoon Building	0.47 – 0.56	0.52	-
9	Lagoon Building Shed	0.76	0.74	-0.02
10	Apex Park Toilet Block	1.21	1.22	+0.01

The accuracy of reported flood marks must be taken into consideration when being used for model calibration and validation purposes. Flood markers may not necessarily correlate with the peak of the flood event. Debris marks could also be produced by secondary peaks during a multi-peak event or from effects of wind and bow waves. Local hydraulic controls or potential spatial uncertainty of the mark location in an area with a steep hydraulic gradient or sudden change in head could skew actual peak flood depths. Despite these factors, a strong correlation between the recorded and modelled results is evident.

In addition to the flood markers, an estimated flood extent was provided by a community member based on a series of photographs of flood debris on public land taken post event. As illustrated in Figure 7-13, strong correlation is achieved between the modelled and estimated extents east of the railway line. As the estimated flood extent west of the railway line is not reflective of the underlying topography, the accuracy of the information should be considered in the comparison against the modelled flood extent.



Figure 7-13 Upper Nogoia River (Clermont) January 2026 Modelled Peak Flood Depth Mapping



7.4.4 January 2008 Model Validation Outcomes

The recorded stage series at the Sandy Creek at Clermont (130207A) gauge indicates a clear double peak event with the main peak occurring on the 19th of January 2008. The historical temporal pattern applied to the Sandy Creek catchment was extracted from the Theresa Creek at Valeria (130210A) pluviograph, located approximately 60 km from the township of Clermont. This pattern was used in place of closer gauges in proximity to Clermont and Sandy Creek due to their unreliability flagged as part of the initial data review. The rainfall recorded at Valeria indicates significant rainfall before the 18th of January 2008, correlating with the first minor peak.

A peak stage and flow of 8.25 m and 697 m³/s was recorded accordingly at the stream gauge on the 19th of January 2008. Comparatively, modelled peak stage and flows were 7.72 m and 624 m³/s respectively on the 18th of January 2008, representing a difference of 0.53 m (6.4%) and 73 m³/s (10.5%) respectively. Stage and flow hydrographs are presented in Figure 7-14 and Figure 7-15 respectively.

The modelled results at Clermont reflect the magnitude of the main peak occurring on the 18th of January 2008 instead of mirroring the recorded 19th of January 2008 peak. The difference in the timing of the peaks and shape of the hydrograph can be attributed to the rainfall temporal pattern applied, where the main burst of rainfall occurs prior to the 18th of January 2008. While the peak flow and stage are reasonably aligned, the timing of the peaks and shape of the hydrograph cannot be improved without more reliable historic information.

The modelled peak flood depth output is presented in Figure 7-16.

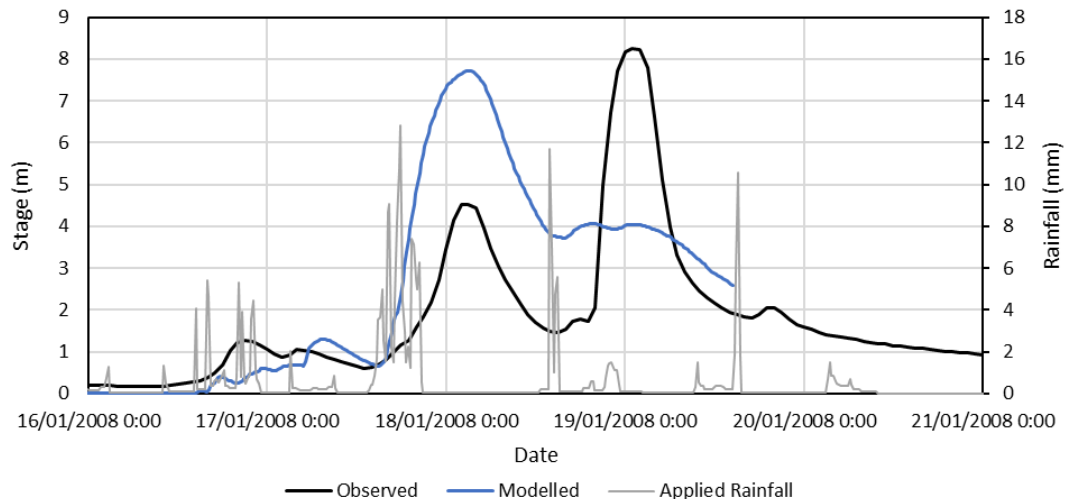


Figure 7-14 January 2008 Observed vs Modelled Stage Results at Clermont (130207A)

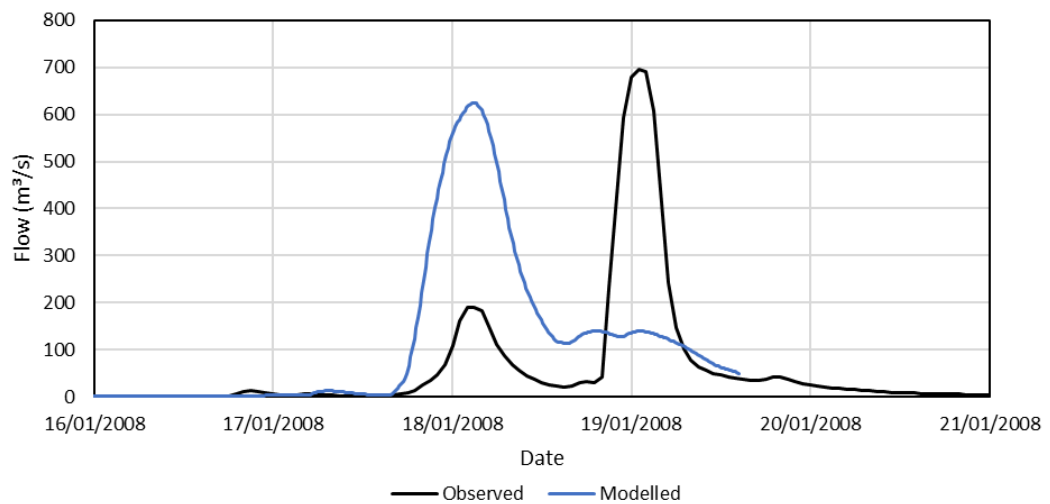


Figure 7-15 January 2008 Observed vs Modelled Flow Results at Clermont (130207A)

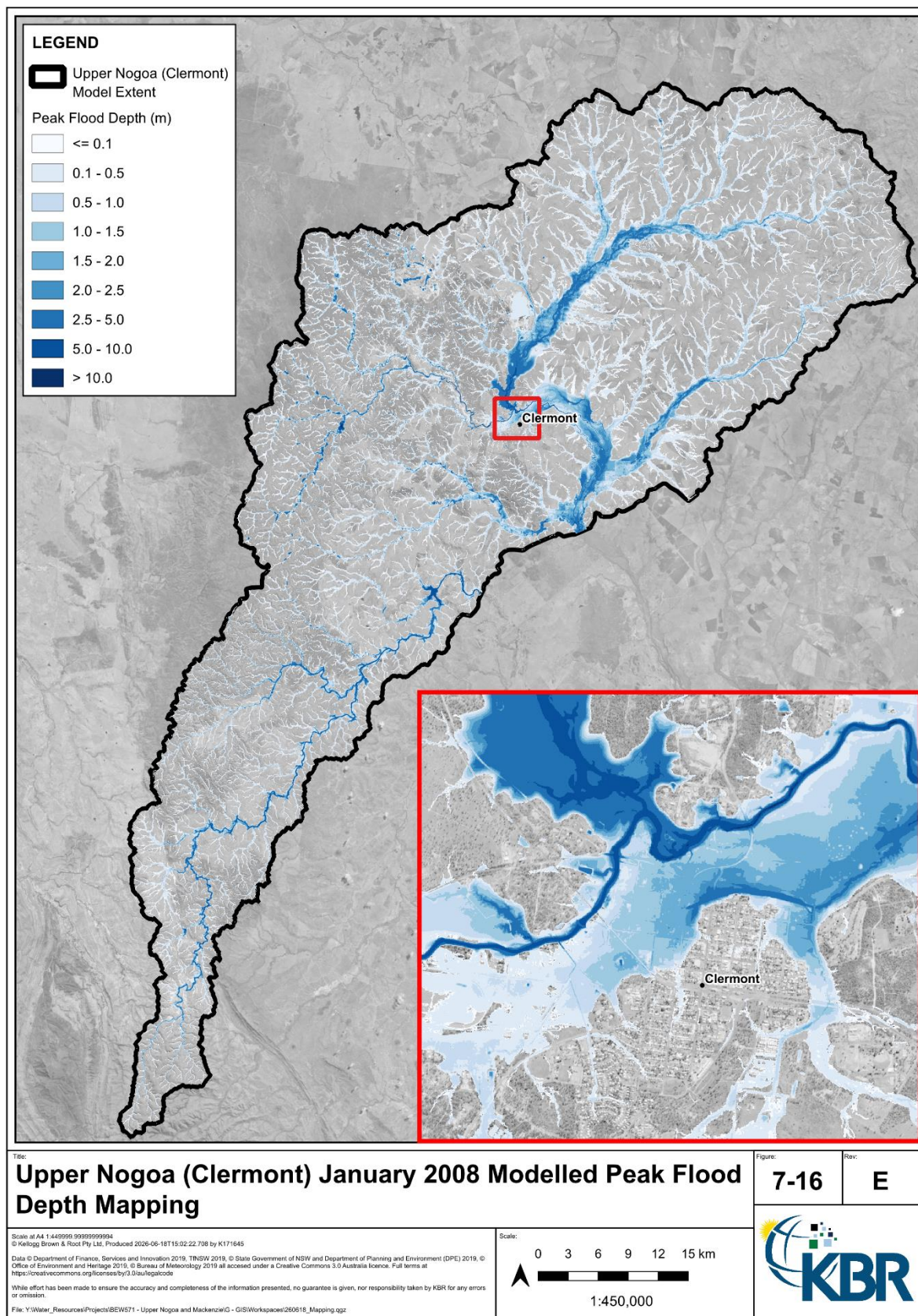


Figure 7-16 Upper Nogoia River (Clermont) January 2008 Modelled Peak Flood Depth Mapping



7.5 UPPER MACKENZIE RIVER (MIDDLEMOUNT) CALIBRATION AND VALIDATION OUTCOMES

The calibration of the Upper Mackenzie River (Middlemount) Local TUFLOW model was undertaken against the following series of stream gauges on the Mackenzie River:

- Mackenzie River at Rileys Crossing (130113A),
- Mackenzie River at Bedford Weir TW (130111A), and
- Mackenzie River at Bingegang Weir TW (130110A).

As the township of Middlemount is located at the far upstream extent of a local catchment with no defined watercourses passing through the town. No stream gauges were available for the purposes of model calibration and validation. Similarly, no historical anecdotal evidence was available or provided by the community during this study. As such, direct calibration within the township was not possible, unlike the extensive calibration and validation undertaken within the Clermont township (refer to Section 7.4).

Due to the extent of the Mackenzie River catchment, the Regional TUFLOW model was calibrated across a series of upstream gauges as well as the above three (3) gauges on the Mackenzie River. The January 2008 and December 2010 historical events were also simulated through the Local TUFLOW model to ensure appropriate model calibration and validation was achieved.

For both the 2010 calibration event and 2008 validation event the regional model was simulated to include localised flows within the local Middlemount model. In addition, a sensitivity was undertaken adopting the recorded hydrograph at Rileys Crossing as the upstream inflow into the local model.

7.5.1 December 2010 Model Calibration Outcomes

The modelled results in comparison to the recorded levels and flows is presented in Table 7-5 and Table 7-6.

Reasonable alignment is achieved between modelled versus observed results at the stream gauges along the Mackenzie River both in terms of peak flood behaviour as well as the shape of the hydrographs. Under estimation is noted across all three gauges in the order of 7-10%.

Table 7-5 December 2010 Model Calibration Outcomes (Flow)

Location	Source	Recorded	Modelled	Difference (m)
Mackenzie River (Rileys Crossing)	Stream Gauge (130113A)	6,612	6,137	-475 (-7.2%)
Mackenzie River (Bedford Weir)	Stream Gauge (130111A)	5,787	5,229	-558 (-9.6%)
Mackenzie River (Bingegang Weir)	Stream Gauge (130110A)	5,787	5,317	-470 (-8.1%)

Table 7-6 December 2010 Model Calibration Outcomes (Level)

Location	Source	Recorded (m AHD)	Modelled (m AHD)	Difference (m)
Mackenzie River (Rileys Crossing)	Stream Gauge (130113A)	149.48	149.15	-0.33
Mackenzie River (Bedford Weir)	Stream Gauge (130111A)	131.02	131.00	-0.02
Mackenzie River (Bingegang Weir)	Stream Gauge (130110A)	N/A	110.23	-

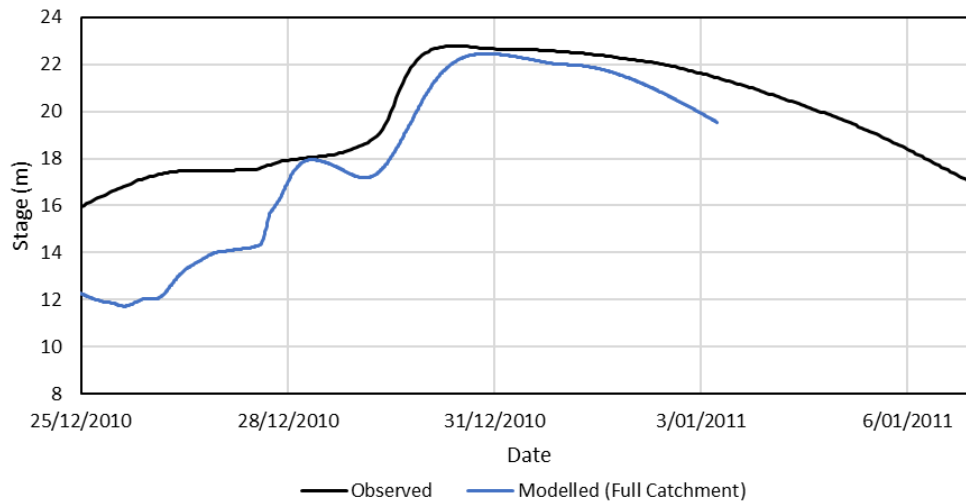


Figure 7-17 December 2010 Observed vs Modelled Stage Results at Rileys Crossing (130113A)

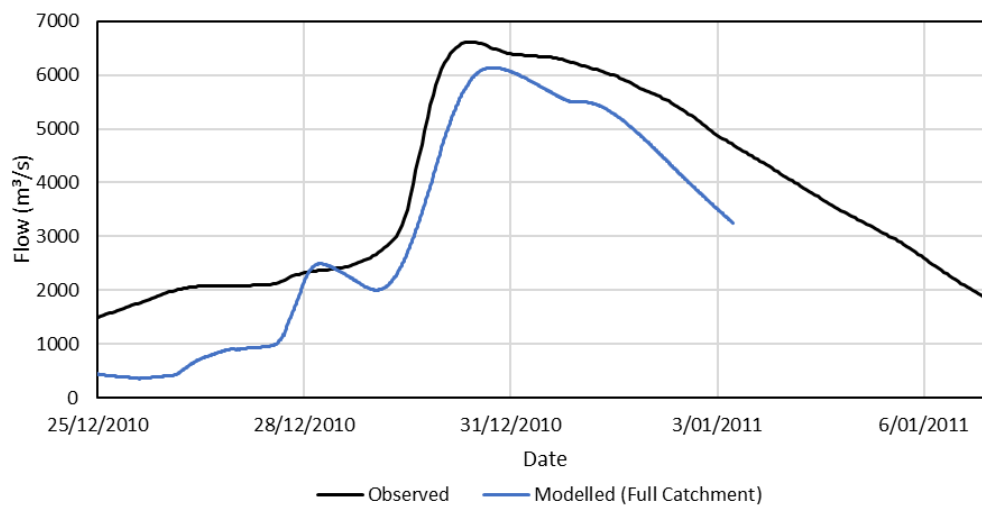


Figure 7-18 December 2010 Observed vs Modelled Flow Results at Rileys Crossing (130113A)

Rileys Crossing Inflow Sensitivity

As peak flows are consistently underestimated along the Mackenzie River by up to 10%, the gauged flow time series at Rileys Crossing was simulated through the model as a sensitivity. The results if adopting the gauge inflow at Rileys Crossing demonstrate closer alignment with the observed series with a minor overestimation (refer to Figure 7-19 to Figure 7-22).

While the observed hydrograph at Rileys Crossing was sourced from WMIP, flood level and overtopping weir flows at Bedford Weir and Bingegang Weir were sourced from SunWater. The reduced frequency of recording for the SunWater datasets translate to the coarser resolution of the observed timeseries at the two weirs. The interpolation between coarser data points could exaggerate the minor differences in hydrograph shape between the modelled and observed results.

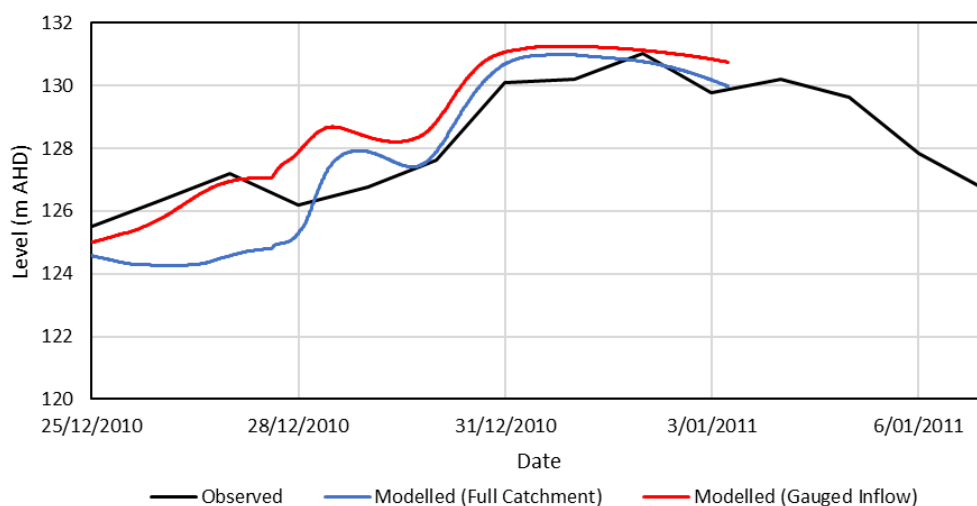


Figure 7-19 December 2010 Observed vs Modelled Level Results at Bedford Weir (SunWater)

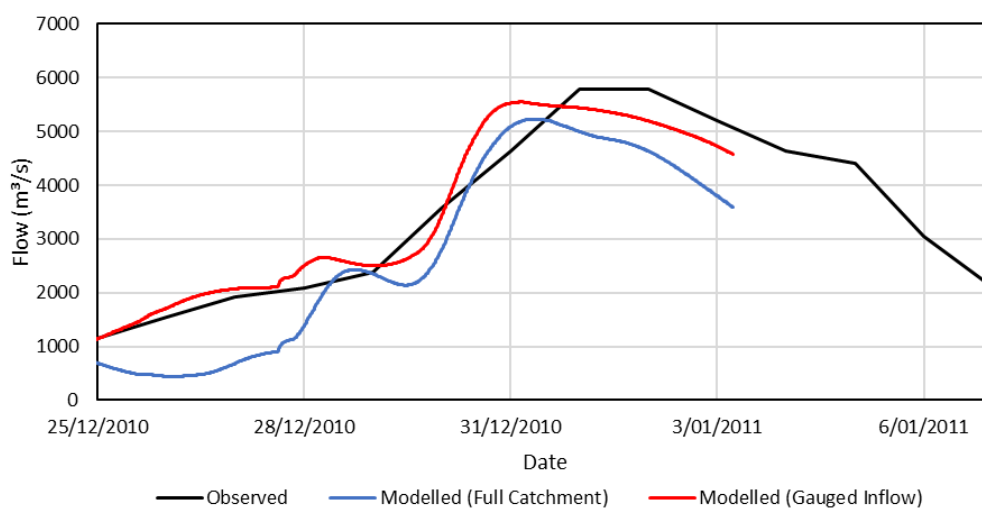


Figure 7-20 December 2010 Observed vs Modelled Flow Results at Bedford Weir (SunWater)

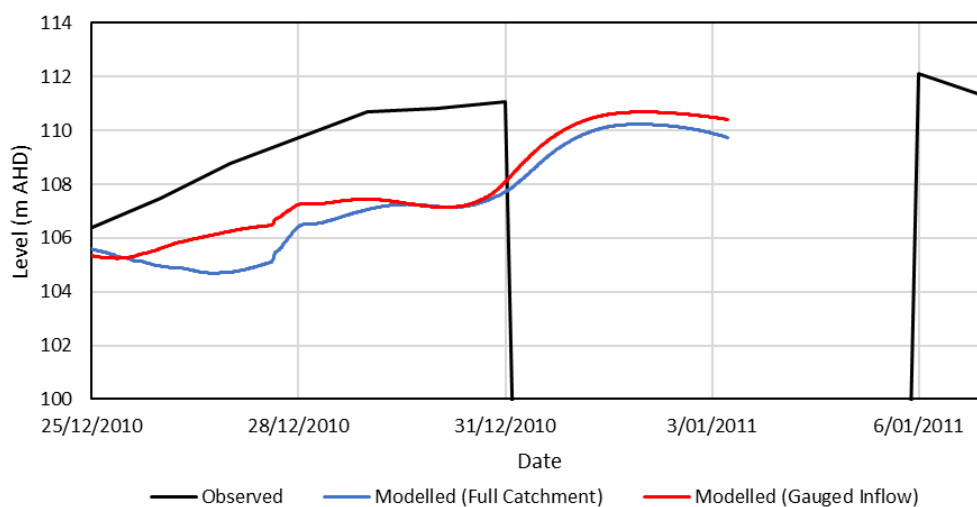


Figure 7-21 December 2010 Observed vs Modelled Level Results at Bingegang Weir (SunWater)

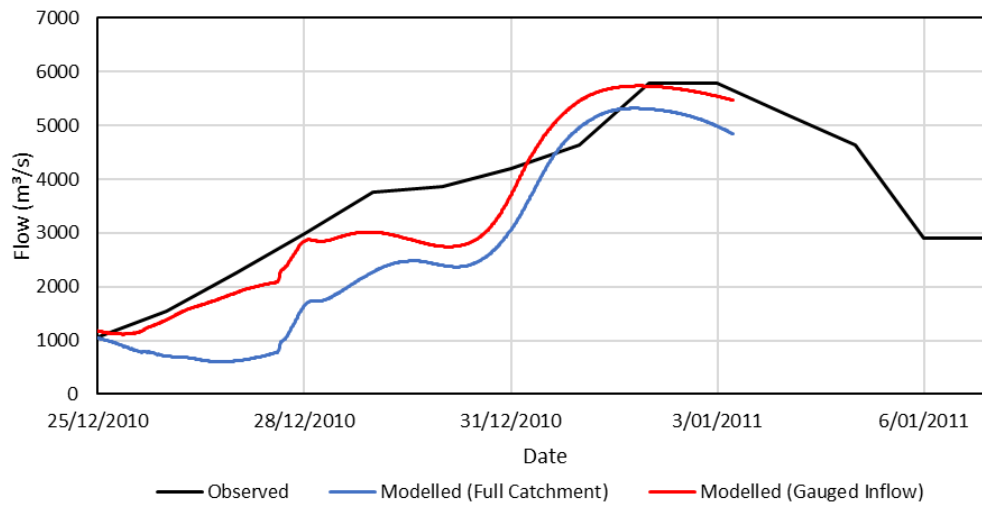


Figure 7-22 December 2010 Observed vs Modelled Flow Results at Bingegang Weir (SunWater)

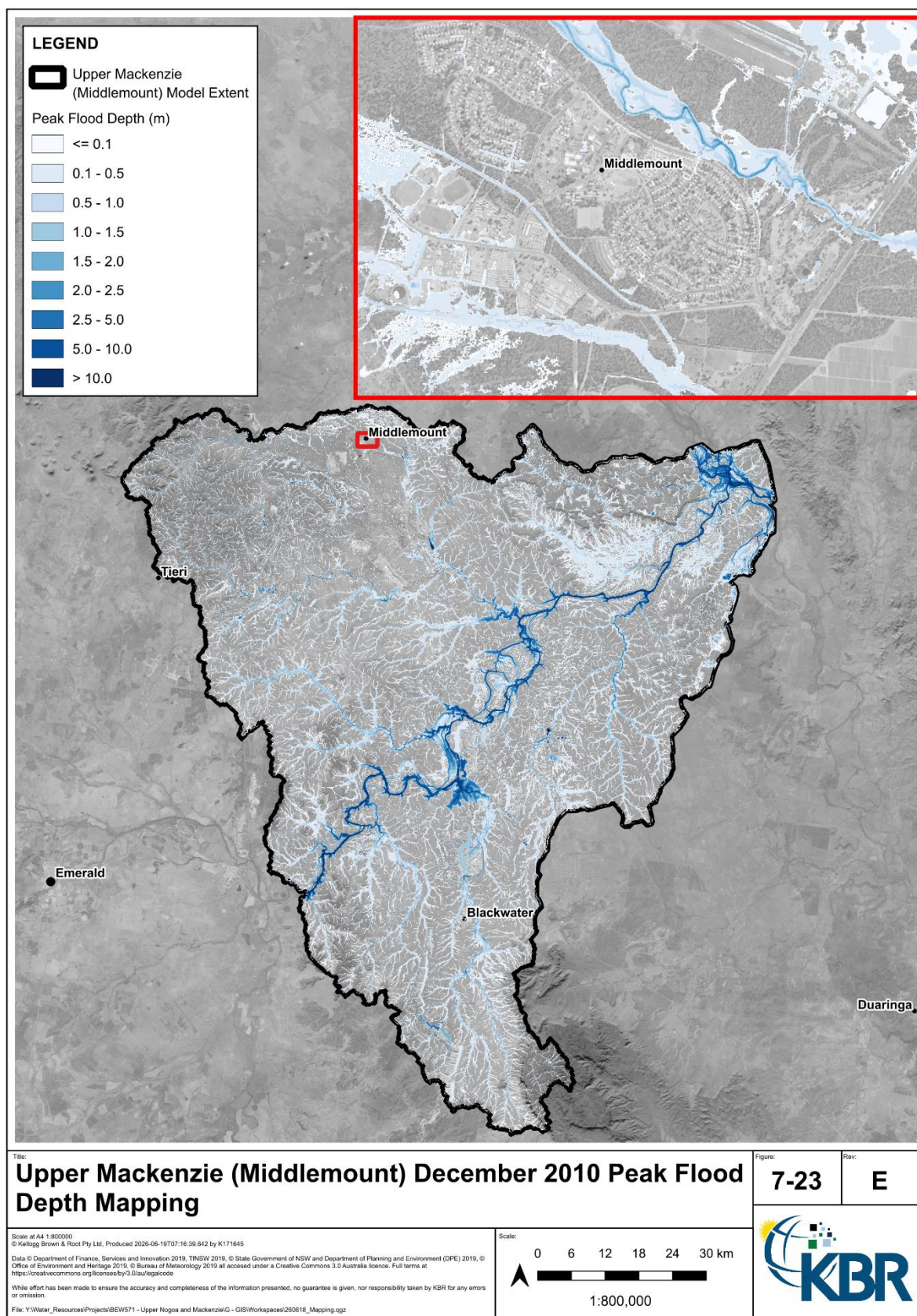


Figure 7-23 Upper Mackenzie River (Middlemount) December 2010 Peak Flood Depth Mapping



7.5.2 January 2008 Model Validation Outcomes

The modelled results adopting the regional hydrology in comparison to the recorded levels and flows is presented in Table 7-7 and Table 7-8. Larger discrepancies in peak flow and level are noted in comparison to those modelled for the December 2010 event. The 2008 event should be considered in light of the limitations of the confluence of the Isaac River to form the Dawson River discussed in previous sections.

Table 7-7 January 2008 Model Validation Outcomes (Flow)

Location	Source	Recorded	Modelled	Difference (m)
Mackenzie River (Rileys Crossing)	Stream Gauge (130113A)	3,977	4,588	+611 (+15.3%)
Mackenzie River (Bedford Weir)	Stream Gauge (130111A)	5,208	4,047	-1161 (-22%)
Mackenzie River (Bingegang Weir)	Stream Gauge (130110A)	4,784	4,101	-683 (-14.3%)

Table 7-8 January 2008 Model Validation Outcomes (Level)

Location	Source	Recorded (m AHD)	Modelled (m AHD)	Difference (m)
Mackenzie River (Rileys Crossing)	Stream Gauge (130113A)	147.29	147.68	+0.39
Mackenzie River (Bedford Weir)	Stream Gauge (130111A)	130.47	130.06	-0.41
Mackenzie River (Bingegang Weir)	Stream Gauge (130110A)	111.41	108.30	-3.11

Level and flow versus time hydrographs have been plotted at the three Mackenzie River gauges respectively in Figure 7-24 to Figure 7-29 from upstream to downstream. Peak flows are overestimated at Rileys Crossing by approximately 15%, with peak flows conversely underestimated at Bedford Weir and Bingegang Weir (approximately 22% and 14% respectively).

Unlike the December 2010 modelling, there is a notable misalignment in hydrograph shape between the modelled and recorded data at all three gauges. This can be attributed to the uncertainty surrounding the volume and temporal distribution of rainfall across the wider Mackenzie River catchment and its tributaries. In addition, large uncertainty is noted regarding the Comet River catchment (upstream of Rileys Crossing).

Within the Comet River negligible flow was modelled, whereas the local gauge recorded over 1,000 m³/s during the peak of the event. This discrepancy has also been noted in previous studies (refer to Section 2.7). In the December 2010 events the peak flows along the Mackenzie River at the three gauges are relatively consistent. However, this is not the case in the January 2008 event recorded flows (refer to Table 7-7). Within the January 2008 event, there is an increase in peak flow by over 1,000 m³/s recorded between Rileys Crossing and Bedford Weir, which are expected to have similar flows in large events. This is attributed to the unaccounted flow from the Comet River that is not being replicated within the regional hydrology.

As described in Section 5.4.9, 6.1.2, and 6.1.4 it is apparent that the Mackenzie River is impacted by a backwatering effect that is not able to be accurately reproduced within the scope of this study. Due to the notable length of the January 2008 storm event and the presence of an elevated baseflow within the Mackenzie River at Bedford Weir, it is suspected that the impacts of the backwatering effect extend beyond the Bingegang Weir up to the Bedford Weir gauge during this event. This is considered a plausible observation noting that the gauging station for Bedford Weir



is on the downstream side of the weir while the gauging station for Bingegang Weir is on the upstream side. As such, the two gauging locations fall on the same stretch of the river with no further hydraulic controls in between.

Rileys Crossing Inflow Sensitivity

In order to further validate the hydraulic performance of the Mackenzie River with the recorded information for the January 2008 event, the recorded flow-time series at Rileys Crossing was simulated as a sensitivity in place of the modelled upstream inflow from the Regional TUFLOW model.

As presented in Figure 7-26 to Figure 7-29, an improved alignment with the hydrograph shape is noted at the Bedford Weir and Bingegang Weir gauges. While a minor underestimation in peak flood level is modelled at Bedford Weir, it is important to note that the TUFLOW model assumes an initially dry river, in comparison to existing baseflow within the Mackenzie River as observed in Figure 7-26 (refer to Section 7.4.1 for additional information).

When adopting the Rileys Crossing recorded flows as an upstream inflow, Bedford Weir is underestimating flow and level. This could be attributed to such backwatering effect where an elevated peak flood level could be translated to a notably higher peak flow (noting that flows are calculated from the recorded level using the stage-discharge rating curve ignoring the effects of hysteresis as well as rising and falling limbs which are critical in this location). This complex hydraulic phenomenon could explain the underestimation of peak flood levels at Bedford Weir and Bingegang Weir despite using the recorded Rileys Crossing flow series as an upstream inflow.

Overall, while the modelling of the January 2008 event for the entire Mackenzie River catchment and its tributaries is unable to provide adequate alignment with the recorded gauged data, the additional sensitivity modelling produces an acceptable validation outcome within the limitations of the hydraulic model and insufficient information to support model detailed hydrology or inclusion of backwatering affects from the Dawson River.

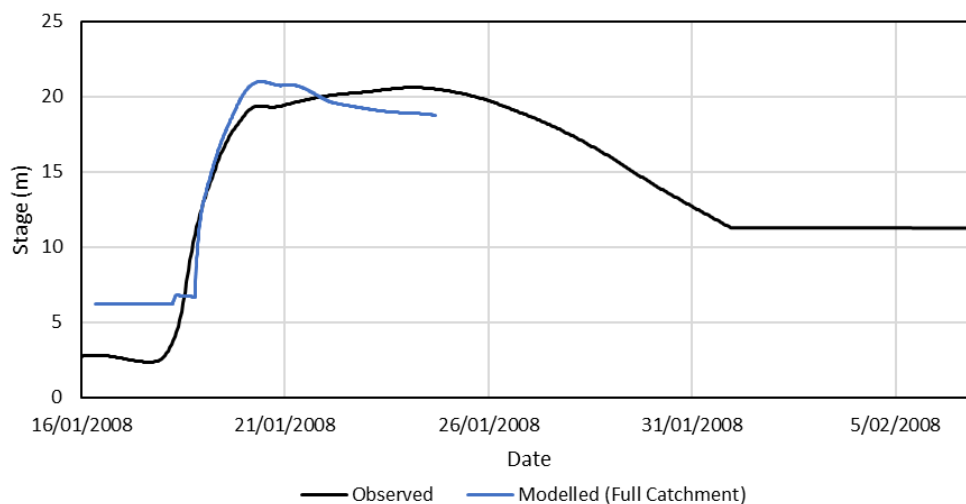


Figure 7-24 January 2008 Observed vs Modelled Stage Results at Rileys Crossing (130113A)

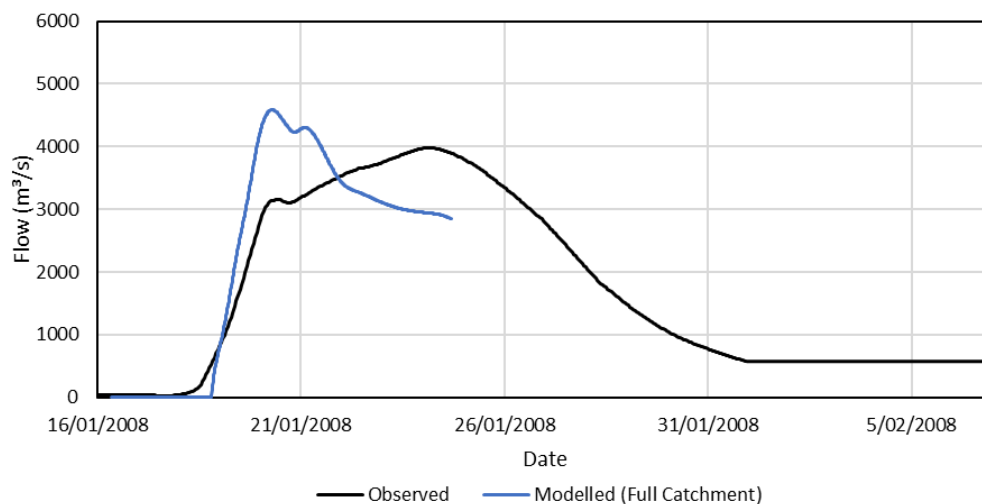


Figure 7-25 January 2008 Observed vs Modelled Flow Results at Rileys Crossing (130113A)

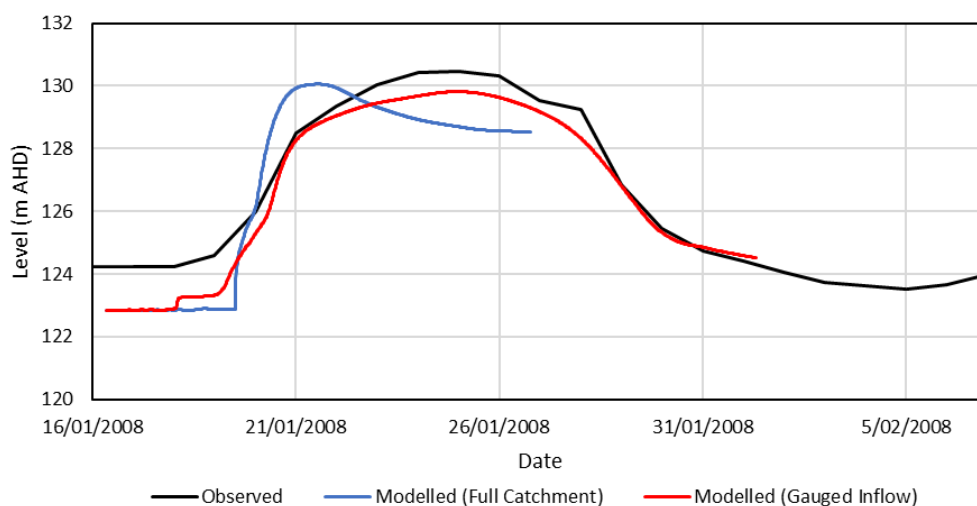


Figure 7-26 January 2008 Observed vs Modelled Level Results at Bedford Weir (SunWater)

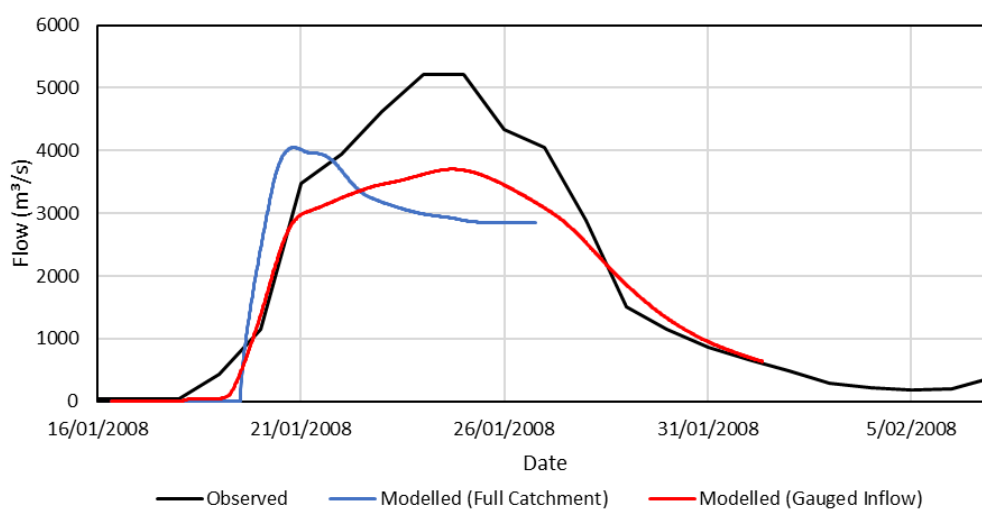


Figure 7-27 January 2008 Observed vs Modelled Flow Results at Bedford Weir (SunWater)

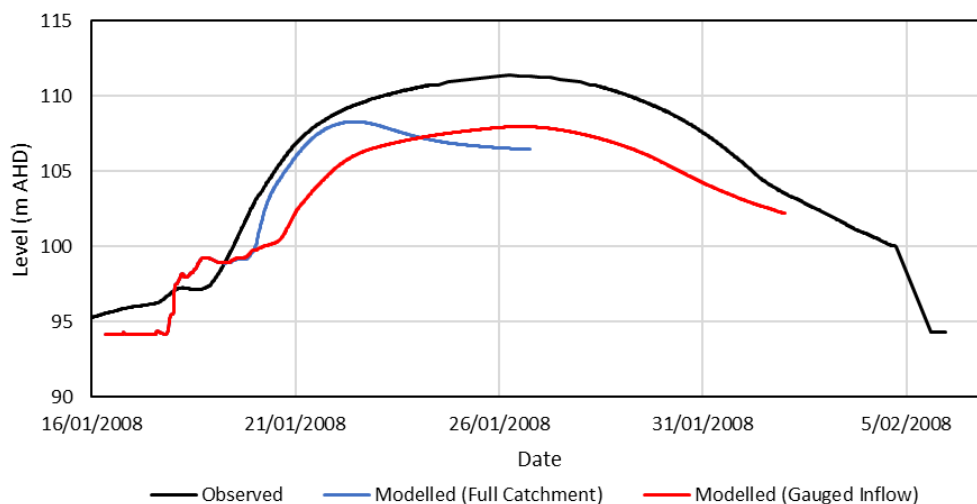


Figure 7-28 January 2008 Observed vs Modelled Level Results at Bingegang Weir (SunWater)

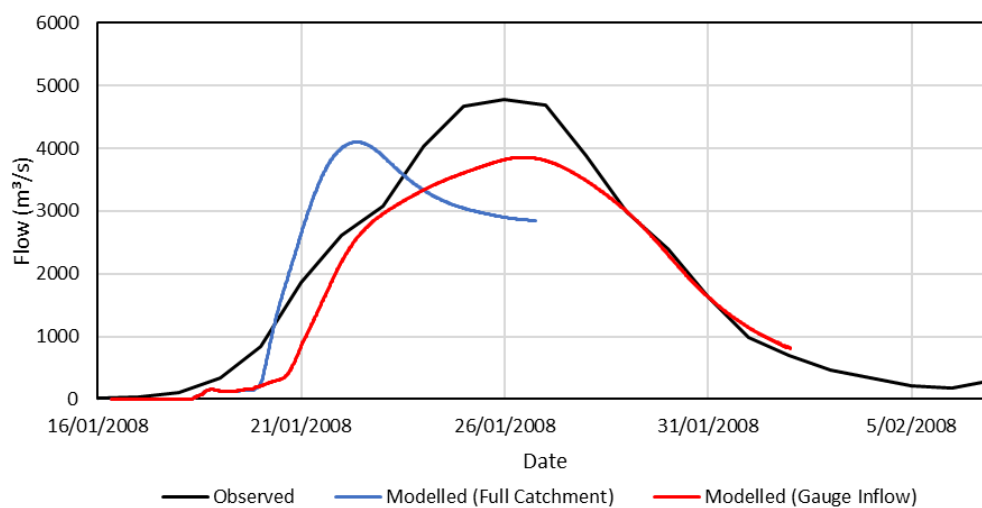


Figure 7-29 January 2008 Observed vs Modelled Flow Results at Bingegang Weir (SunWater)

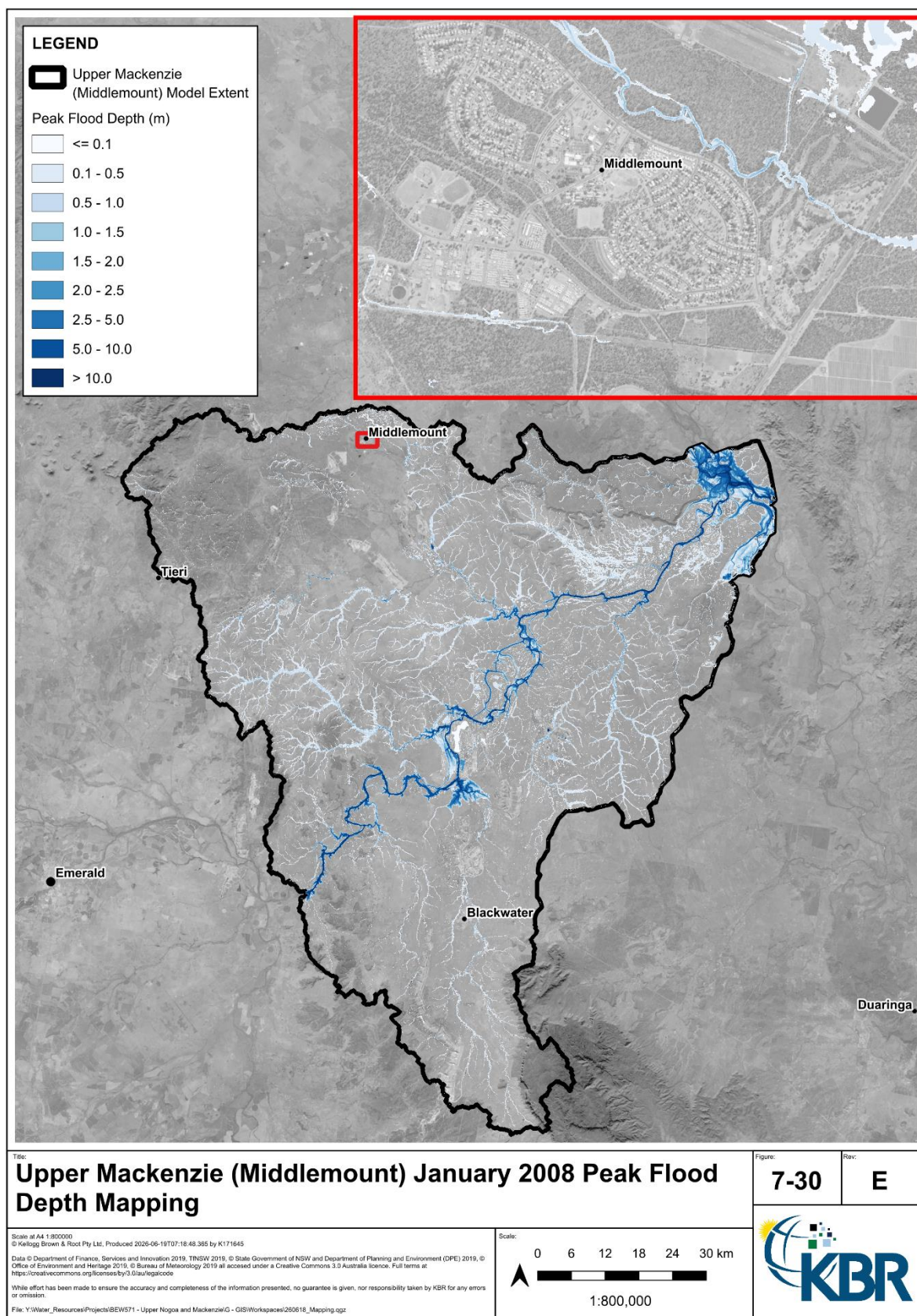


Figure 7-30 Upper Mackenzie River (Middlemount) January 2008 Peak Flood Depth Mapping



7.6

CONCLUSION

As part of the model calibration and validation process, key model parameters were iteratively adjusted until a reasonable match to the historical gauged flood data (i.e. flow and stage) was produced within the limitations of the data. For both the Upper Nogoa River (Clermont) and Upper Mackenzie River (Middlemount) catchments, the December 2010 event was used as the calibration event with the January 2008 event used as the validation event. From 2010, additional rainfall gauges have been established across the wider Mackenzie River catchment, allowing for increased confidence in the historical information underpinning the selection of the December 2010 event as the primary calibration event.

During the delivery of this Study, the township of Clermont was impacted by a significant rainfall event in January 2026. 10 flood markers were recorded and provided by Council as well as an estimated flood extent by a community member. KBR was subsequently engaged by Council to undertake further calibration and validation of the January 2026 event for the Upper Nogoa River (Clermont) model.

For the Upper Nogoa River (Clermont) model, strong correlation between observed and modelled flows and levels was achieved across the three (3) historical events. The modelled results achieved convergence with all 10 flood markers within ± 0.10 m with nine (9) of the 10 locations falling within ± 0.03 m. The comparison of the modelled flood extent against the community provided information also indicated strong alignment, providing a high degree of confidence in the model's ability to represent historical flooding associated with the Upper Nogoa River catchment.

As described in Section 6, the Upper Mackenzie River (Middlemount) model is unable to accurately represent the backwatering effects of the Mackenzie River up to Bedford Weir. As such, modelled flood levels are underestimated beyond Bedford Weir when compared against the historical gauged records. The shape of the modelled time series is closely aligned for the December 2010 event.

Unlike the December 2010 modelling, there is misalignment in hydrograph shape between the modelled and recorded data for the January 2008 event. This can be attributed to the uncertainty surrounding the volume and temporal distribution of rainfall across the wider Mackenzie River catchment and its tributaries. When simulating the recorded time series at Rileys Crossing as an upstream inflow to the Upper Mackenzie River (Middlemount) model, the shape of the time series is significantly improved with strong correlation against the historical gauged records on the Mackenzie River. However, similar to the December 2010 event, modelled flood levels and flows are underestimated due to the inability to accurately represent the backwatering mechanism.

Overall, the calibration and validation process demonstrated that the TUFLOW models provide a reasonable and reliable representation of historical flood behaviour across both catchments within the limitations of the data. This process provides confidence that the model parameters and schematisation defined can be confidently utilised for the purposes of design event modelling.



8 Design Event Modelling

Design floods are defined based on their probability of occurrence, typically expressed as a flood with a specific Annual Exceedance Probability (AEP). In line with the ARR Version 4.2 guidelines, design events are essential for evaluating the frequency and severity of flooding and can be used to inform flood management and mitigation strategies.

The combined hydrologic and hydraulic TUFLOW models, developed as a part of the model calibration and validation process (as detailed in Section 7), have been relied upon for the simulation of the design events. Design event modelling has been undertaken for the 50%, 20%, 5%, 2%, 1%, 0.5%, and 0.2% AEP events, as well as the Probable Maximum Flood (PMF) event for the 2030 year horizon using the SSP2-4.5 scenario. The 1% AEP event for the 2100 year horizon using the SSP2-4.5 scenario was additionally simulated as part of the future climate change assessment (refer to Section 10.2 for further information).

8.1 AUSTRALIAN RAINFALL AND RUNOFF VERSION 4.2 GUIDELINES

In August 2024, ARR was updated from Version 4.1 to 4.2. The primary focus of the update was to revise the consideration of climate change in ARR to be in line with the Intergovernmental Panel on Climate Change (IPCC) 6th Assessment Report (AR6) and its associated studies. As part of this update, the climate change scenarios are considered under Shared Socio-economic Pathways (SSP) as opposed to the previously adopted Reconciled Concentration Pathways (RCP) of the IPCC 5th Assessment Report (formerly adopted in ARR Version 4.1).

The implications of the updated guidance not only encapsulate a new approach to the modelling of future climate scenarios, but also recommend the upscaling of design event rainfall, inclusive of the Probable Maximum Precipitation (PMP), and associated hydrologic losses to be reflective of the climate change that has occurred since the development of the rainfall and loss data.

With this in mind, the design event modelling for the Upper Nogoia and Mackenzie River Catchments Hydraulic Flood Study has been undertaken in accordance with the latest ARR Version 4.2 guidelines.

8.2 DESIGN INPUTS

8.2.1 Rainfall Depth

Design rainfall depths have been extracted from the BoM 2016 IFDs at the centroid of each rainfall catchment (refer to Figure 5-1). Derived through statistical analyses, the IFDs represent a relationship between rainfall intensity, return period (or probability of exceedance), and storm duration.

In accordance with the recommendations from the latest ARR Version 4.2 guidelines, rainfall scaling factors were extracted from the ARR Datahub. In agreeance with Council, the SSP2-4.5 scenario for the 2030 year horizon was selected to represent the present-day conditions.

The applied upscaling factors are presented in Table 8-1.

Table 8-1 ARR Version 4.2 Rainfall Upscaling Factors (SSP2-4.5)

Year	< 1 h	1.5 h	2 h	3 h	4.5 h	6 h	9 h	12 h	18 h	> 24 h
2030	1.18	1.17	1.16	1.14	1.13	1.12	1.12	1.11	1.10	1.10
2100	1.41	1.37	1.35	1.32	1.29	1.27	1.25	1.24	1.22	1.21



Up to the 2030 year horizon, minimal difference in scaling factors is acknowledged for the SSP1-2.6, SSP2-4.5, and SSP3-7.0 scenarios. When rounding of the scaling factors to two (2) decimal places are considered, the factors are identical for the three (3) lower scenarios. More notable differences are provided for the worst case SSP5-8.5 scenario and divergence of the scaling factors is far more noticeable for the 2040 year horizon and onwards (refer to Figure 8-1).

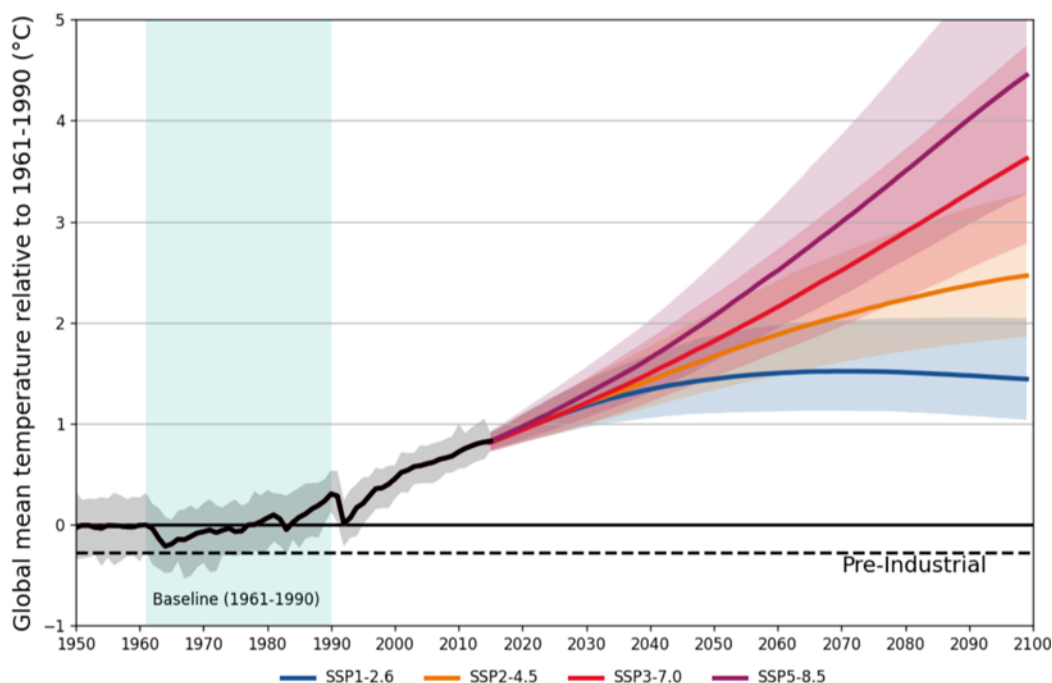


Figure 8-1 Projected Temperature Increases Associated with AR6 Socioeconomic Pathways Relative to 1961-1990 (Extracted from ARR Version 4.2)

The applied rainfall for the present day conditions at Clermont and Middlemount are presented in Table 8-2 and Table 8-3 respectively.

Table 8-2 Applied Present- Day Design Event Rainfall Depths (mm) at Clermont

Duration	50%	20%	5%	2%	1%	0.5%	0.2%
6 hour	64.2	90.5	128.8	155.7	178.1	200.5	234.1
9 hour	71.3	101.1	145.6	175.8	201.6	227.4	265.4
12 hour	76.4	108.6	156.5	190.9	218.7	245.3	287.5
18 hour	84.7	121.0	174.9	213.4	245.3	276.1	322.3
24 hour	91.7	130.9	190.3	233.2	267.3	301.4	353.1
30 hour	97.7	139.7	203.5	248.6	286.0	323.4	378.4
36 hour	102.7	147.4	214.5	261.8	301.4	341.0	400.4
48 hour	111.1	159.5	232.1	284.9	326.7	370.7	435.6
72 hour	122.1	176.0	258.5	316.8	364.1	413.6	485.1
96 hour	129.8	188.1	277.2	339.9	389.4	443.3	517.0
120 hour	136.4	196.9	291.5	356.4	408.1	463.1	540.1
144 hour	139.7	204.6	302.5	369.6	423.5	478.5	556.6
168 hour	143.0	210.1	312.4	380.6	434.5	490.6	568.7



Table 8-3 Applied Present- Day Design Event Rainfall Depths (mm) at Middlemount

Duration	50%	20%	5%	2%	1%	0.5%	0.2%
6 hour	64.2	87.9	122.1	146.7	165.8	193.8	229.6
9 hour	71.1	98.1	136.6	164.6	188.2	219.5	261.0
12 hour	76.1	105.3	147.6	178.7	204.2	238.7	284.2
18 hour	84.4	117.7	166.1	202.4	232.1	271.7	322.3
24 hour	91.5	128.7	181.5	223.3	257.4	300.3	356.4
30 hour	97.5	137.5	194.7	240.9	278.3	323.4	386.1
36 hour	102.6	145.2	206.8	256.3	297.0	345.4	412.5
48 hour	111.1	158.4	226.6	281.6	327.8	379.5	454.3
72 hour	123.2	177.1	255.2	319.0	371.8	429.0	512.6
96 hour	132.0	190.3	275.0	343.2	400.4	459.8	547.8
120 hour	137.5	199.1	288.2	359.7	419.1	479.6	568.7
144 hour	141.9	205.7	298.1	369.6	429.0	490.6	579.7
168 hour	145.2	210.1	303.6	375.1	432.3	496.1	584.1

8.2.2 Areal Reduction Factors

Application of an Areal Reduction Factor (ARF) accounts for the application of IFD data over a larger area as the probability of a point IFD is not directly applicable over a large catchment. Due to the size of Mackenzie River catchment and its tributaries, application of appropriate ARFs was a key consideration of the design event modelling stage of this study.

As the entire Mackenzie River study area falls within the 'Semi-arid Inland QLD' zone, associated ARF parameters were extracted from the ARR datahub as presented in Table 8-4.

For the Upper Nogoia River (Clermont) model, ARFs were calculated for the Sandy Creek and Wolfgang Creek catchments up to Clermont. While a conservative approach, this allows for appropriate comparison of modelled peak flows to those estimated by the Flood Frequency Analysis (refer to Section 8.5 for further information). Additionally, with the proximity of the town to the confluence of both Sandy Creek and Wolfgang Creek, the applied methodology was considered appropriate.

For the Regional Mackenzie River model, ARFs were calculated up to Rileys Crossing for the development of inflow hydrographs with the exception of the Sandy Creek and Wolfgang Creek catchments (as described above), allowing for a consistent representation between models. This results in a slightly conservative representation of the Sandy Creek flows within the Regional Mackenzie River model, however with the dominant flooding mechanism being from the Fairbairn Dam catchment, the effects were considered negligible. Localised ARFs were developed for the Upper Mackenzie River (Middlemount) model to be local to the township of Middlemount, considering only the catchment area upstream of the town.

Table 8-4 Applied ARF Parameters

Zone	a	b	c	d	e	f	g	h	i
Semi-arid Inland QLD	0.159	0.283	0.25	0.308	0.00000073	1.0	0.039	0.0	0.0



8.2.3 Temporal Patterns

Temporal patterns are used in design flood estimation to account for the distribution of rainfall depth within a given rainfall duration. The ARR Version 4.2 guidelines prescribe an ensemble approach, whereby a suite of 10 rainfall temporal patterns is applied to the design rainfall depths of the simulated range of event magnitudes and durations.

Due to the size of the catchment areas being modelled ($> 75 \text{ km}^2$), areal temporal patterns for the 'East Coast North' region have been adopted for this study. It should be noted that areal temporal patterns are only applicable to durations greater than or equal to 12 hours. For the township of Middelmount, point temporal patterns for the 'East Coast North' region was also extracted to supplement the analysis of shorter durations less than 12 hours in consideration of the immediate catchment area to Middelmount township being less than 70 km^2 .

The ARR Version 4.2 guidelines aggregate the ensemble of point temporal patterns into three (3) distinct groups, defined by the frequency of the design storm event (refer to Figure 8-2). A critical duration assessment has been conducted for each temporal pattern group and is discussed in further detail in Section 8.3.

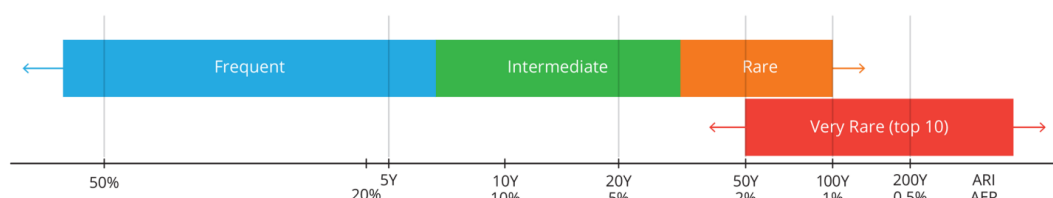


Figure 8-2 Temporal Pattern Ranges (ARR, 2019)

8.2.4 Design Rainfall Losses

As per the ARR recommended loss hierarchy, the highest priority of design losses is to utilise the calibrated losses derived from model calibration. As described in Section 5.3.3, the Green-Ampt loss model produced modelled results that were better aligned with the calibration and validation data points (refer to Section 7 for further information). As such, the calibrated loss approach and parameters were maintained for the purposes of design event modelling.

8.2.5 Isaac River Coincidence

As described in Section 5.4.8, 5.4.9, and 7.5, the Upper Mackenzie River (Middelmount) study area extends to the confluence of the Mackenzie River with the Isaac River. For the purposes of model calibration and validation, the historical gauged flows at the Isaac River at Yatton stream gauge (130401A) were injected into the model as an upstream flow-time boundary.

However, for the purposes of design event modelling, it was not within the scope of works for the inclusion of flows from the Isaac River. The outcomes of the model calibration indicate that uncertainty in representing the downstream boundary and subsequent backwatering up to Bedford Weir is noted.

8.2.6 Probable Maximum Flood

Within Australia, there are several methodologies to modelling the PMF event. Due to the location and size of the study area, the Generalised Tropical Storm Method (GTSMR) for the Coastal Zone was applicable for the majority of the study area. The Generalised Short Duration Method (GSDM) was considered only for the township of Middelmount due to its locality being near the top of the catchment correspondingly smaller catchment size and shorter critical durations.

PMP rainfall depths were derived for the study area for a range of storm durations between one (1) to 120 hours, in accordance with the Bureau of Meteorology's GSDM (BoM, 2003) and GTSMR



(BoM, 2005) guidelines. The spatial variation was defined as per the methodology to derive ARFs (refer to Section 8.2.2 for further information).

For the township of Clermont, as the catchment area exceeded the limit of the GSDM application ($> 1,000 \text{ km}^2$), only the GTSMR method was applied. PMP rainfall depths were generated accordingly for durations between 24 hours and 120 hours. Extrapolation of the derived PMP rainfall depths was undertaken to obtain depths for the 12 and 18 hour storms.

For the township of Middelmount, GSDM ellipses were centred upon the town with PMP rainfall depths calculated accordingly. The GSDM PMP was simulated only for the catchment local to the town due to its independence of backwatering from the Mackenzie River.

The factors used in the estimation of the PMP are summarised in Table 8-5 and Table 8-6. The calculated PMP rainfall depths are presented in Table 8-7 and Range of rainfall values includes spatial variation between Ellipse A to J

Table 8-8.

Table 8-5 GSDM Input Parameters

Parameter	Middelmount (mm)
Area (km^2)	284
Catchment Type	Rough
Moisture Adjustment Factor (MAF)	0.87
Elevation Adjustment Factor (EAF)	1.00

Table 8-6 GTSMR Input Parameters

Parameter	Clermont	Rileys Crossing
Area (km^2)	1,345	45,000
Extreme Precipitable Water (EPW)	88.99	87.01
Moisture Adjustment Factor (MAF)	0.74	0.73
Decay Amplitude Factor (DAF)	1.00	0.96
Topographic Adjustment Factor (TAF)	1.00	1.03

Table 8-7 Applied GSDM PMP Present-Day Rainfall Depths

Parameter	Middelmount (mm)
1 hour	280 – 510
1.5 hour	370 – 650
2 hour	430 – 750
2.5 hour	480 – 820
3 hour	510 – 890
4 hour	580 – 1,010
5 hour	610 – 1,110
6 hour	650 – 1,170

Range of rainfall values includes spatial variation between Ellipse A to J

Table 8-8 Applied GTSMR PMP Present-Day Rainfall Depths

Parameter	Clermont (mm)	Rileys Crossing (mm)
24 hour	990	470
36 hour	1,160	580



Parameter	Clermont (mm)	Rileys Crossing (mm)
48 hour	1,330	680
72 hour	1,620	850
96 hour	1,840	960
120 hour	1,940	980

8.2.7 Structure Blockage

Hydraulic structure blockage has been applied in accordance with the ARR Version 4.2 recommended blockage procedures. The blockage assessment has been undertaken for an L_{10} value of 1.5 m as observed during the site visit. The outcomes of the blockage assessment form are detailed in Table 8-9 with the calculated factors presented in Table 8-10.

Table 8-9 ARR Blockage Assessment Outcomes

Type	Upper Nogoia River (Clermont)	Upper Mackenzie River (Middlemount)
Debris Availability	High	High
Debris Mobility	High	Medium
Debris Transportability	High	Medium
Site Based Debris Potential	DP _{High}	DP _{Medium}
Site Debris Potential	High	Medium

Using the calculated Site Debris Potential (refer to Table 8-9), blockage factors were calculated for the 1% AEP event. It is acknowledged that the blockage assessment recommends different factors for different groups of event magnitudes. However, to allow a like-for-like assessment and considering the consistency of blockage potential observed on site across the study area, blockage factors were maintained irrespective of event rarity.

Table 8-10 ARR Blockage Assessment Factors

Type	Upper Nogoia River (Clermont)	Upper Mackenzie River (Middlemount)
Blockage Factor for Width < 1.5 m	100%	50%
Blockage Factor for 4.5 m ≥ Width ≥ 1.5 m	20%	10%
Blockage Factor for Width ≥ 4.5 m	10%	0%

8.3 CRITICAL DURATION ASSESSMENT

A critical duration assessment refers to the selection of durations that can best represent the flood behaviour of a specified design flood event. Within the study area, flooding is largely driven by mainstream flow. As such critical durations were generally longer duration events driven by large rainfall volumes.

Due to the nature of the combined hydrologic and hydraulic modelling approach, a critical duration assessment was undertaken using the peak flood level outputs from TUFLOW. The full ensemble of 10 point temporal patterns were simulated for durations less than 12 hours, and the full ensemble of 10 areal temporal patterns was simulated over a range of durations between 12 and 144 hours. The critical duration assessment was undertaken for the 20%, 5%, 1%, and 0.2% AEP events, representative of the frequent, intermediate, and rare temporal pattern groups respectively as explained in Section 8.2.3.



To select the critical duration from the range of simulated design events, a median peak water level surface of the 10 temporal patterns was produced for each simulated duration. The median durations which produced the maximum water level across the study area were selected to be the critical duration(s). Once the critical duration(s) were established, the temporal patterns that were closest to but biased to be above the median were selected to be the representative temporal pattern for each critical duration.

The focal points at which this assessment has been undertaken are:

- Sandy Creek at Clermont (130207A) stream gauge,
- Mackenzie River at Rileys Crossing (130113A) stream gauge,
- Clermont township, and
- Middlemount township.

The selected critical duration(s) and adopted representative temporal patterns for each AEP event are summarised in Table 8-11.

Table 8-11 Summary of Adopted Critical Durations and Representative Temporal Patterns

Event	Upper Nogoia River (Clermont)	Upper Mackenzie River (Middlemount)
50% AEP and 20% AEP	24 hour TP10 (Areal)	12 hour TP05 (Areal) 96 hour TP10 (Areal)
5% AEP	24 hour TP09 (Areal)	12 hour TP07 (Areal) 96 hour TP06 (Areal)
2% AEP and 1% AEP	18 hour TP09 (Areal)	6 hour TP05 (Point) 96 hour TP09 (Areal)
0.5% AEP and 0.2% AEP	18 hour TP04 (Areal)	6 hour TP05 (Point) 96 hour TP09 (Areal)
PMF	12 hour GTSMR	4 hour GSDM 96 hour GTSMR

As described in Section 8.2.6, PMP rainfall depths were derived for the Upper Nogoia River (Clermont) model between 12 and 120 hours. While the critical duration assessment identified the 12 hour GTSMR storm to be critical, it should be noted that no durations less than 12 hours were simulated due to limitations in the available guidelines at the time of this study. It is possible that a shorter duration could produce more critical flood behaviour within the Upper Nogoia River (Clermont) study area.

8.4 FLOOD FREQUENCY ANALYSES

The ARR guidelines emphasise the value of local gauge data in their ability to be utilised for the purposes of a Flood Frequency Analysis (FFA). A FFA is a hydrological technique employed to estimate flow values corresponding to a specific exceedance probability.

Within this study, an Annual Maximum Series (AMS) was adopted as the basis of the FFA. The AMS is a series of the peak flows recorded at the gauge for each year of recording. A statistical distribution is then fitted to the data. It should be noted that the quality of the FFA is highly dependent on the reliability and consistency of the AMS (i.e. reliable data with no gaps between years).

For this study, an AMS dataset was compiled for the Sandy Creek at Clermont (130207A) gauge, detailed in Appendix B. A total of 57 years of continuous record between 1965 to 2026 was sourced.



Due to the model's limitations in representing flood behaviour towards the lower reaches of the Mackenzie River, limited benefit would be provided by undertaking a FFA for the Mackenzie River at Bingegang Weir (130110A) gauge for the purposes of model validation.

The FFA was developed by fitting a Log Pearson 3 (LP3) distribution to the AMS dataset using the TUFLOW FLIKE software. Results from the FFA are presented in Table 8-12 and illustrated in Figure 8-3.

Table 8-12 FFA Outputs

Event	Sandy Creek at Clermont (m ³ /s)
50% AEP	112
20% AEP	246
5% AEP	509
2% AEP	732
1% AEP	930
0.5% AEP	1,155
0.2% AEP	1,498

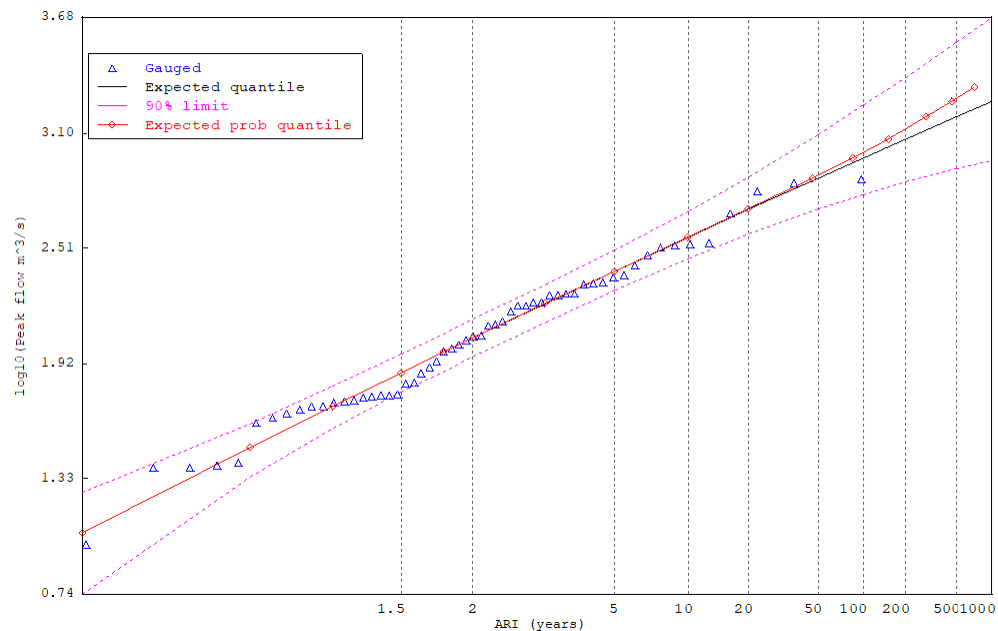


Figure 8-3 FFA Outputs at the Sandy Creek at Clermont Gauge (LP3)

8.5 DESIGN EVENT FLOW VALIDATION

The modelled design event flows were compared against the flows estimated from the FFA as described in Section 0. The design event flow validation was undertaken at the Sandy Creek at Clermont gauge due to the extensive years of gauged record allowing for a robust and appropriate FFA. The modelled flows against the estimated flows are presented in Table 8-13 and illustrated in Figure 8-4.

For the 2% AEP onwards, a strong correlation between estimated and modelled flows is achieved. At these higher order events, flood behaviour typically exceeds the banks of Sandy Creek, and the impact of infiltration losses becomes less significant.

An underestimation of peak flows is modelled up to the 5% AEP event when compared against the FFA derived flows. This can largely be attributed to the calibration and validation of model



parameters being biased toward more volume heavy storm events associated with the 2008, 2010, and 2026 historical events. The underestimation of lower order events could be a symptom of the applied soil types being too porous (of which the effect becomes less noticeable as the catchment is more saturated in higher order events). Should the lower order events (i.e. 50% AEP) be required for strategic planning purposes, it would be recommended to consider the use of the 2010 event as an approximate proxy to align with the FFA. Alternatively, an Initial and Continuing Loss model adopting recommended ARR datahub values may be more suitable.

Table 8-13 Design Event Flow Validation Outcomes at the Sandy Creek at Clermont Gauge

Event	FFA Flows (m ³ /s)	Modelled Flows (m ³ /s)	Difference (m ³ /s)
50% AEP	112	35	-77
20% AEP	246	134	-112
5% AEP	509	425	-84
2% AEP	732	687	-45
1% AEP	930	896	-34
0.5% AEP	1,155	1,136	-19
0.2% AEP	1,498	1,518	+20

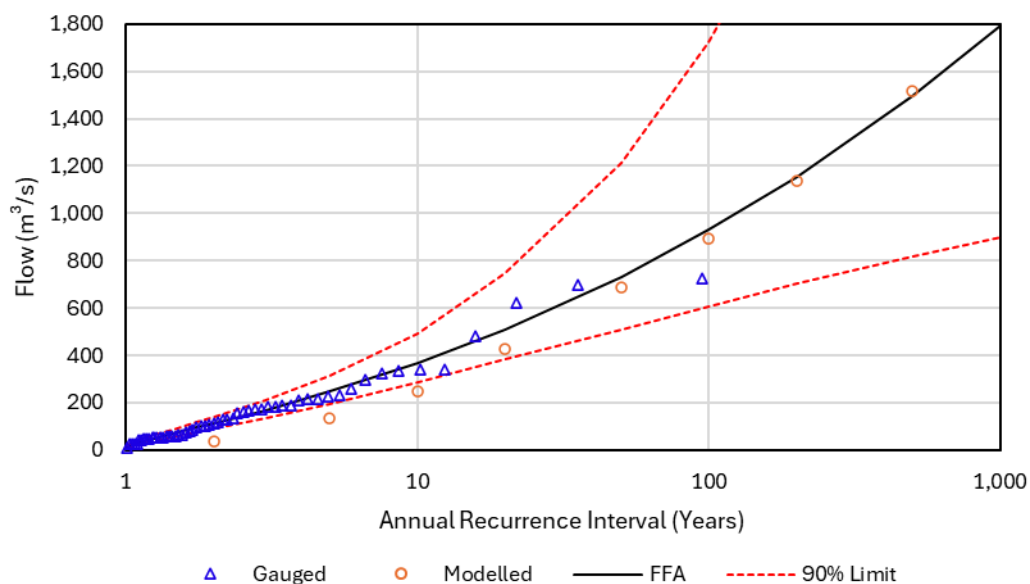


Figure 8-4 Design Event Flow Validation Outcomes at the Sandy Creek at Clermont Gauge



9 Modelled Results

9.1 MODELLED RESULT POST-PROCESSING

A raw (unfiltered) TUFLOW Direct Rainfall result can depict a large amount of 'noise' due to the nature of the approach distributing rainfall across all active cells within the model domain. The post-processing of the raw model results is a necessary step to appropriately depict the developed flow paths without unrealistic shallow depths across the entire active model domain. The reinstatement of velocities is a necessary step in order to capture shallow, yet fast moving flows and improve flow path connectivity. Due to the direct rainfall approach wetting all cells within the model domain, a large enough isolated area cut off was required to effectively filter out isolated flood islands. A wide range of values and combinations were tested and reviewed to ensure that the post-processed flood extents were appropriate and reflective of flood risk across the study area.

The following post-processing criteria was applied across all modelled design events:

- Depths < 0.15 m were removed,
- Velocity > 0.40 m/s were reinstated,
- Velocity depth product > 0.10 m²/s were reinstated, and
- Isolated flood islands < 1500 m² have been removed.

9.2 FLOOD MAPPING

One of the benefits and outcomes of two-dimensional modelling is the ability to visualise the spatial distribution of modelled outputs such as peak flood level, depth, and velocity as a high-definition flood map. The visualisation of the various model outputs is a critical component in developing an understanding and appreciation of the flood behaviour across the study area.

Flood mapping undertaken as a part of this study is presented in Appendix C and Appendix D for the Upper Nogoa River (Clermont) and Upper Mackenzie River (Middlemount) study areas. In consideration of the limitations associated with the representation the backwater effect up the Mackenzie River, areas below the Bedford Weir spillway level have been highlighted in Appendix D.

The following outputs have been mapped:

- Peak flood level,
- Peak flood depth,
- Peak flood velocity,
- Flood hazard categorisation, and
- QRA Hazard level categorisation.

9.2.1 Flood Hazard Categorisation

Flood hazard is typically derived from a combination of peak flood depth and velocity. The visualisation of flood hazard provides for a better understanding of the potential flood risk within the study area. Handbook 7 – Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia (2013) provides a revised hazard classification, which adds clarity to the hazard categories and what they mean in practice. The classification is divided into six (6)



categories as depicted in Figure 9-1. These categories indicate the restrictions on people, buildings, and vehicles:

- 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, and
- H6 – Unsafe for people and vehicles. All building types considered vulnerable to failure.

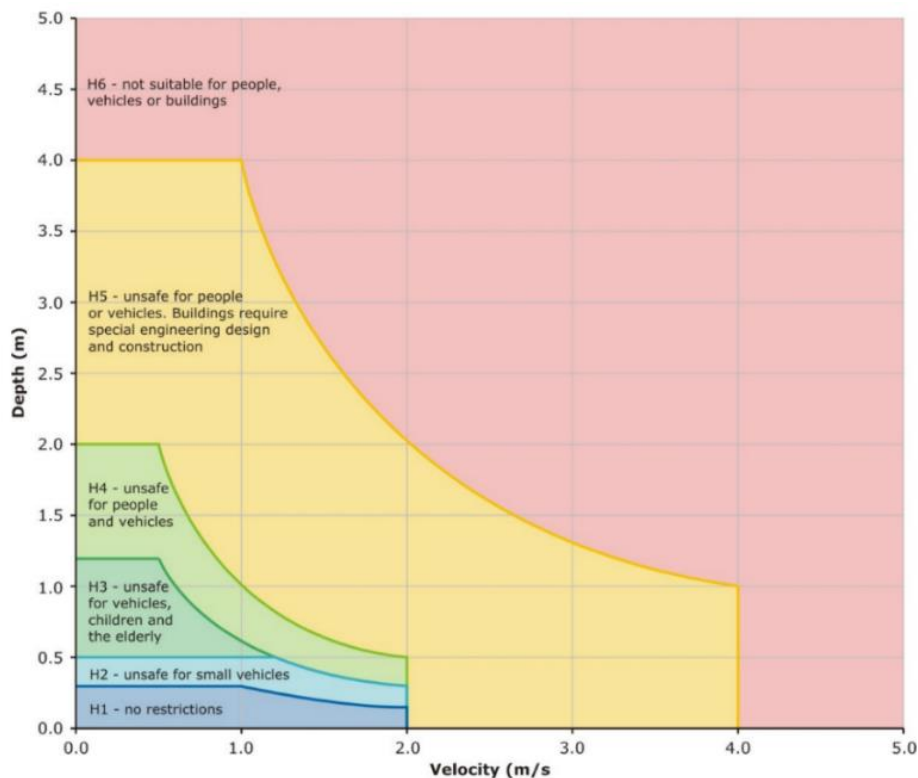


Figure 9-1 Combined Flood Hazard Categories (AIDR, 2017)

9.2.2 Queensland Reconstruction Authority Hazard Level Categorisation

In addition to the Flood Hazard Categorisation described in Section 9.2.1, the study areas were assessed against the Hazard Level Categorisation derived by the QRA as per the QRA Floodplain Management Guideline (QRA, 2012). The QRA guideline provides an indicative flood hazard criterion which is similarly derived from a combination of peak flood depth and velocity. The QRA Hazard Level Classification is divided into four (4) categories as depicted in Figure 9-2 and summarised as follows:

- Low Risk – Self evacuation possible for adults and children, vehicle stability within tolerance for large four wheel drive (4WD) vehicles,
- Significant – Working limit for trained safety workers. Vehicle evacuation unsuitable. Building Code limitation,
- High – Limit of uncompromised stability for adults (dangerous to most), and
- Extreme – In excess of known stability limits.

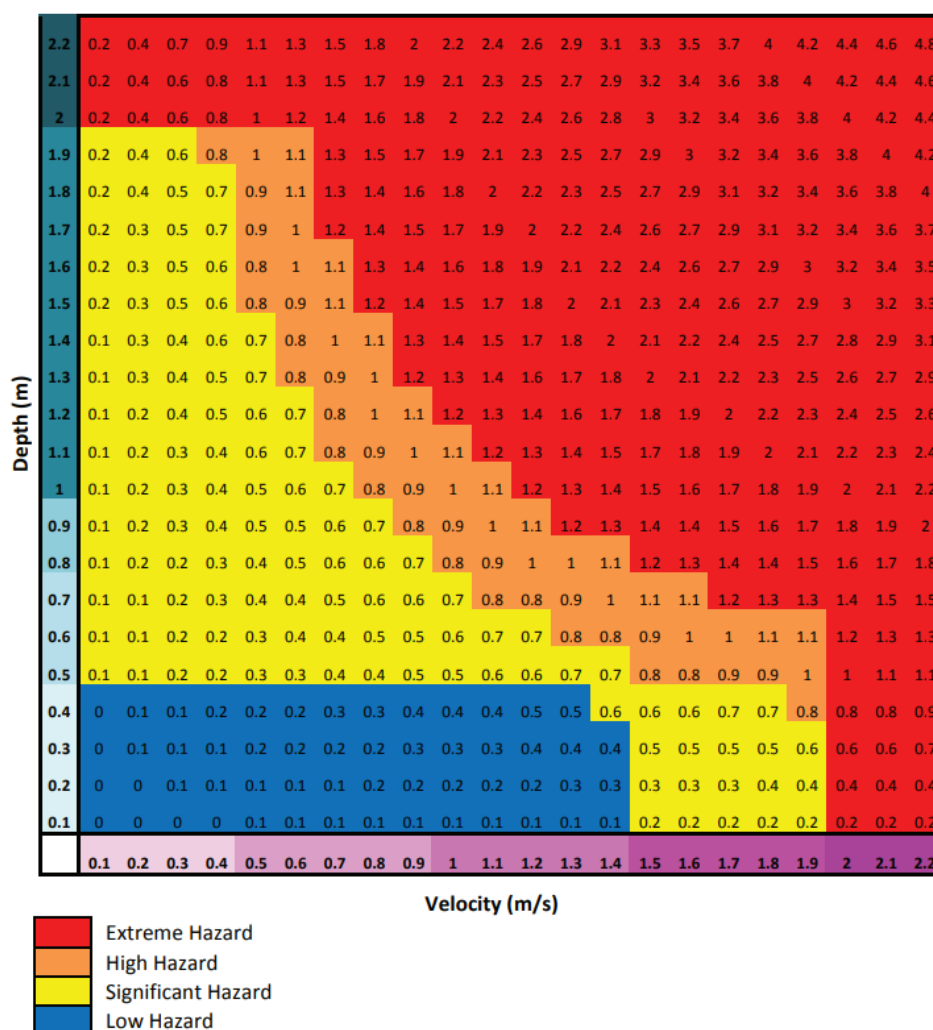


Figure 9-2 QRA Hazard Level Categorisation (QRA, 2012)

9.3 CULVERT VOLUME CAPACITY ASSESSMENT

The 1D TUFLOW ESTRY engine produces results which present how much volume within the culvert is filled with floodwater. Figure 9-3 and Figure 9-4 present at which event the culverts available volume is exceeded

These results can act as an indicator to the culvert capacity under differing design events. While the volume of a culvert may be full under the simulated conditions, more flow may be facilitated dependent on other hydraulic factors such as upstream and downstream water levels, or culvert slope. The percentage full results can indicate locations where further investigations into upgrades may be beneficial.

It should be noted that for the Upper Nogoia River (Clermont) region, culverts less than 1.5 m in width are modelled as 100% blocked in accordance with the ARR Blockage Assessment. Despite this, most culverts are modelled to be reaching capacity even for the 50% AEP event due to the widespread nature of flooding. Upgrading culvert capacity for key flow paths or the regular clearance of blocked culverts should be considered as future mitigation measures.

Due to the locality of Middlemount being near the top of the catchment, most culverts are modelled to have available capacity up to the 2% AEP event, with several culverts with available capacity up to the PMF event.

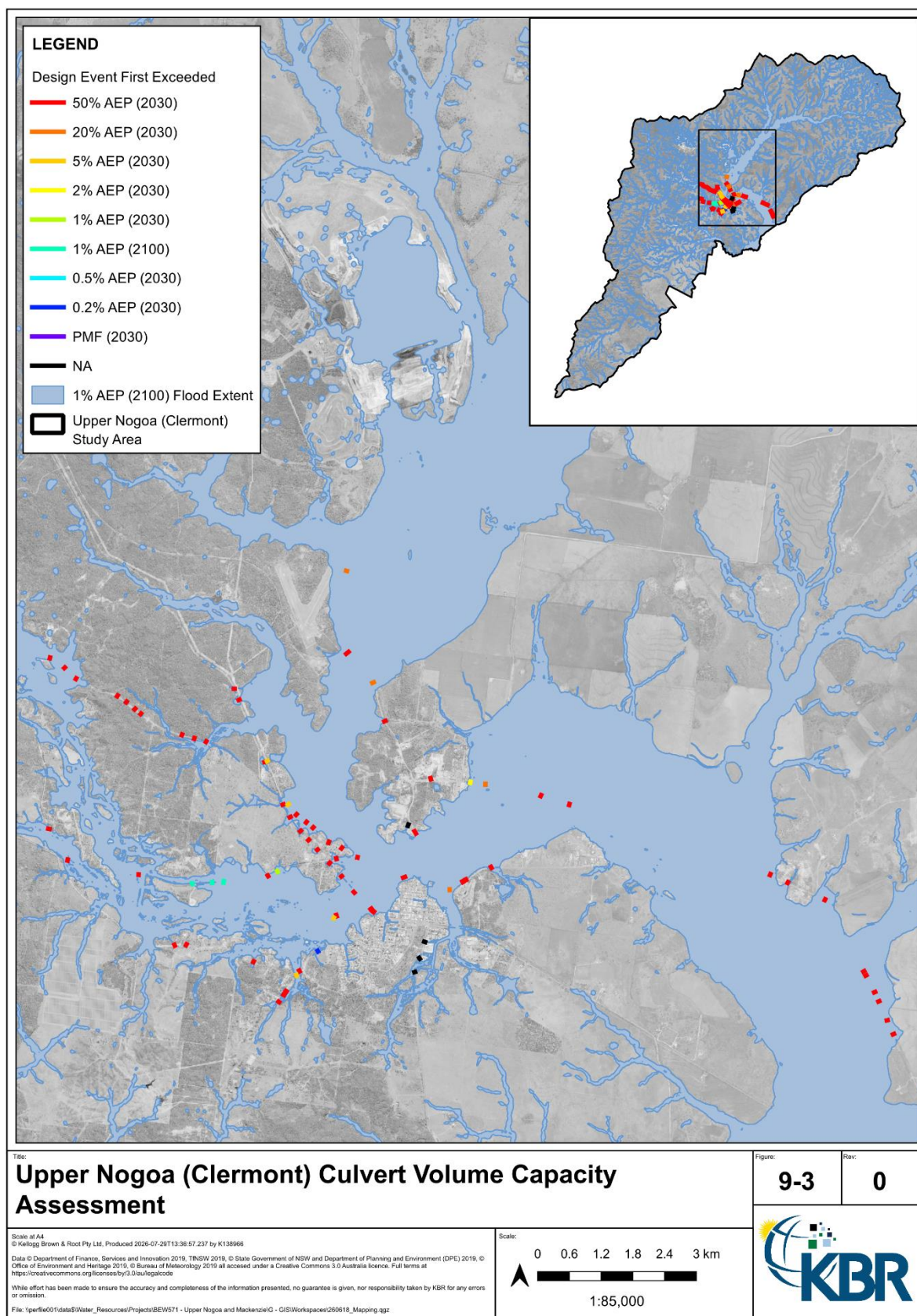


Figure 9-3 Upper Nogoa River (Clermont) Culvert Volume Capacity Assessment

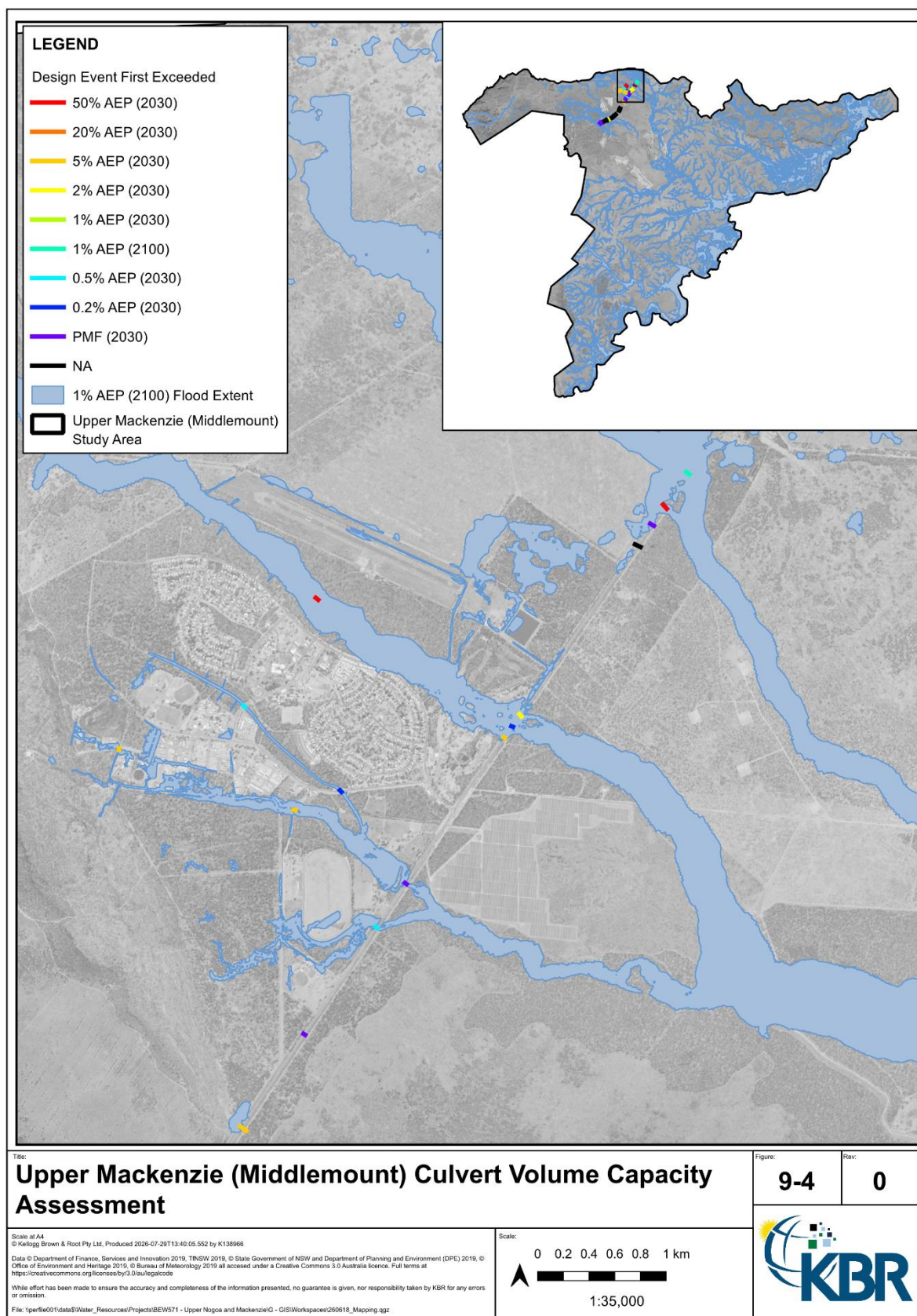


Figure 9-4 Upper Mackenzie River (Middlemount) Culvert Volume Capacity Assessment



10 Model Sensitivity Analyses

Sensitivity analyses are undertaken to assess the relative influence and uncertainty associated with certain model parameters on both the magnitude and extent of the simulated flood events. A sensitivity analysis is completed by adjusting model parameters within reasonable bounds and assessing their impact on the modelled outcomes. In addition to the model parameter sensitivity analysis, a future climate change sensitivity was completed as a part of this assessment.

10.1 MODEL PARAMETER SENSITIVITY ANALYSIS

The following model parameter sensitivity scenarios were simulated through the calibrated and validated models:

- 20% increase of Manning's 'n' hydraulic roughness values globally,
- 20% decrease of Manning's 'n' hydraulic roughness values globally,
- Application of 100% blockage factors to cross-drainage culverts, and
- Removal of all cross-drainage culvert blockage factors.

Peak flood level difference mapping between each sensitivity scenario and the baseline conditions has been undertaken on the 1% AEP event.

10.1.1 Manning's 'n' Hydraulic Roughness Sensitivity Assessment

As part of this sensitivity assessment, the Manning's 'n' values for the various surface types (as detailed in Table 5-2), while established as part of the model calibration and validation process, have been increased and decreased by 20% to assess the impact on flood behaviour across the study area. Peak flood level difference mapping between the roughness sensitivity scenarios and the baseline conditions has been undertaken on the 1% AEP event and presented in Figure 10-1 to Figure 10-4.

The holistic decrease in hydraulic roughness allows runoff to move more 'freely' across the study areas, resulting in generally improved catchment response times and higher velocities with reductions in peak flood levels across the major flow paths. Changes in flood behaviour are less noticeable in the minor tributaries with larger reductions in peak flood levels noted within the major watercourses. Consequently, within flood storage areas (i.e. Theresa Creek Dam), an increase in peak flood levels is modelled as runoff accumulates quicker within these areas. Similarly flood waters will back up behind major cross drainage structures as they reach capacity.

The converse of the observations noted above are modelled when the hydraulic roughness values are increased.

10.1.2 Blockage Factor Sensitivity Assessment

As detailed in Table 8-10, 10-100% and 0-50% blockage factors have been applied to culverts and bridges for the Upper Nogoia River (Clermont) and Upper Mackenzie River (Middlemount) models in accordance with the ARR Blockage Assessment. To understand the model's sensitivity to either extremes of debris blockage or lack thereof, the application of 100% blockage and removal of all blockages has been modelled as part of this sensitivity assessment. The outcomes of this assessment have been presented in Figure 10-5 to Figure 10-8.

The blockage sensitivity assessment indicates that the modelling of the areas surrounding the Clermont and Middlemount townships are not very sensitive to the increase or decrease of culvert blockage. Within the Upper Nogoia River (Clermont) study area, the culverts are typically minor



structures drainage small tributaries so the influence of the increase or decrease in blockage factors are highly localised and typically within ± 100 mm in the 1% AEP event.

Within the Upper Mackenzie River (Middlemount) study area, eight (8) 2.13 m box culverts drain the channel cutting through the Middlemount Golf Course underneath the Dysart Middlemount Road. While the majority of the Upper Mackenzie River (Middlemount) study area is not largely affected by the increase or decrease of blockage factors, the blocking of this key bank of culverts results in notable increases in peak flood levels of up to 320 mm in the 1% AEP event, increasing the extent of the H2 to H4 road hazard. The extent of the increase in peak flood levels however is still largely contained to the immediate locality of the site and is modelled to present minimal risk to the township of Middlemount itself. Ensuring the maintenance and blockage clearance of this asset is noted to be critical in maintaining usability of this key road.

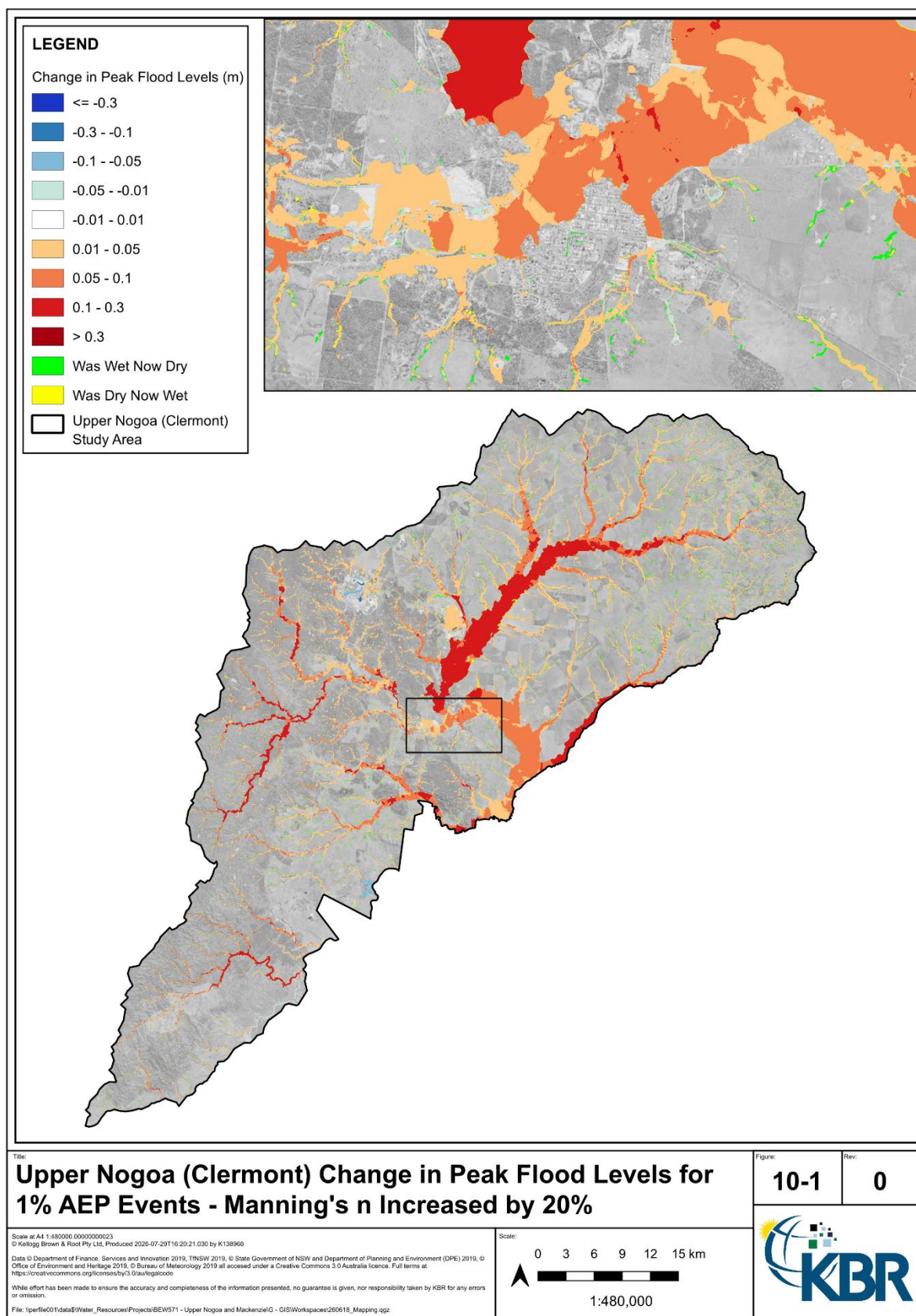


Figure 10-1 Upper Nogoia River (Clermont) Increased Manning's 'n' Sensitivity Assessment

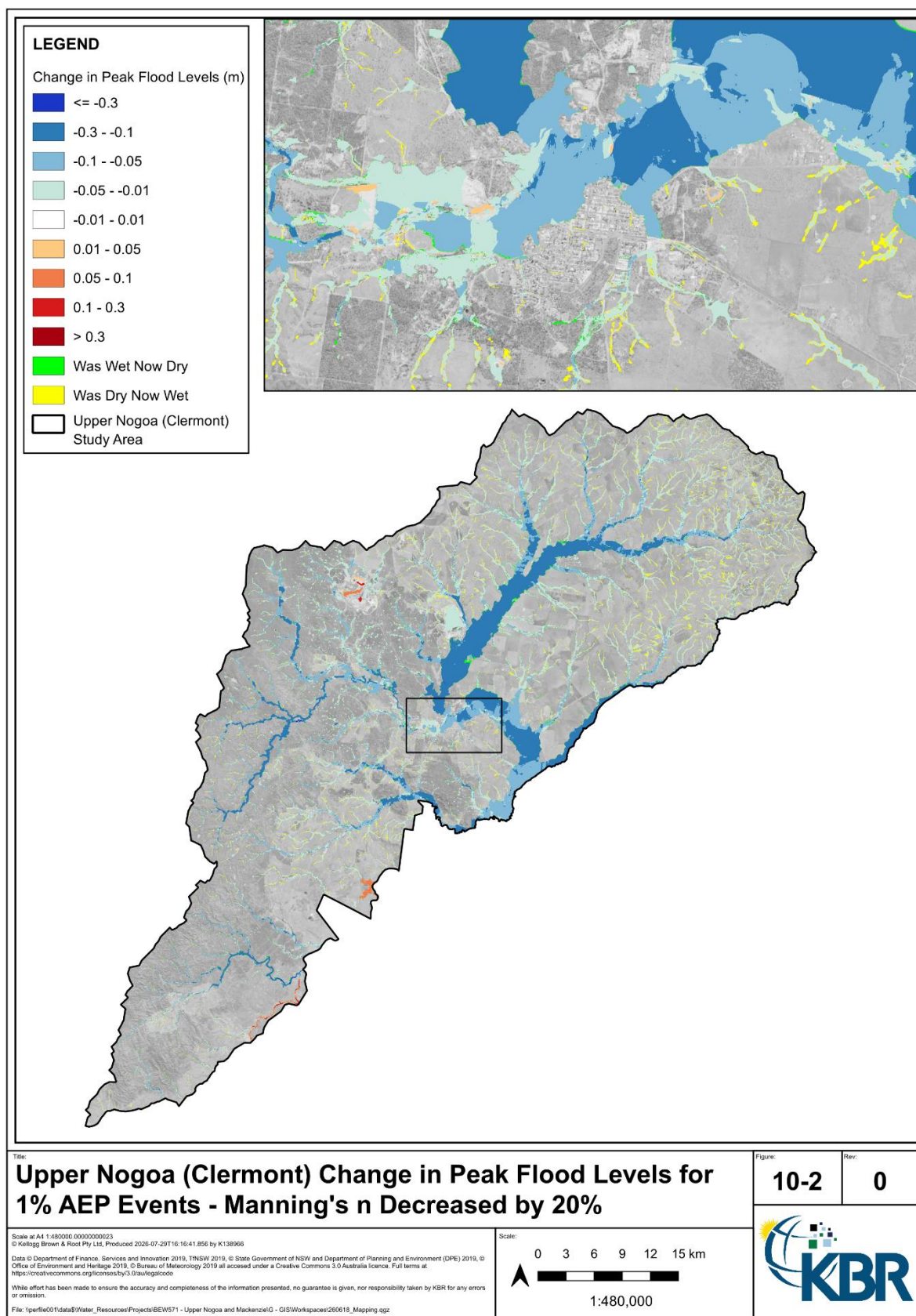


Figure 10-2 Upper Nogoia River (Clermont) Decreased Manning's 'n' Sensitivity Assessment

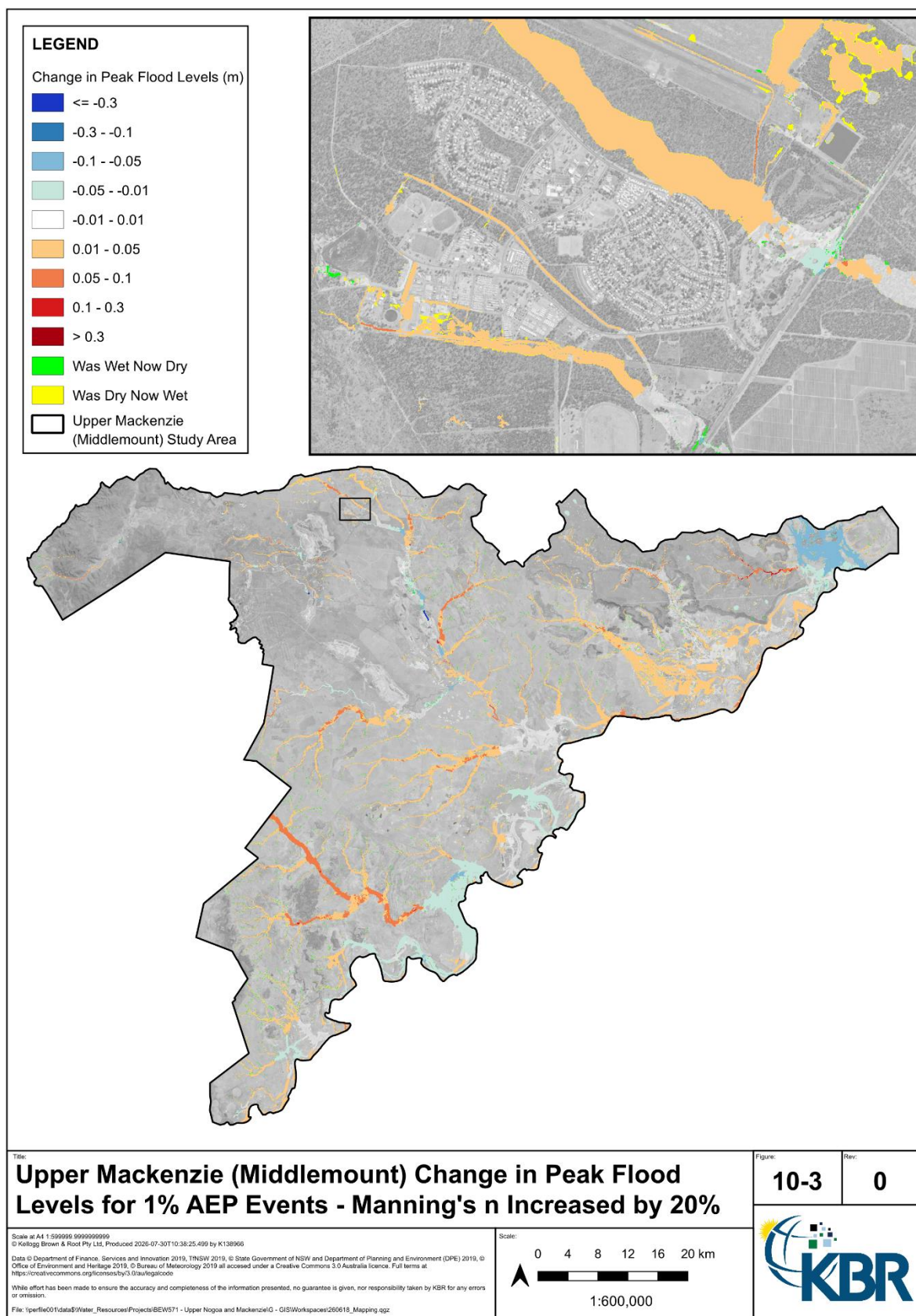


Figure 10-3 Upper Mackenzie River (Middlemount) Increased Manning's 'n' Sensitivity Assessment

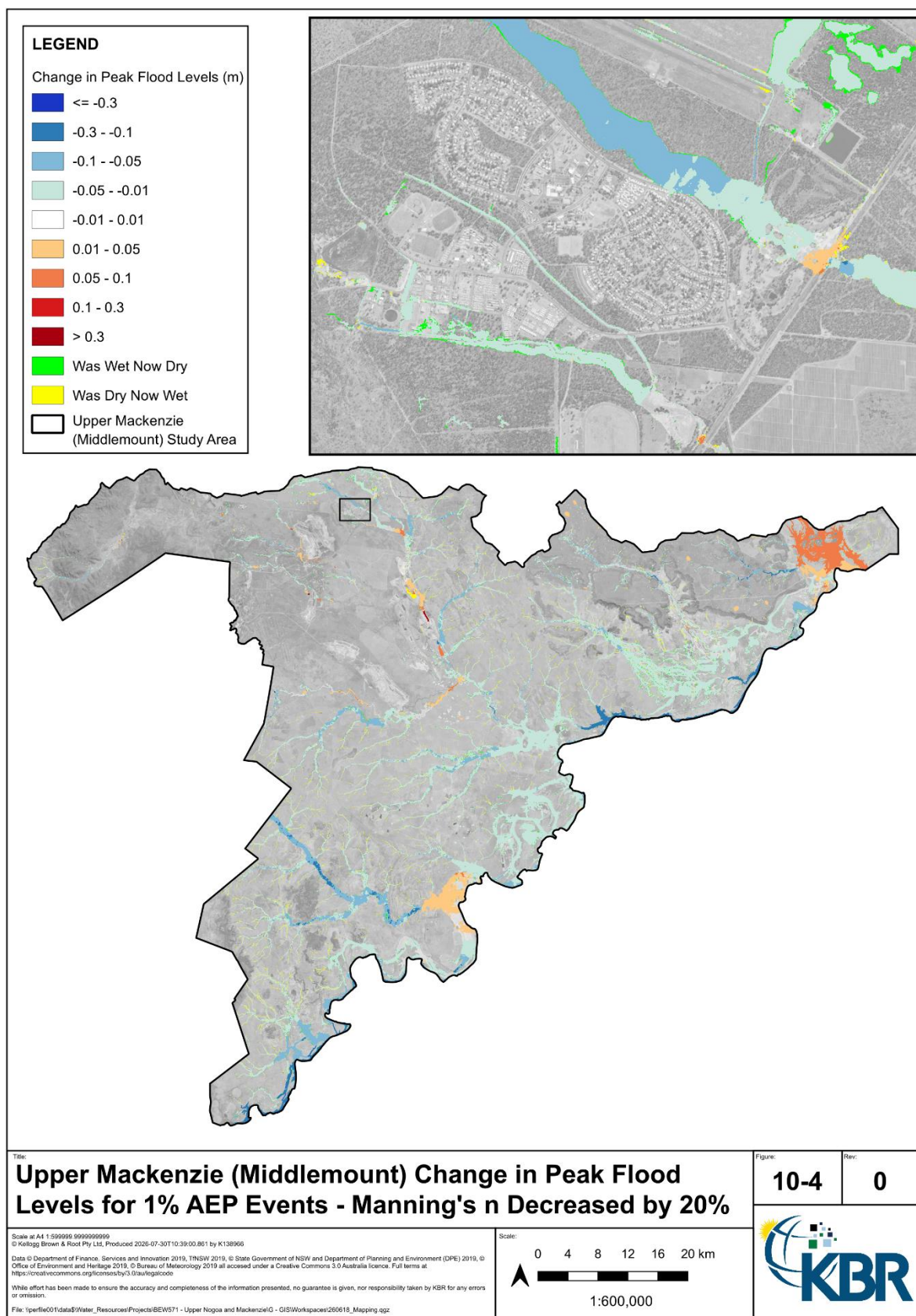


Figure 10-4 Upper Mackenzie River (Middlemount) Decreased Manning's 'n' Sensitivity Assessment

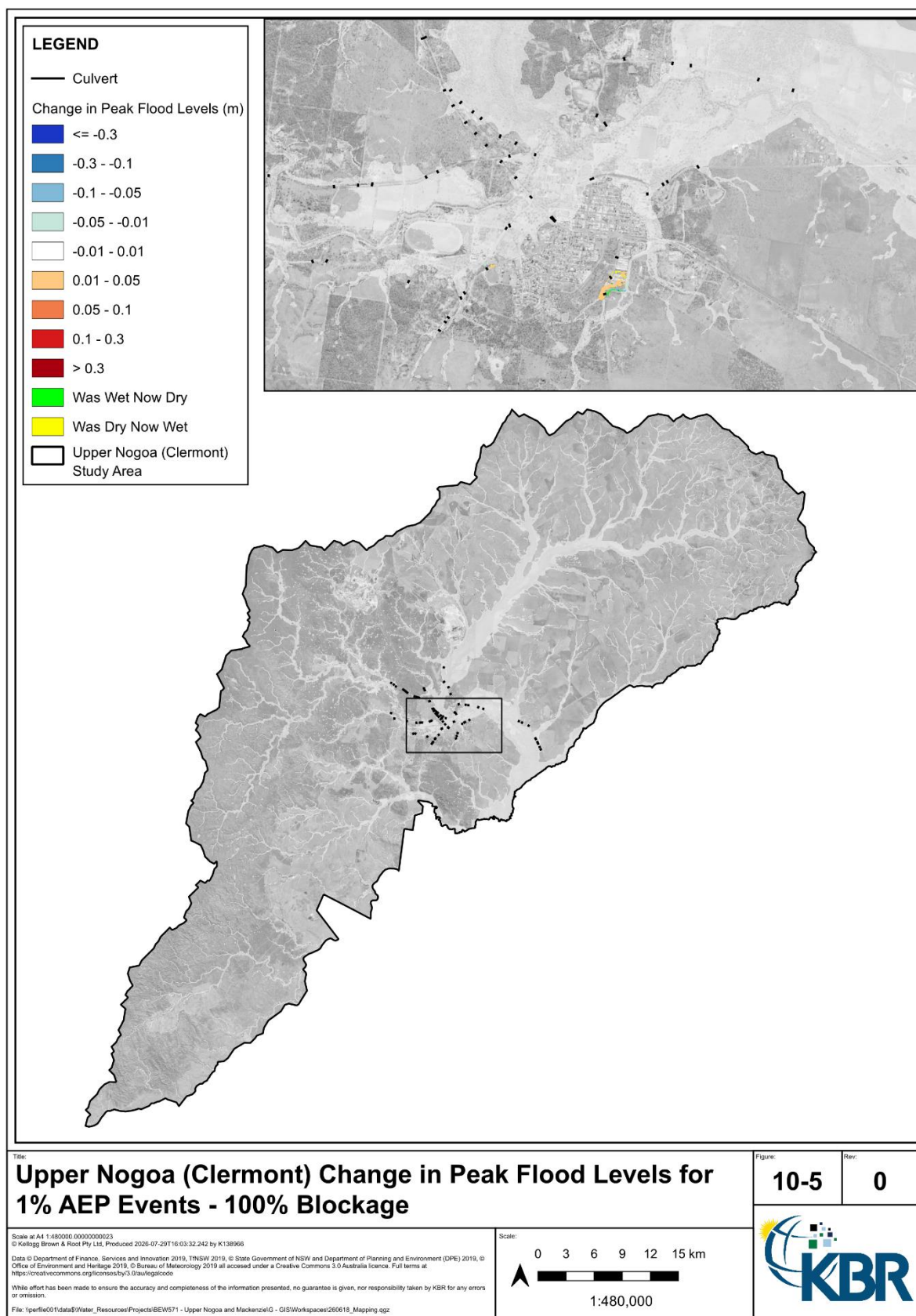


Figure 10-5 Upper Nogoa River (Clermont) 100% Blockage Sensitivity Assessment

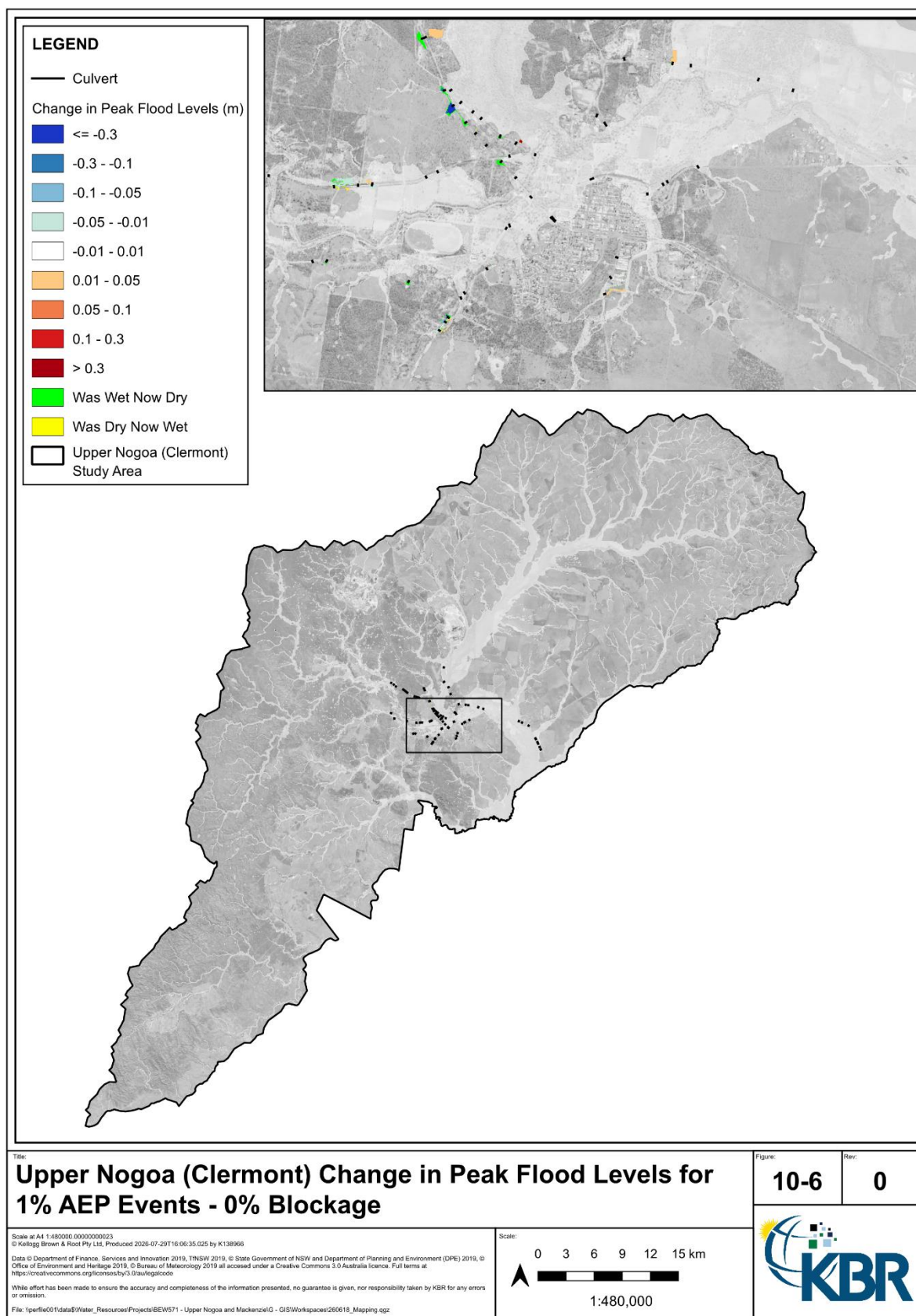


Figure 10-6 Upper Nogoia River (Clermont) 0% Blockage Sensitivity Assessment

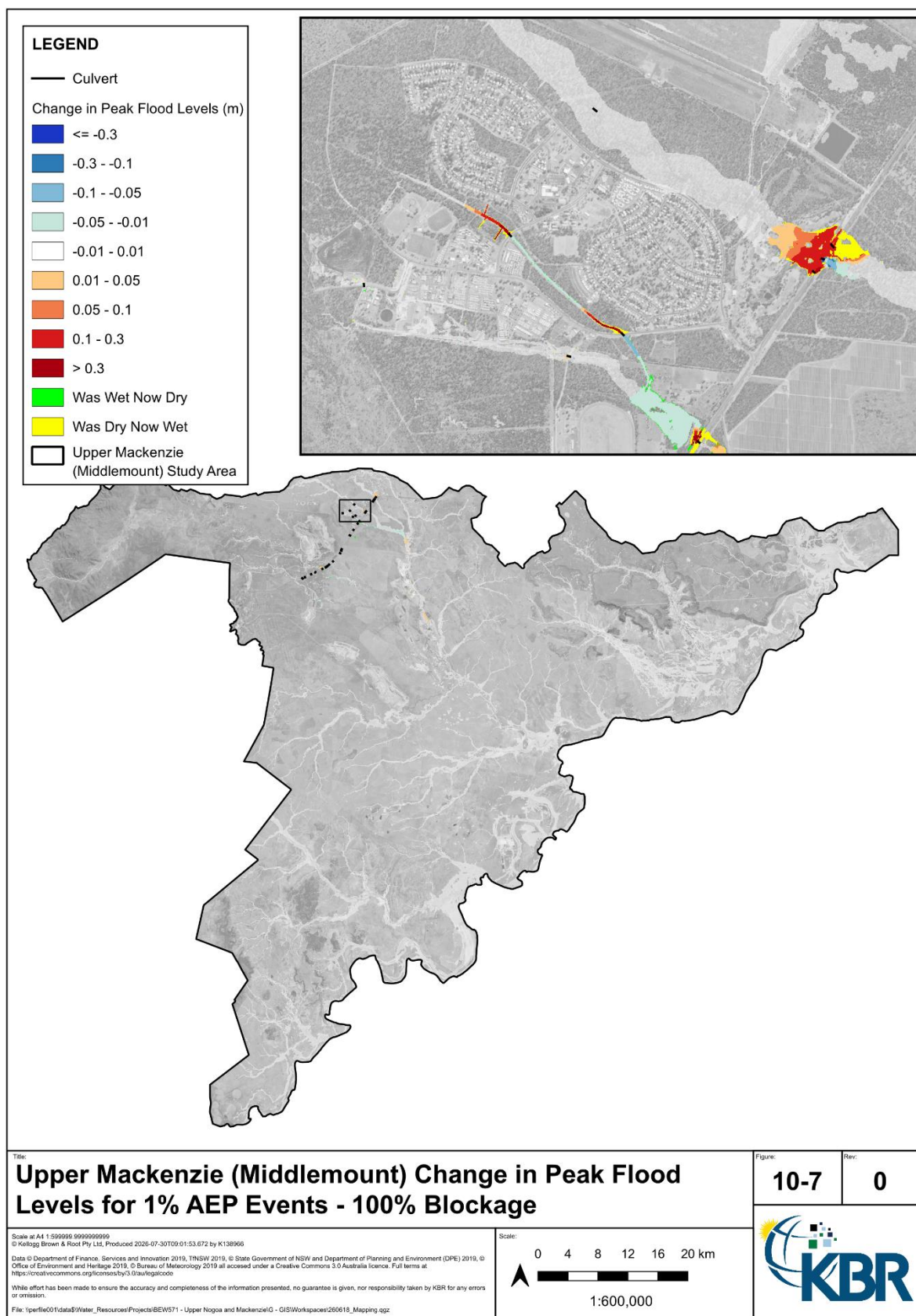


Figure 10-7 Upper Mackenzie River (Middlemount) 100% Blockage Sensitivity Assessment

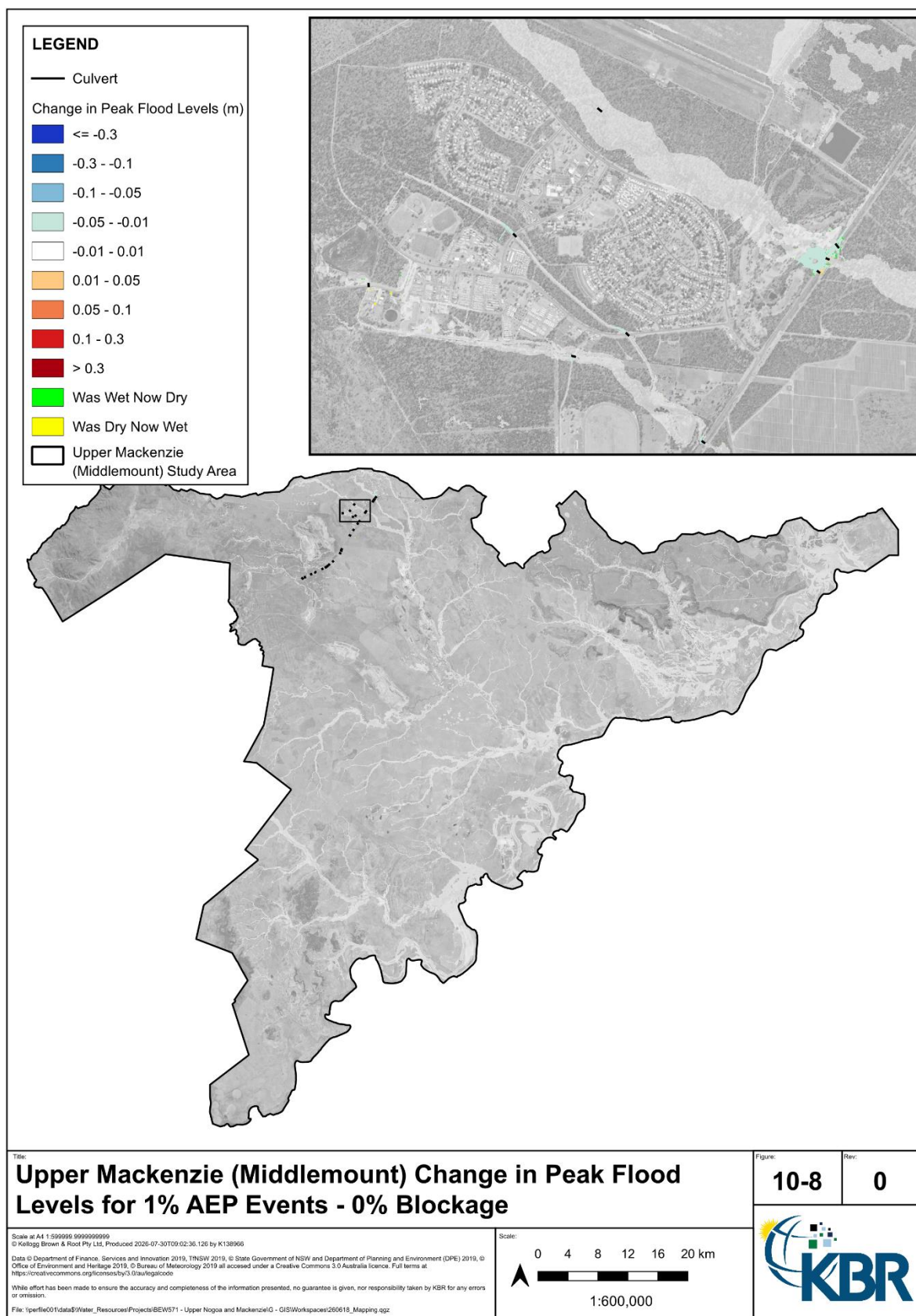


Figure 10-8 Upper Mackenzie River (Middlemount) 0% Blockage Sensitivity Assessment



10.2 FUTURE CLIMATE CHANGE ASSESSMENT

Following discussions with Council, the SSP2-4.5 scenario for the 2100 year horizon was adopted as the future climate scenario. The modelling of a future climate scenario provides insight into the sensitivity of the catchment and consequences to the community in relation to the changing climate.

Climate change is increasingly demonstrated to be a key planning requirement due to the potential long-term impacts posed to the community. In accordance with the latest ARR Version 4.2 guidelines, the relevant climate change factors have been extracted from the ARR Datahub and applied to the BoM 2016 IFDs (refer to Table 8-1 for 2030 and 2100 rainfall upscaling factors).

Peak flood level difference mapping between the future climate scenario and the baseline conditions has been undertaken on the 1% AEP event and presented in Figure 10-9 and Figure 10-10. Flood mapping for the 1% AEP future climate event has been included in Appendix C and Appendix D for the Upper Nogoia River (Clermont) and Upper Mackenzie River (Middlemount) study areas respectively.

The increase in applied rainfall has led to a broadscale increase in peak flood levels across the study areas. In particular, the major watercourses, lower reaches of the study areas, and locations where flood waters pond (e.g. upstream of hydraulic structures or flood storage locations) are indicative of larger increases as rainfall runoff accumulates and is unable to drain freely. While the majority of the study area maintains a similar flood extent between 2030 and 2100, notable increases in flood extent are modelled for Sandy Creek (immediately upstream of Clermont) and the Mackenzie River where the watercourse is braided. The increase in flood risk associated with the climate change should be considered for future development and planning policies.

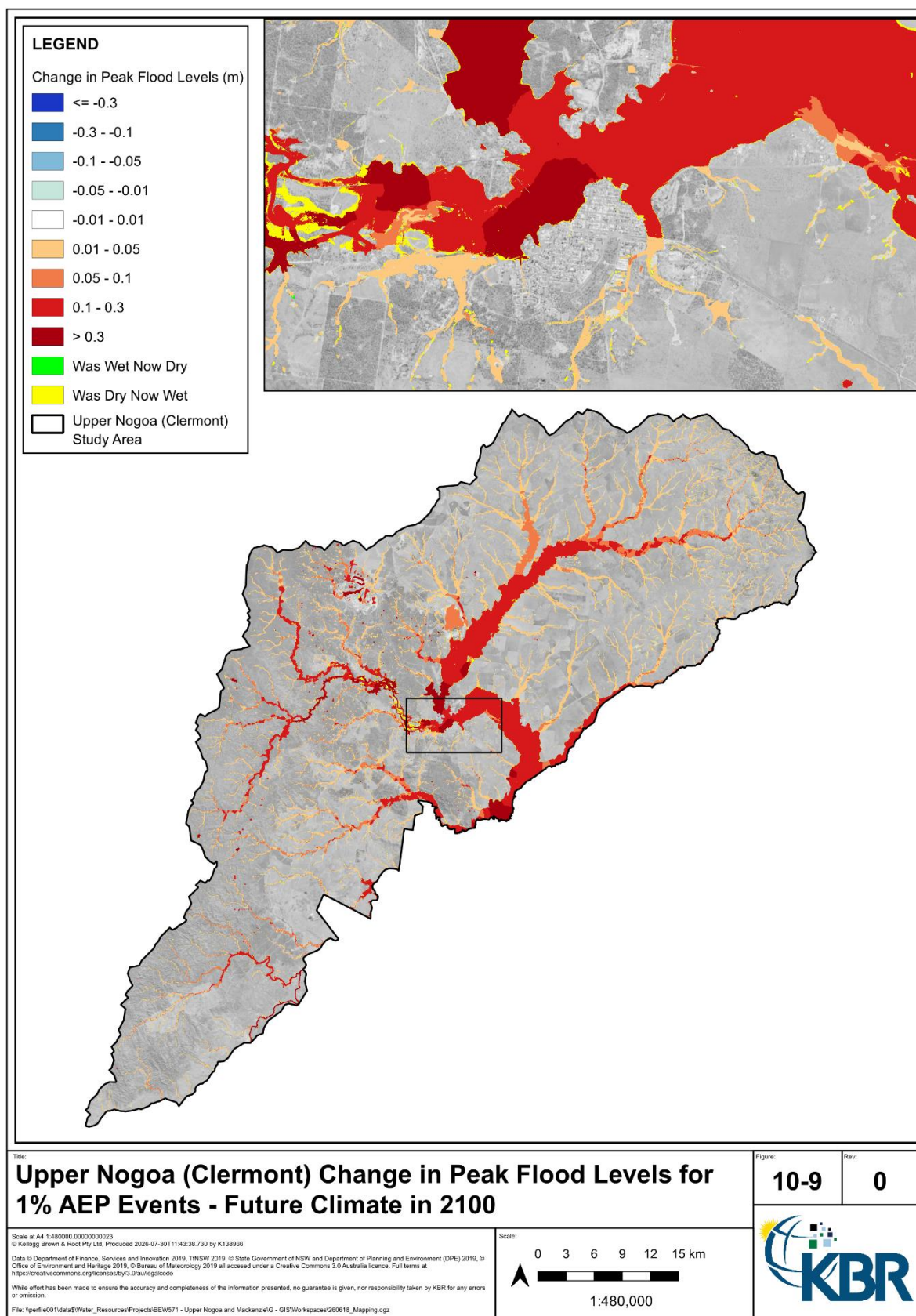


Figure 10-9 Upper Nogoia River (Clermont) 2100 Future Climate Sensitivity Assessment

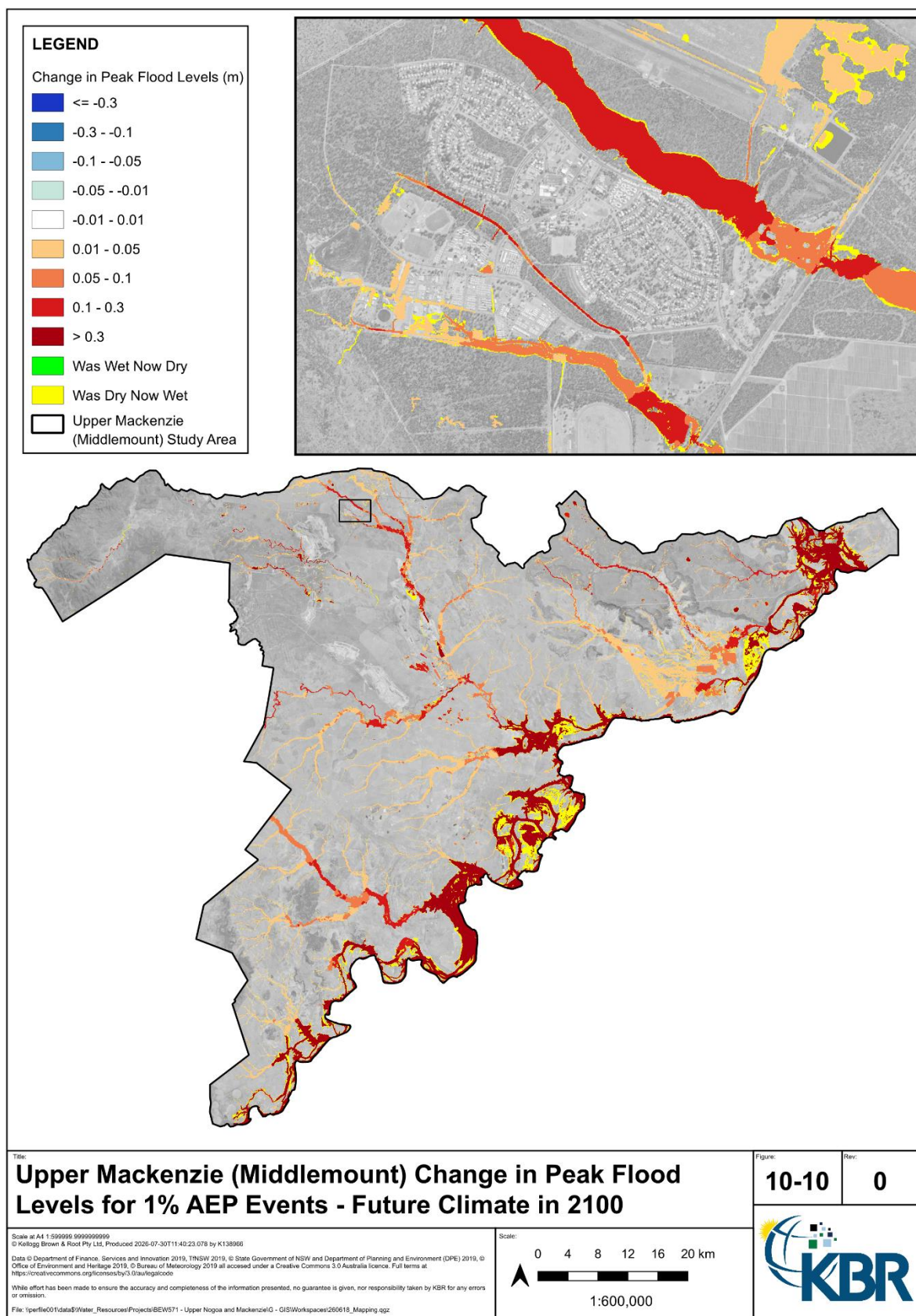


Figure 10-10 Upper Mackenzie River (Middlemount) 2100 Future Climate Sensitivity Assessment



11 Information to Support Disaster Management

A key outcome of the study is to provide an improved understanding of flood behaviour to better inform the management of flood risk within Council's LGA. An assessment of the consequences of flooding on the community has been completed using the outcomes of the modelling.

11.1 FLOOD BEHAVIOUR OVERVIEW

Across the Upper Nogoa River and Upper Mackenzie River catchments, flooding associated with the breakout of major riverine flows has been identified to be the dominant flooding mechanism. Due to the township of Middlemount being located towards the top of the catchment, minimal direct flood risk is modelled with flood waters largely contained within the banks of the watercourses running adjacent to the town.

On the other hand, the township of Clermont is impacted by the breakout flows from Sandy Creek with widespread inundation across the town modelled beyond the 20% AEP event. All key access roads are modelled to be overtopped, cutting off the town even during events as frequent as the 50% AEP event (refer to Section 11.2 for further information).

11.2 CLERMONT PROPERTY AFFECTATION AND STREAM GAUGE ASSESSMENT

A high-level assessment of flood risk to properties has been undertaken using the outcomes of the Upper Nogoa River (Clermont) modelling. Properties were identified using the publicly available Queensland Government DNRMMRRD cadastre layer. For smaller properties, the centroid of the cadastre was used to represent the building. For larger, rural properties, the lot centroid was manually moved to the building location. The design event for which each property becomes flood affected has been identified.

Additionally, the modelled peak stage, level, and rate of rise have been extracted at the Sandy Creek at Clermont (130207A) stream gauge for each modelled design event. The rate of rise at the Sandy Creek at Clermont stream gauge ranges from 38 hours (50% AEP event) to 10 hours (PMF event), with an approximate one (1) day rate of rise modelled for most design event magnitudes. While the development of a flood warning and evacuation system is not within the scope of works for this study, this information can provide a strong basis for future studies. The outcomes of this assessment have been presented in Table 11-1 and Figure 11-1.

Table 11-1 Clermont Property Affection Assessment Outcomes

Event	Gauge Peak Stage (m)	Level (m AHD)	Rate of Rise (Hours)	Number of Properties Affected
50% AEP (2030)	2.20	264.66	38.50	5
20% AEP (2030)	4.21	266.67	29.50	18
5% AEP (2030)	6.39	268.85	27.50	85
2% AEP (2030)	8.06	270.52	21.00	132
1% AEP (2030)	9.05	271.51	21.00	175
1% AEP (2100)	9.63	272.09	20.25	202
0.5% AEP (2030)	9.73	272.19	21.00	247
0.2% AEP (2030)	9.98	272.44	20.00	251
PMF (2030)	12.66	275.12	10.25	721

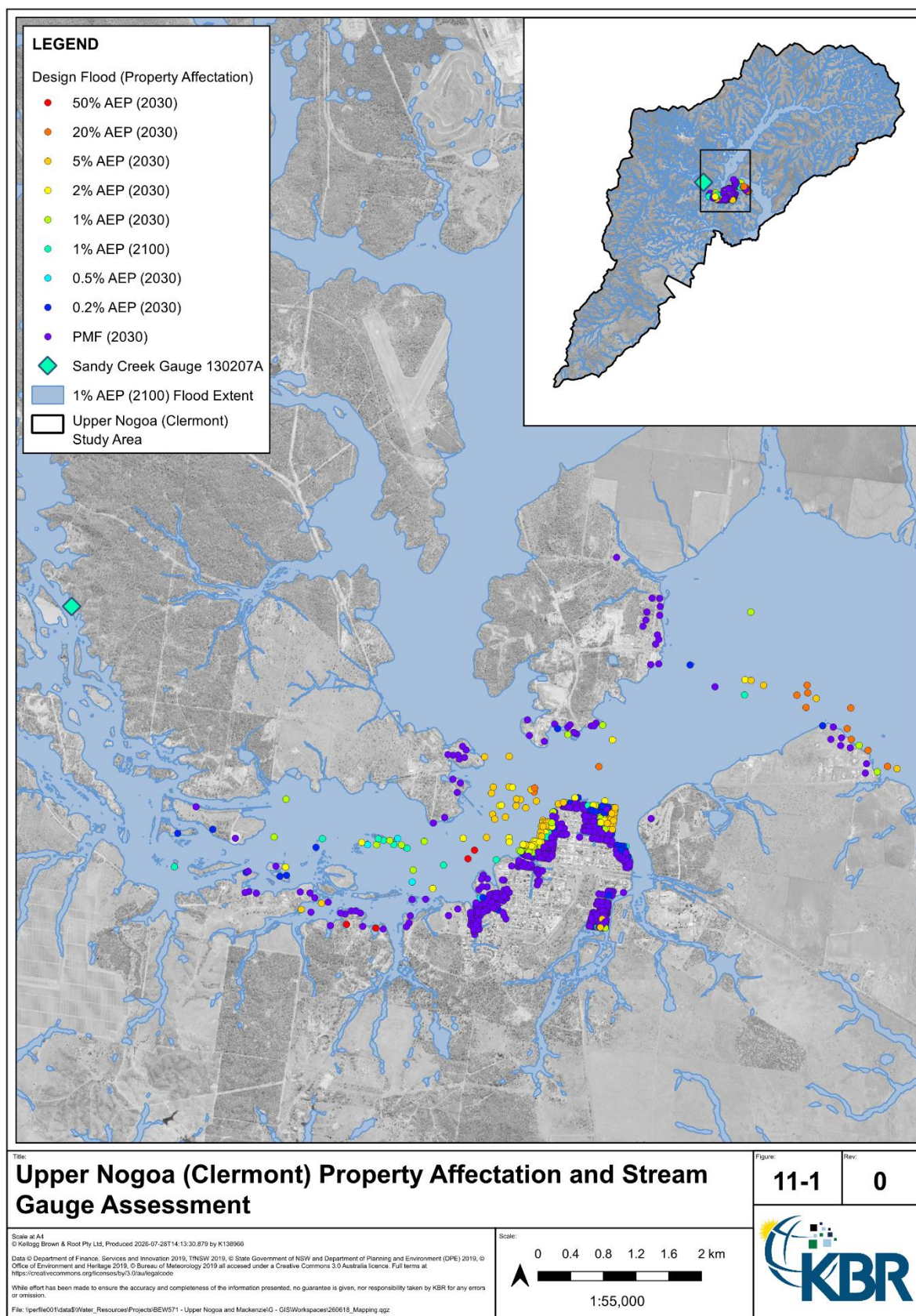


Figure 11-1 Upper Nogoia River (Clermont) Property Affection and Stream Gauge Assessment



11.3 ROAD OVERTOPPING ANALYSIS

A high-level analysis of the impact of flood waters to vehicles and roads has been undertaken across the range of design events simulated. As the representation of roads is dependent on the quality of the underlying topographic data, this analysis has only been undertaken for the areas where high-resolution LiDAR was available (i.e. the townships of Clermont and Middelmount).

The road layer provided by Council was segmented at each intersection with a different road, resulting in a total of 103 unique roads and 289 road segments for the Clermont region. Similarly, a total of 51 unique roads and 137 road segments for the Middelmount region were identified.

Roads with flood depths greater than 150 mm have been identified as being cutoff. While no prescriptive depth criteria are stated within relevant guidelines or standards, research has indicated that 150 mm depth of water is sufficient to float small vehicles (G P Smith, B D Modra, T A Tucker, and R J Cox, 2017). This also corresponds with the common kerb height and has been selected as the criteria for which a roadway has been completely inundated and therefore cut off.

Across each road segment, the maximum post-processed flood depth and time of duration of inundation above 150 mm were sampled.

The outcomes of the road overtopping analyses have been mapped in Figure 11-2 to Figure 11-4 for the Upper Nogoa River (Clermont) study area and Figure 11-5 to Figure 11-7 for the Upper Mackenzie River (Middelmount) study area. A summary of the number and proportion of roads cut off in each AEP event is presented in Table 11-2. A summary of the average roadway duration of inundation above 150 mm for the identified critical events has been presented in Table 11-3.

Table 11-2 Road Overtopping – Number of Road Segments Above 150 mm

Event	Upper Nogoa River (Clermont)	Upper Mackenzie River (Middelmount)
50% AEP (2030)	21 [7%]	1 [1%]
20% AEP (2030)	48 [17%]	1 [1%]
5% AEP (2030)	84 [29%]	6 [4%]
2% AEP (2030)	91 [31%]	7 [5%]
1% AEP (2030)	99 [34%]	9 [7%]
1% AEP (2100)	104 [36%]	10 [7%]
0.5% AEP (2030)	104 [36%]	10 [7%]
0.2% AEP (2030)	111 [38%]	10 [7%]
PMF (2030)	152 [53%]	112 [82%]

Table 11-3 Road Duration of Inundation– Average Duration of Road Segments Inundated Above 150 mm

Event	Upper Nogoa River (Clermont)	Upper Mackenzie River (Middelmount)
50% AEP (2030)	18 hours	18 hours
20% AEP (2030)	17 hours	10 hours
5% AEP (2030)	17 hours	5 hours
2% AEP (2030)	18 hours	8 hours
1% AEP (2030)	18 hours	8 hours
1% AEP (2100)	19 hours	9 hours
0.5% AEP (2030)	18 hours	9 hours
0.2% AEP (2030)	19 hours	9 hours
PMF (2030)	17 hours	5 hours



From Clermont, the key roads out of the town to the east and west are modelled to be cut from the 50% AEP event. This is primarily due to the roads intersecting watercourses or being situated in close proximity of major waterways. Similarly, the key roads out of the town to the north and south are modelled to be cut from the 20% to 5% AEP events. The modelling indicates that the majority of roads are generally trafficable after 24 hours for a storm duration of 18 to 24 hours. As the elevated portion of the town of Clermont itself is free from flood affectation up to the PMF event, evacuation to higher ground and the establishment of dedicated flood evacuation centres should be considered for the purposes of emergency management.

All roads within the township of Middlemount have been modelled to be trafficable up to the 5% AEP event apart from Airstrip Road as it intersects the watercourse adjacent to the town. Airstrip Road connects the town to the airport and is identified to be cut off in the 50% AEP event with a duration of inundation above 150 mm of approximately 45 hours in the 1% AEP present day event (more than 50 hours in the 1% AEP future climate event). Improving the resilience of this road is recommended to provide safer vehicular access between the town and the airport.

Dysart Middlemount Road is the only access route into and out of Middlemount. The modelling indicates that this road is cut off in the 0.5% AEP event in the north easterly direction and only in the PMF event in the south westerly direction. However, as this road assessment is limited to the extent of high-resolution LiDAR, the trafficability of the road beyond the Middlemount Coal Mine and towards the intersection with the Fitzroy Developmental Road is unknown and cannot be recommended as a potential evacuation route without further detailed analysis.

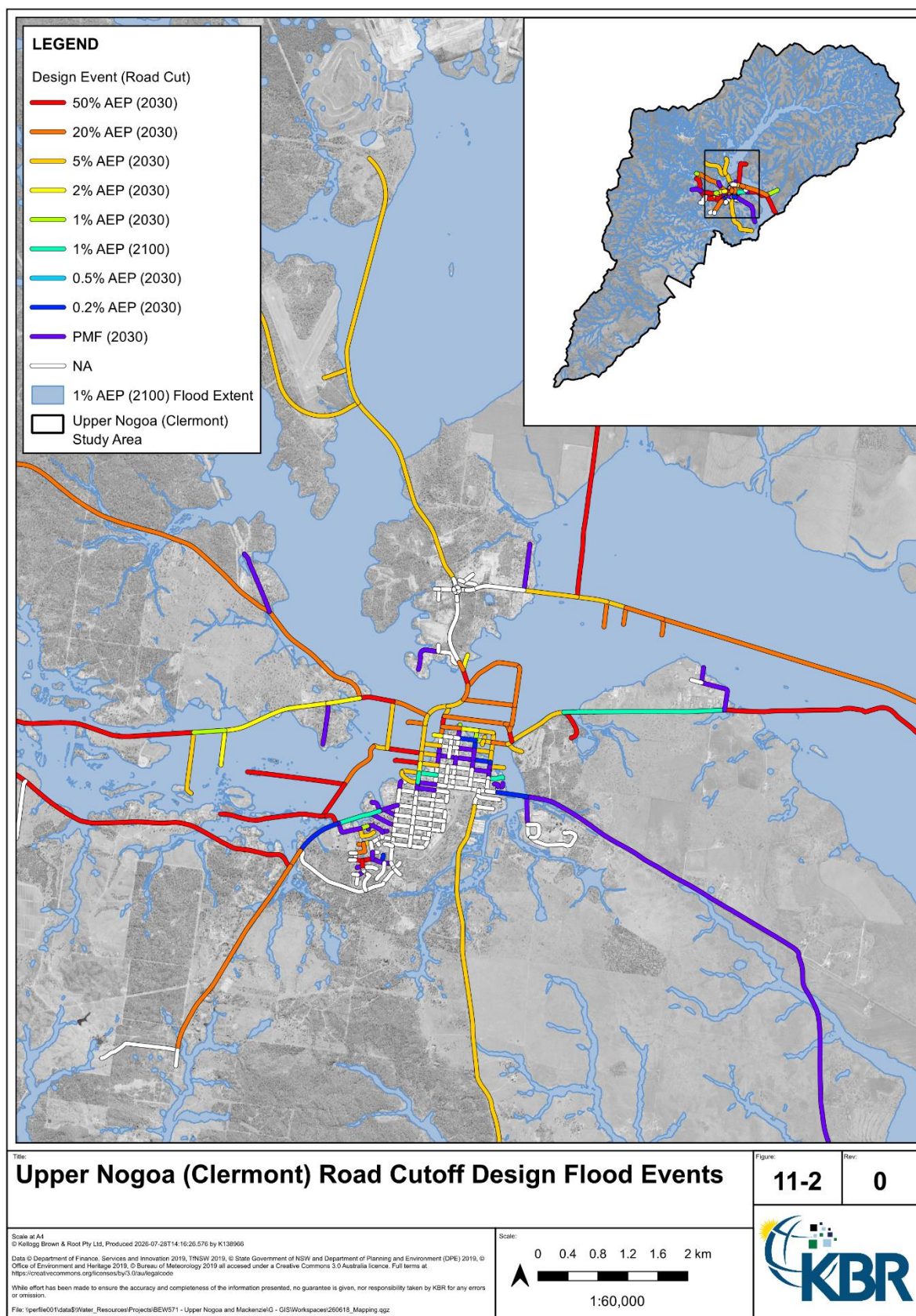


Figure 11-2 Upper Nogoia River (Clermont) Road Cutoff Outcomes

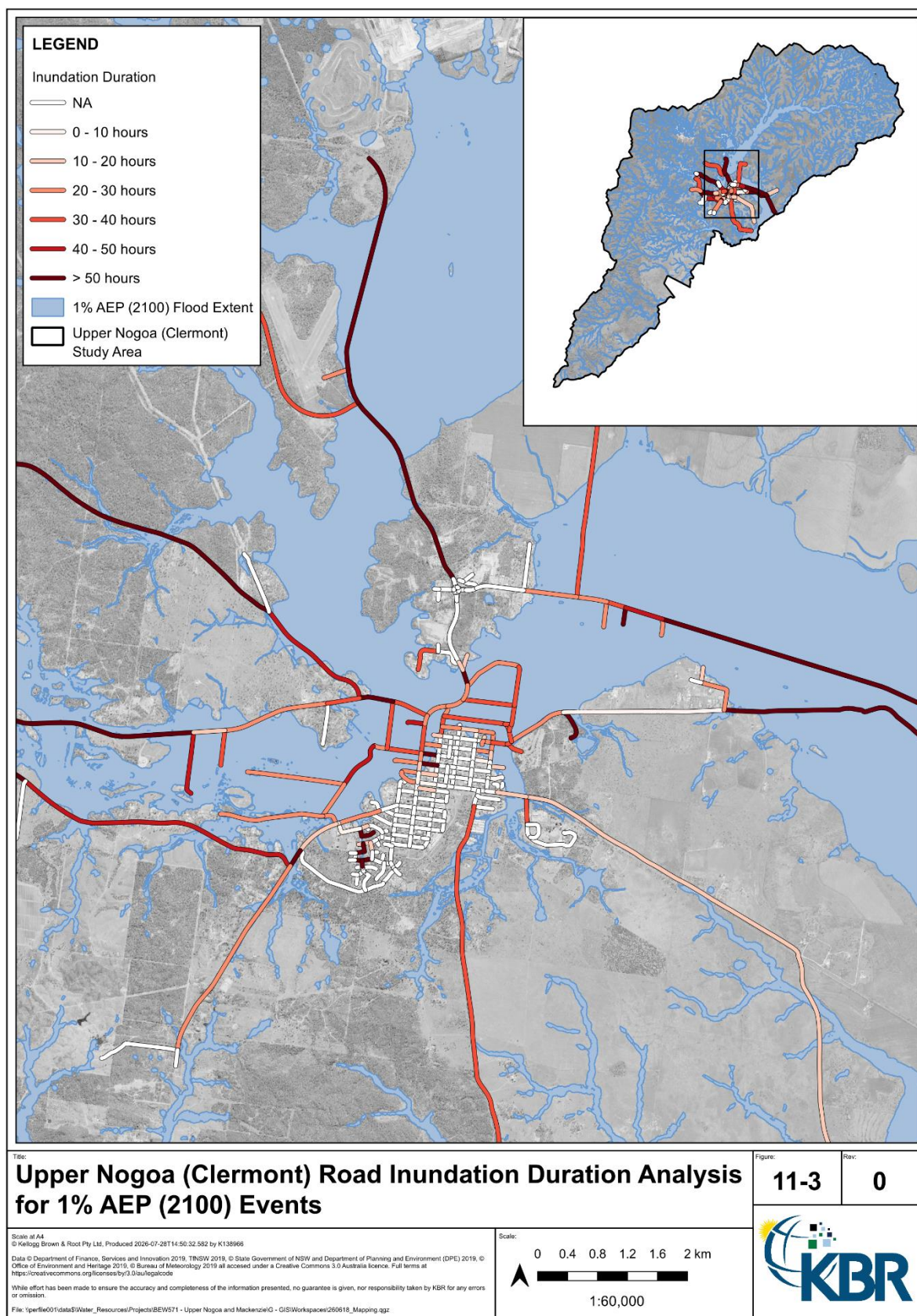


Figure 11-3 Upper Nogoia River (Clermont) Road Inundation Duration Analysis 1% AEP (2100) Event

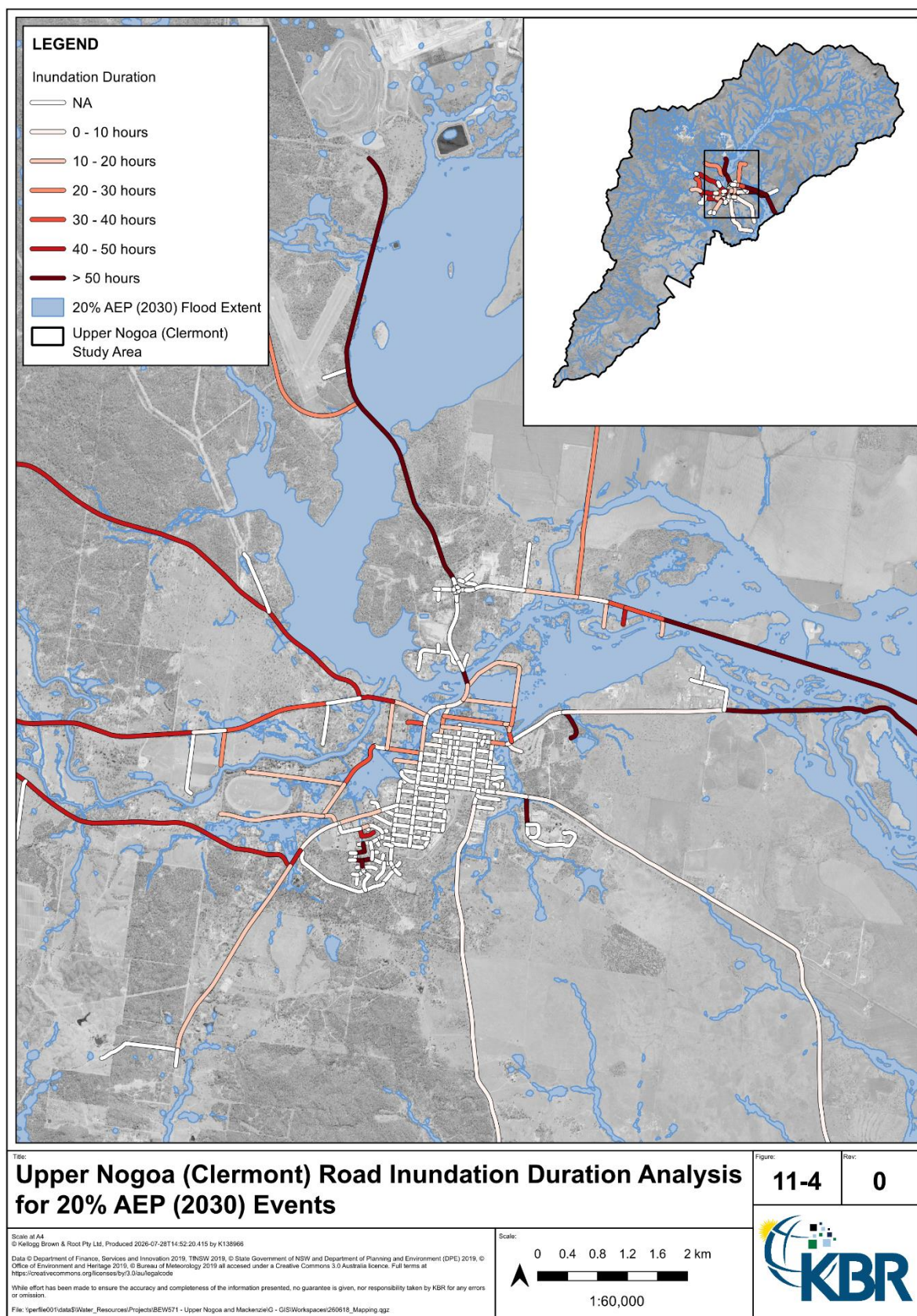


Figure 11-4 Upper Nogoia River (Clermont) Road Inundation Duration Analysis 20% AEP (2030) Event

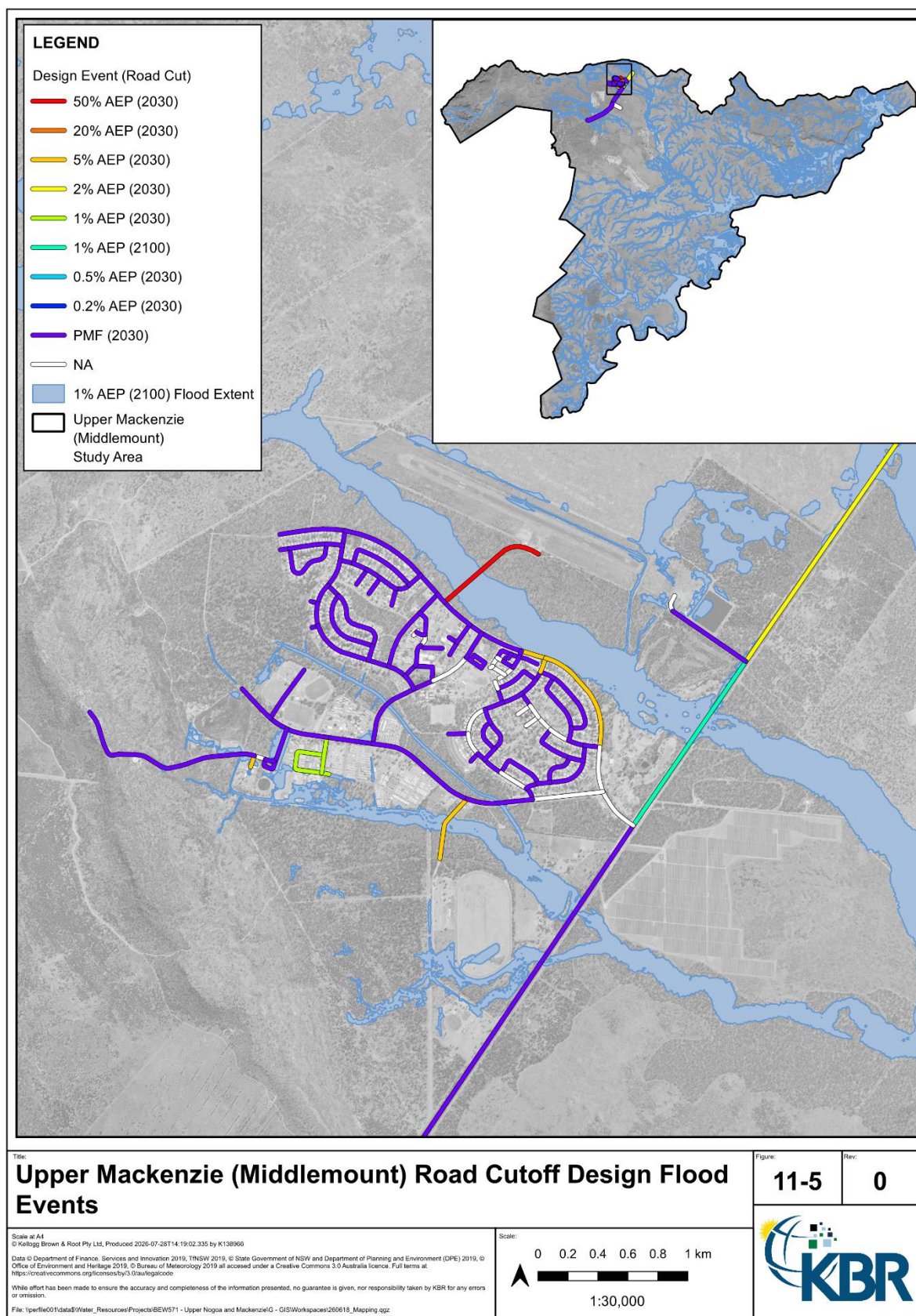


Figure 11-5 Upper Mackenzie River (Middlemount) Road Cutoff Outcomes

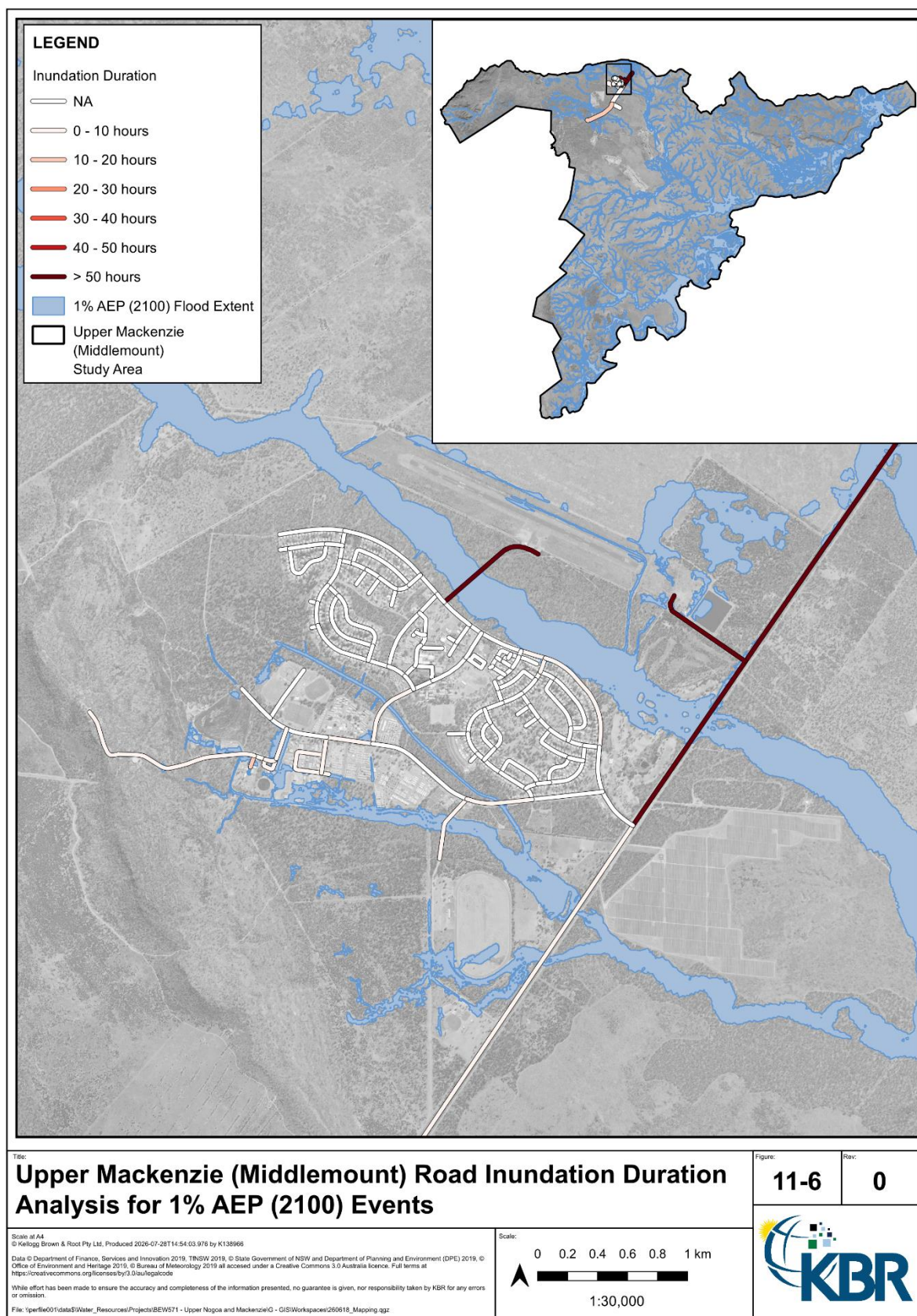


Figure 11-6 Upper Mackenzie River (Middlemount) Road Inundation Duration Analysis 1% AEP (2100) Event

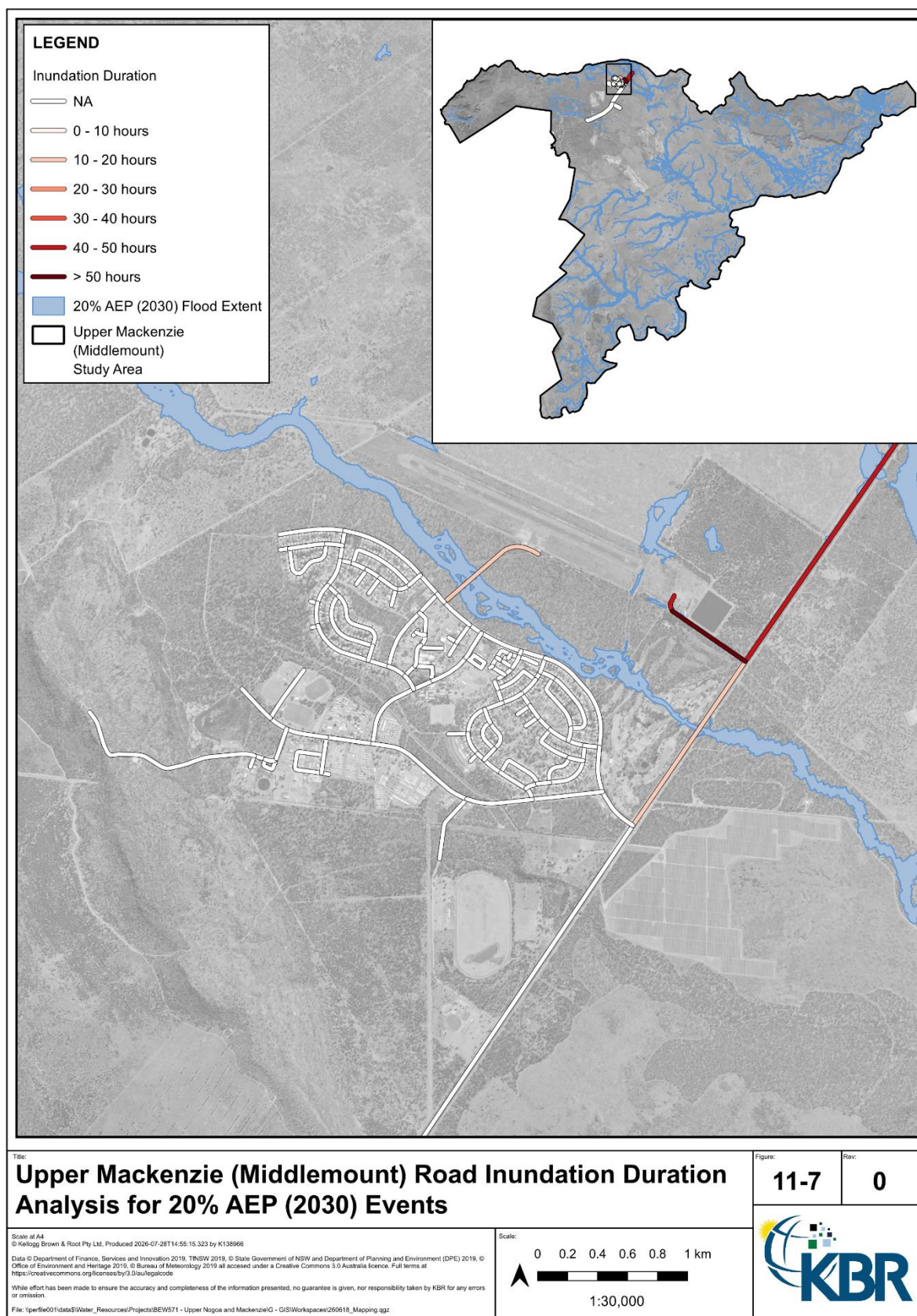


Figure 11-7 Upper Mackenzie River (Middlemount) Road Inundation Duration Analysis 20% AEP (2030) Event

11.4 FLOOD EMERGENCY RESPONSE CLASSIFICATION

KBR has completed the Flood Emergency Response Classification (FERC) of communities in accordance with the Australian Disaster Resilience Handbook – Flood Emergency Response Classification of the Floodplain (AIDR, 2017). The FERC system offers a structure method to classify and manage flood risk across Australia. This framework aims to enhance flood risk understanding and management by categorising areas based on their flooding characteristics, thereby aiding emergency services, planners, and communities in developing targeted strategies to mitigation and respond to flood events effectively.

The FERC system uses three (3) levels of classification (primary, secondary, and tertiary), each providing increasing detail about the flood risk and response requirements. Figure 11-8 presents the AIDR flow chart detailing the FERC definition process.

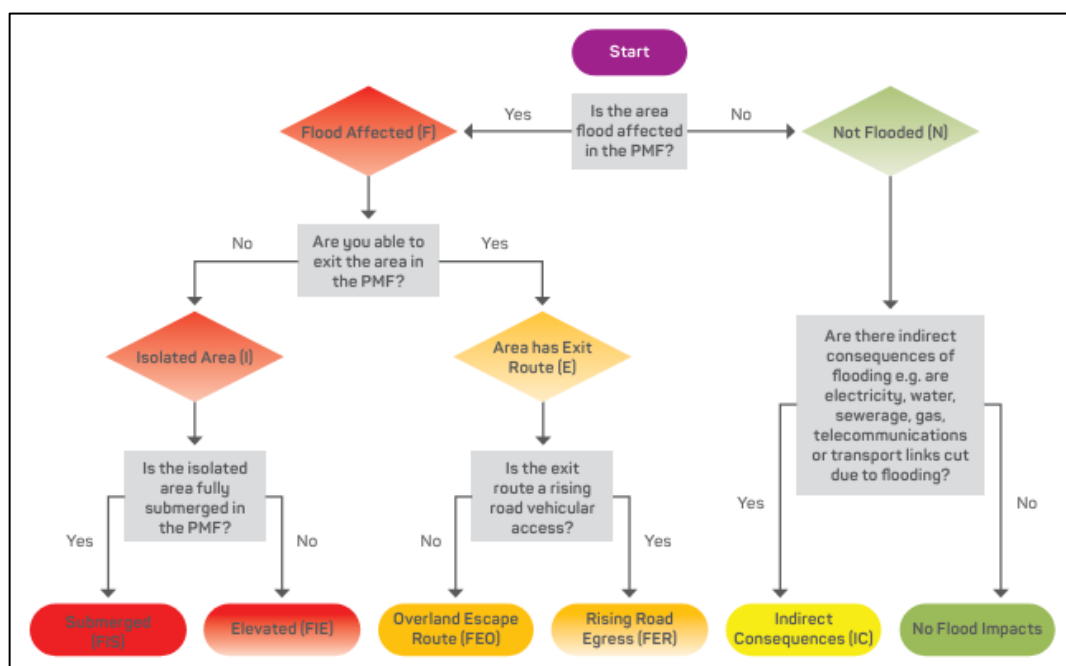


Figure 11-8 FERC System Process Flowchart

Each classification process has been summarised as follows:

- Flooded (F): The area is flooded in the PMF event.
 - Isolated (I): Areas isolated from community evacuation facilities by floodwater and/or impassable terrain. Likely to lose electricity, gas, water, sewerage, and telecommunications.
 - Submerged (S): Where all land in the isolated area is fully submerged.
 - Elevated (E): Where there is substantial elevated land in the isolated area above the flood.
 - Exit Route (E): Areas not isolated in the PMF event with an exit route to community evacuation facilities.
 - Overland Escape (O): Evacuation relies on escape routes that rise out of the floodplain.
 - Rising Road (R): Evacuation follows roads that rise out of the floodplain.
- Not Flooded (N): The area is not flooded in the PMF event.



- Indirect Consequence (IC): Areas not flooded but may lose services like electricity, gas, water, sewerage, telecommunications, and transport due to flooding elsewhere.
- Flood Free: Areas not affected by flooding or its indirect consequences.

The Flood Emergency Classification of communities was undertaken for the PMF event and centred upon the townships of Clermont and Middlemount. The FERC captures the full extent of flood risk and can be used to determine whether evacuation may be required and how it would be undertaken.

Both the townships of Clermont and Middlemount have been classified as FIE and FIS in the PMF event.

Clermont is situated adjacent to and south of Sandy Creek with minor tributaries traversing south to north on either side of the town. During the PMF event, the modelling indicates that the lower portions of the town closer to the creek become completely inundated as Sandy Creek breaks its banks. While parts of the town on higher ground are modelled to be free from flooding in the PMF event, the town itself becomes surrounded by floodwaters and cut off.

In a similar manner, the township of Middlemount is situated between two watercourses adjacent to the town. During the PMF event, the modelling indicates that floodwaters surround and inundate the town. As the town itself is situated on relatively higher ground, modelled flood depths for the PMF event are mostly shallow and less than 0.15 m in the southern portion of the town.

As both towns become isolated in the PMF event, vehicular evacuation outside of the town is anticipated to be difficult. However, as portions of both townships are elevated outside of the PMF event extent, shelter in place (where feasible) or the establishment of dedicated evacuation centres should be considered as part of future flood risk management studies.



12 Conclusion

The primary objective of this Study has been to understand the risk associated with flooding across past, existing, and future catchment and climatic conditions for the Upper Nogoa River and Upper Mackenzie River catchments within the Isaac Regional Council Local Government Area. The study has been completed in accordance with the Queensland Reconstruction Authority Flood Risk Management Program objectives and the latest Australian Rainfall and Runoff 2019 Version 4.2 guidelines. The outcomes of this assessment can inform decision making processes within Council as well as form the basis of later, more detailed studies.

At the onset of the Study, KBR completed an extensive data collection and review exercise to derive a suitable methodology for the scope of the Study. An initial community consultation process was established to inform the community of the Study and to ensure that the adopted methodology is suitable to meet the community's needs.

A coarser resolution regional TUFLOW model was developed to derive upstream inflows into the Upper Mackenzie River catchment model at Rileys Crossing. Two localised hydrologic and hydraulic TUFLOW direct rainfall models were developed covering the Upper Nogoa River (Clermont) and Upper Mackenzie River (Middlemount) catchments. The models were developed to include finer detail within the townships of Clermont and Middlemount supported by high-resolution LiDAR datasets.

All models were calibrated and validated to the January 2008 and December 2010 historical events. Due to the recency and relevance of the January 2026 event and availability of suitable anecdotal information, further calibration of the Upper Nogoa River (Clermont) model was undertaken. As a part of this process, clear limitations were identified with the inability to accurately represent the tailwater and subsequent backwatering phenomenon at the downstream end of the Mackenzie River within the defined scope of works for this study.

A series of model parameter sensitivity analyses was undertaken as well as a future climate assessment. High level information to support disaster management was subsequently prepared using the modelling outcomes from this study.



13 Recommendations

Following the completion of the Upper Nogoia and Mackenzie River Catchments Hydraulic Flood Study, the following recommendations are provided:

- The outputs from this Study can be used to inform a subsequent Flood Risk Management Study. The subsequent study should include a review of Council's planning policies.
- With the updated information around catchment response to flood events, Council can lead more informed discussions with emergency services in a more transparent and objective manner. Consultation with emergency services can help Council refine emergency response planning for their residents.
- In consideration of the strong calibration and validation of the Upper Nogoia River model to the January 2026 event, an assessment of historic disaster response is recommended for future flood risk management.
- Establishment of dedicated evacuation centres is recommended within the elevated regions outside of the PMF event within the townships of Clermont and Middlemount.
- Development of a flood warning system for the township of Clermont is recommended using the outcomes of the property affectation and stream gauge assessment.
- Further consideration of property floor levels is recommended for buildings within the PMF flood extent to better inform the understanding of above floor property impact. Additionally, the property floor level survey is a key input to a flood damages assessment that can be utilised to compare flood damage estimates of future mitigation options in subsequent studies.
- Continued maintenance of the existing rain gauges and stream gauges throughout the study area to minimise the data quality limitations encountered and discussed within this report.
- Investigation of potential culvert capacity upgrades at key flow paths to improve road trafficability and nuisance flooding should be considered as future mitigation measures.
- Regular clearing of blocked culverts and maintenance is recommended.
- Improving the resilience of Airstrip Road in Middlemount is recommended to provide safer vehicular access between the town and the airport.
- Collaboration and data sharing with mining operators within the study area to allow for the incorporation of high-quality datasets and information in future studies.
- Given the limitation of the modelling in the representation of the Mackenzie River beyond Bedford Weir, extension of the downstream model extent should be considered in conjunction with further rating curve analysis of the stream gauges along the Mackenzie River.



14 Limitations and Exclusions

This report and associated modelling contain but are not limited to the following limitations and exclusions:

- The purpose of this study is to reflect the high-level risk presented by flooding within the study area. For site specific information and understanding, further detailed modelling should be undertaken. Due to the scope of the study being a LGA wide assessment, the adopted parameters are established in accordance with a catchment-wide basis.
- All hydrologic and hydraulic modelling has been completed in accordance with the ARR Version 4.2 guidelines. The design event modelling component of the study has assumed the year 2030 for the SSP 2-4.5 scenario to be established as the present day conditions. All future studies should take into consideration the latest guidelines at the time of undertaking.
- All modelling has been undertaken using the best available topographic datasets available to KBR at the commencement of the study. The noted accuracy of these datasets must be taken into consideration in comparison to surveyed levels and noting the cumulative effect of inaccuracies within the base topographic datasets. Outside of the townships of Clermont and Middlesbrough, the utilisation of the photogrammetry and SRTM datasets may potentially compromise the level of detail in those regions.
- The downstream boundary on the Mackenzie River has been represented using a free flow HQ boundary in lieu of available gauged information or significant extension of the model domain. This representation is not able to accurately model the backwatering effects of the Mackenzie River up to Bedford Weir.
- Coincident flooding of the Mackenzie River and the Isaac River has not been assessed as a part of this Study.
- The culvert capacity and road overtopping analyses has been undertaken only for the areas with high-resolution LiDAR data.



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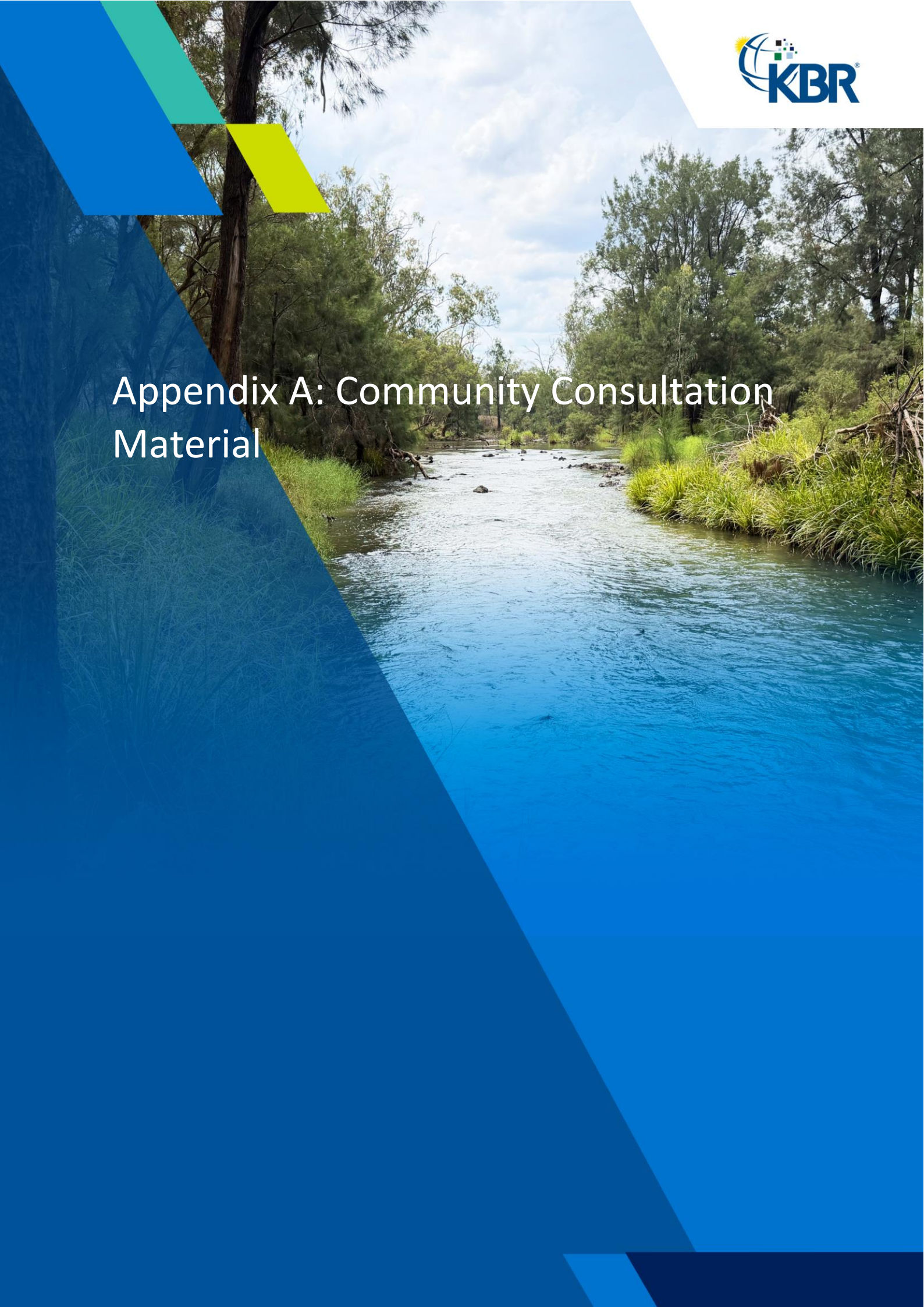


McKenzie N. J., Hook J., Interpretations of the Atlas of Australian Soils, 1992.

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Bradley J. N., Hydraulics of Bridge Waterways, FHWA, 1978.

Chow., Open Channel Hydraulics, 1959.

The background of the page is a photograph of a river flowing through a lush, green landscape. The river is in the foreground, with its surface reflecting the sky and surrounding trees. The banks are covered in dense vegetation, including tall grasses and various trees. The sky is blue with some white clouds. On the left side of the image, there are several overlapping geometric shapes in shades of blue and yellow, creating a modern, abstract design element.

Appendix A: Community Consultation Material

14 November 2025

[Owner Name]
[Owner Address]
[Town, State, Post Code]

Dear Sir/ Madam

RE REQUEST FOR FLOOD INFORMATION - UPPER NOGOA AND MACKENZIE FLOOD STUDY

Isaac Regional Council (Council) has recently commenced development of a Flood Study for the Upper Nogoa and Mackenzie Catchments within our local government area. You are receiving this letter as a property owner of land located in the study area of the flood study.

About the Flood Study

Council has engaged engineering consultants KBR to prepare the flood study, which is being funded with support from the Queensland Resilience Authority program, *Disaster Recovery Funding Arrangements: Flood Risk Management*.

The flood study focuses on understanding flood hazards across the study area under existing and projected climate conditions for several key rainfall events. The results of the study will provide a better understanding of the flood risk posed to property and people and will support the improved management of these risks in the future.

The study was commissioned in October 2025 and is currently in the data collection stage. Development of the flood study will take approximately eight months and will involve public consultation, during which stakeholders and landowners will be provided with project updates and the opportunity to comment on findings. Council and KBR will be undertaking site visits throughout the study area during November.

How can you help?

Did you know that you can help Council with our flood planning? As a landholder in the study area, Council is seeking any information you may have about historic flood events throughout the study area.

Specifically, we would love to hear from you if you took any photos, made a flood marker, or have a rain gauge that recorded flooding within the study area. This kind of information will help by providing inputs into modelling to ensure that the calibration of our flood modelling is as accurate as possible.

If you have access to any information that you believe may be able to assist, you are encouraged to contact Council via:

- **Completing an online survey** via Council's Speak Up Community Engagement platform accessible via visiting <https://speakup.isaac.qld.gov.au/> and clicking 'Upper Nogoa and Mackenzie River Catchment Flood Study'
- **Email** at Planning.Environment@isaac.qld.gov.au
- **Telephone** on 1300 472 227.
- If you would like to discuss your experience in-person please contact the project team via the above methods to arrange an appointment.

Further information including FAQs, can be viewed online at <https://speakup.isaac.qld.gov.au/> or by visiting the Flood Studies section on Council's website at <https://www.isaac.qld.gov.au/Residents/Planning-and-Development/Flood-Studies/Public-Consultation>.

Included with this correspondence is a Fact Sheet regarding the flood study and a flyer on *How to Record a Flood Marker*, which we encourage you to read to support Council and the community's ongoing knowledge and understanding of flood risk and disaster management. Any information that you can provide regarding the impacts of flooding following a flood event will support Council and emergency services to better manage future responses.

For more information, please contact Council's Planning and Environment Department on 1300 ISAAC (1300 47 2227) or via Planning.Environment@isaac.qld.gov.au.

Yours sincerely



Michael St Clair
Manager Planning and Environment
(On behalf of Cale Dendle, Chief Executive Officer)

FACT SHEET: UPPER NOGOA / MACKENZIE RIVER CATCHMENTS FLOOD STUDY

Introduction

Council has engaged engineering consultants KBR to prepare the Upper Nogoa and Mackenzie River Catchment Flood Study which is being funded with support from the Queensland Resilience Authority program, '*Disaster Recovery Funding Arrangements: Flood Risk Management*'.

The primary objective of this Flood Study is to define the flood behaviour under historical, existing, and future conditions within the catchment study areas for a full range of design flood events. The study will provide information on modelled flood levels and depths, velocities and flows. The flood study will provide flood hazard mapping that will assist disaster management and land use planning.

Key Points

- The study will update the hydrological model (where rain falls) then develop and calibrate a hydraulic model (how water moves).
- This is the first hydraulic study that focuses on riverine flooding in the rural parts of the flood study area. The towns of Clermont and Middelmount, as well as Theresa Creek Dam, have been the subject of earlier studies and are not part of this study.
- The study includes the upper catchment of the Nogoa River with its major tributaries of Theresa Creek, Sandy Creek and Wolfgang Creek.
- The study includes the upper catchment of the Mackenzie River with its tributaries: Oaky Creek, Roper Creek, Cooroora Creek and Honeycombe Creek.
- The study will model various flood events including 5%, 2%, 1%, 0.5%, 0.1% Annual Exceedance Probability (AEP) and Probable Maximum Flood (PMF) event.
- The study will meet best practice requirements and will incorporate relevant State Government standards and guidelines, utilising the latest available data from the Bureau of Meteorology, including considerations of climate change.
- The study is anticipated to be completed by July 2026.

How can you help?

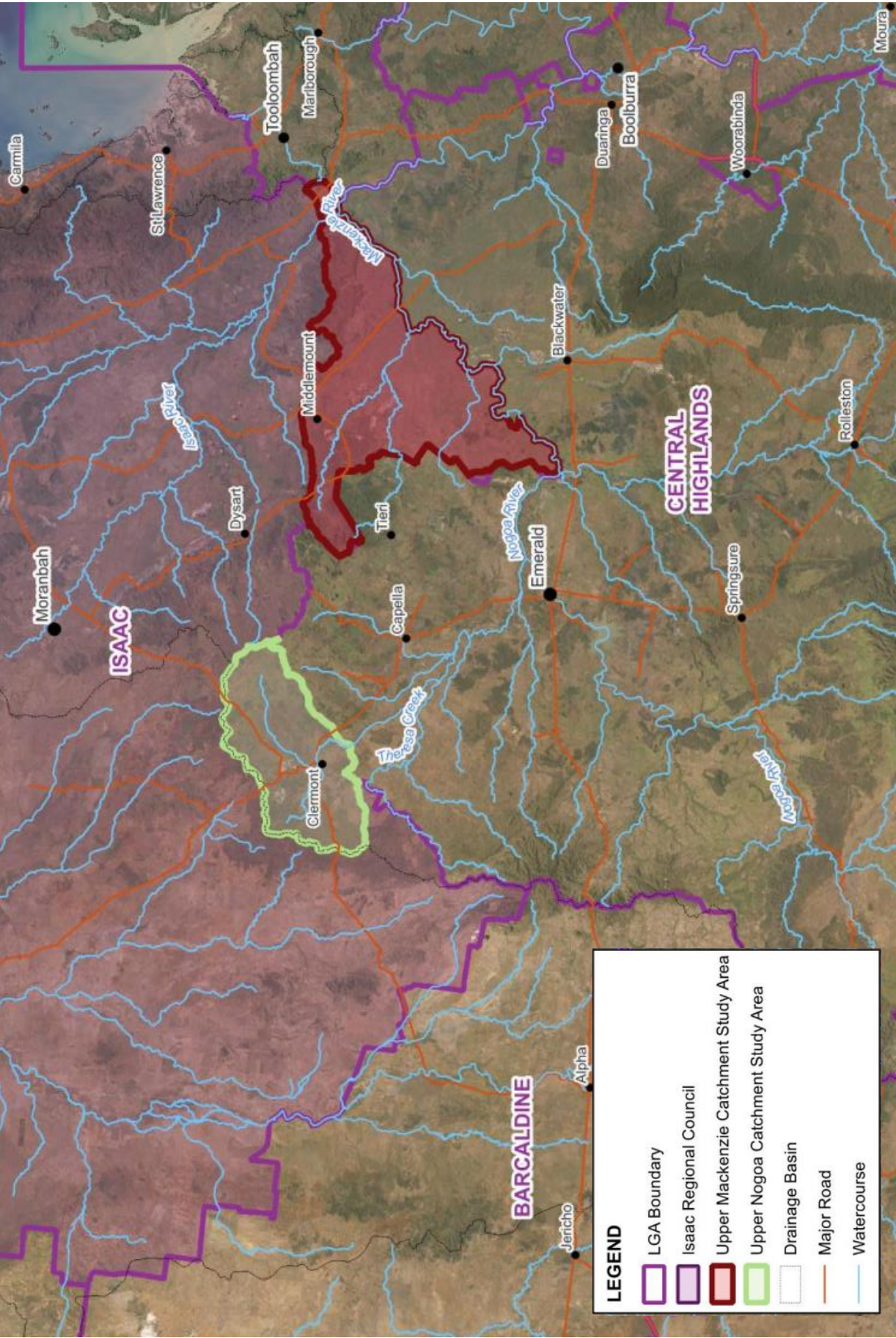
Did you know that you can help Council with flood planning? Council is seeking any information that property owners or stakeholders may have about historic flood events throughout the study area.

Specifically, we would love to hear from you if you took any photos, made a flood marker, or have a rain gauge that recorded flooding within the study area. This kind of information will help by providing inputs into modelling to ensure that the calibration of our flood modelling is as accurate as possible.

Information can be provided in the following ways:

- By completing the survey accessible at <https://speakup.isaac.qld.gov.au/>
- **Email** at planning.environment@isaac.qld.gov.au
- **Telephone** on 1300 472 227
- To discuss your experience **in-person** please contact the project team via the above methods to arrange an appointment.

Study Area



RECORDING A FLOOD EVENT

MAKING A FLOOD MARKER TO RECORD A FLOOD EVENT

Isaac Regional Council is inviting our residents to identify and preserve high water marks after flooding events before nature or human activity has destroyed the evidence. Every flood event is unique. Where rain falls, for how long and to what intensity affects determines who is affected. By making a flood marker you are recording the peak of an event and your flood marker, which, when collated with other flood markers generates an overall picture of that flood event.

How can I participate?

Did you take any photographs, make a flood marker, or have a rain gauge that recorded flooding on your property or in the local area? If so, Council would appreciate a copy of this information.

The community's responses to the survey will help to identify flooding issues and improve our preparedness for future flood events.

You can do this by:



Online

Completing the survey and email documents to records@isaac.qld.gov.au



In person

Submit survey and copy of your documents to any Isaac Regional Council office.

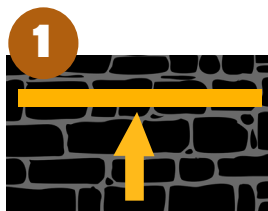
Did you know?

You can keep a copy of rainwater gauge in handwriting or digital format



How can I record a flood event?

You can keep a record of your rainwater gauge in handwriting or digital format. Below are some handy tips on how to best record a flood event.



Be quick – make record before clean up or later rain affects the high water mark.



If known, record approximate time of highest water.



Include a GPS co-ordinate or plan showing location of rain gauge or where mark is located.



Provide a measurement from ground or floor to mark. You can do an up-close photo of the measurement.

FOR MORE INFORMATION:

ISAAC.QLD.GOV.AU | 1300 ISAACS (1300 47 22 27)

f isaacregionalcouncil

isaacregionalcouncil

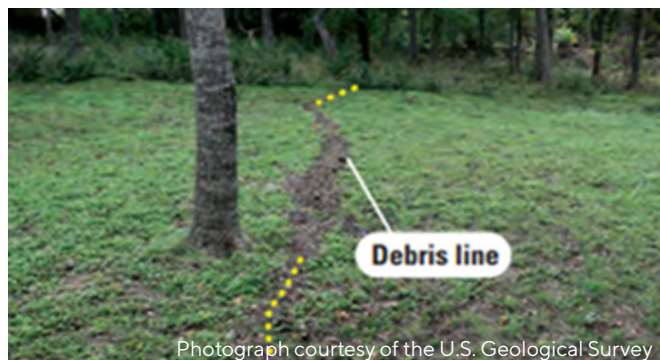
isaaccouncil

ISAAC
REGION

What are flood marker examples?

FLOOD EXTENT ON BANK

Put a row of stakes in alignment with highest debris. Take photo (with phone location tag settings on) of debris and stake.



FLOOD EXTENT ON ROAD

Mark your fence with paint or place a distinctive stake off the side of the road in alignment with highest debris. Take photo (with phone location tag settings on) of debris and stake / fence marker.



FENCE DEBRIS

Mark the fence posts to indicate the debris line. Take photo (with phone location tag settings on) of debris and fence markers.



BUILDING INTERIOR

Mark wall or put in row of nails to indicate high water mark. If possible label in inconspicuous location (eg inside cupboard). Take photo (with phone location tag settings on) prior to clean up.



BUILDING EXTERIOR

Mark the structure and if possible add date. Pick one location to record flood events. Take photo (with phone location tag settings on) prior to clean up.



FOR MORE INFORMATION:
ISAAC.QLD.GOV.AU | 1300 ISAACS (1300 47 22 27)

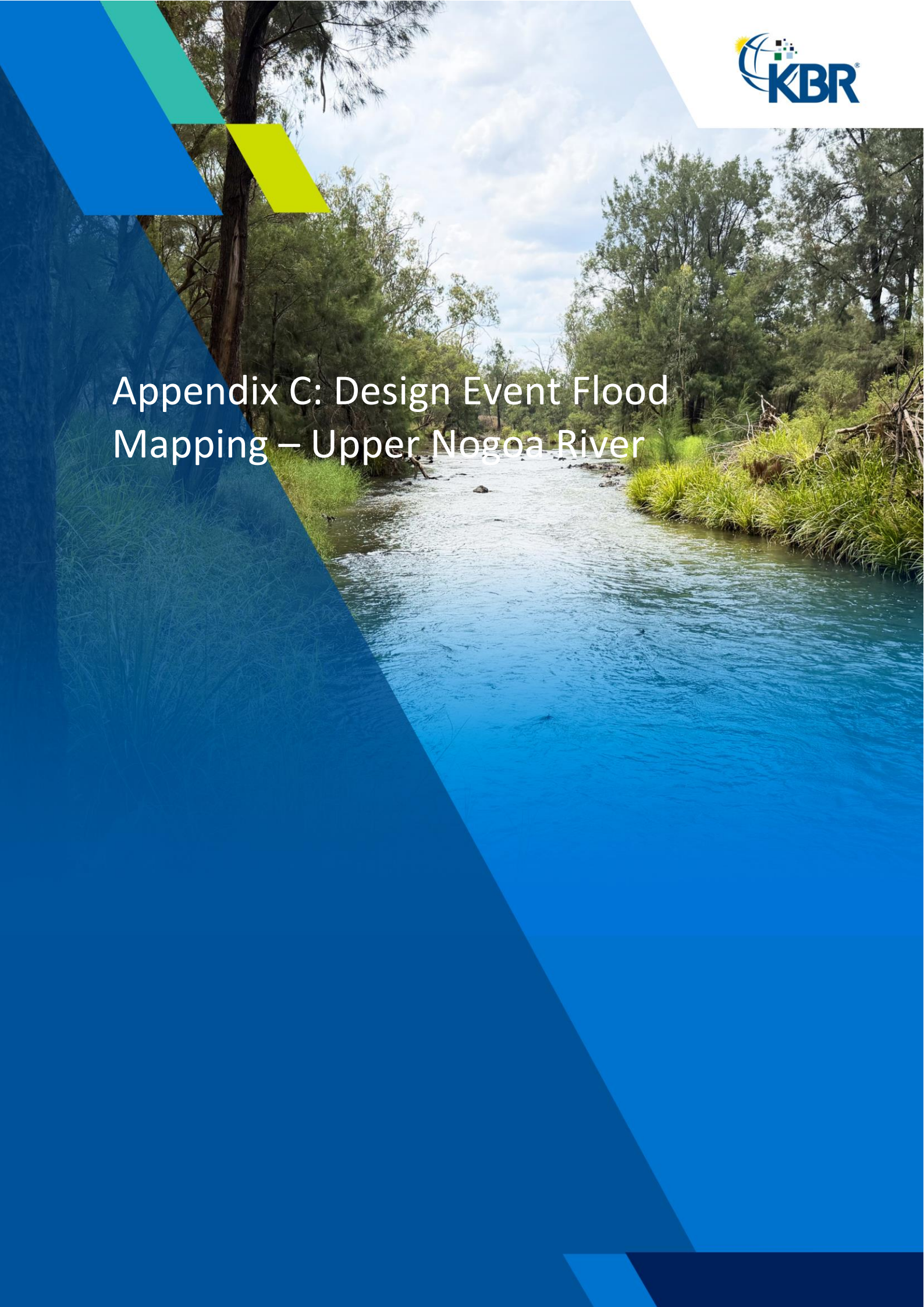
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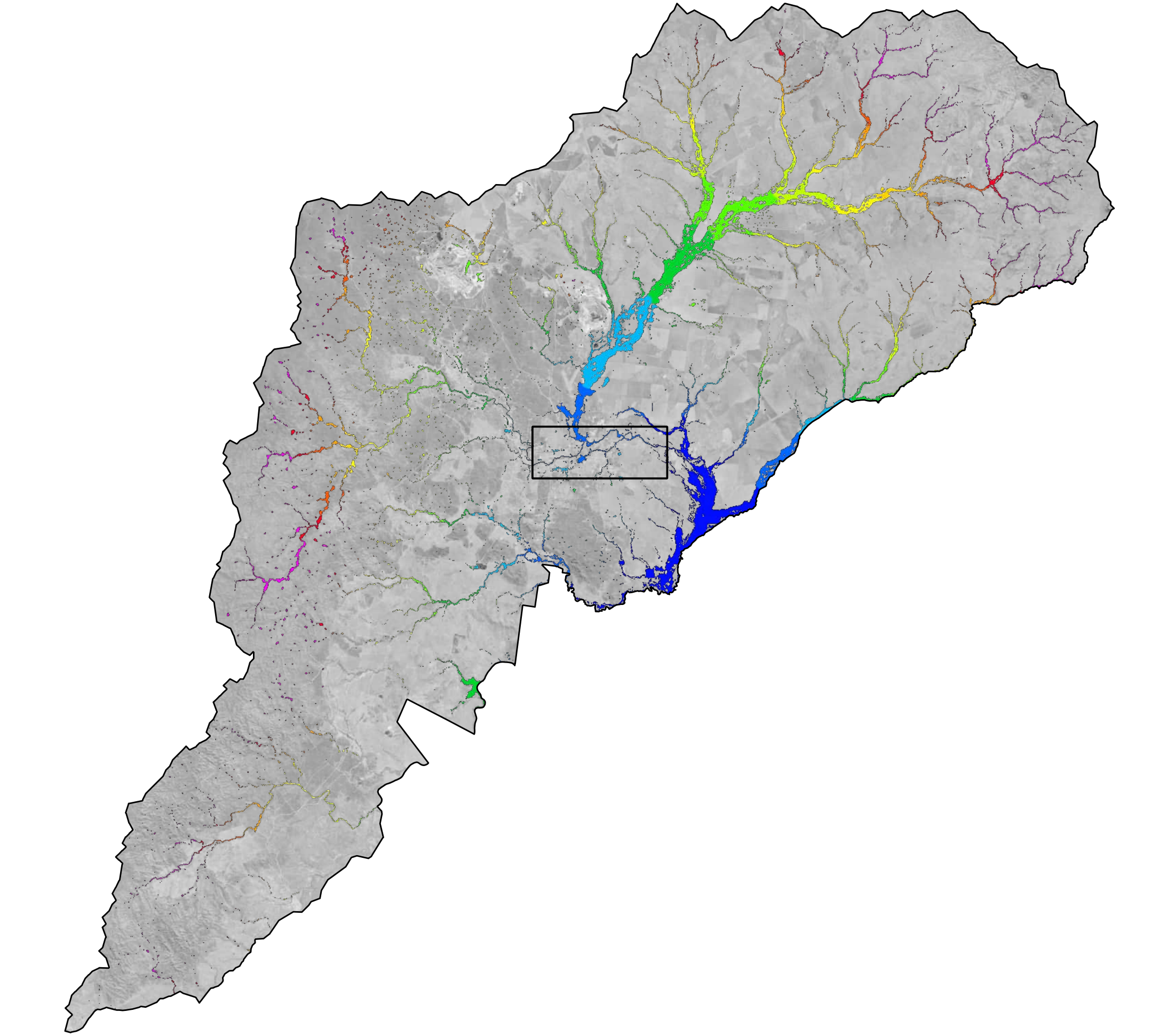
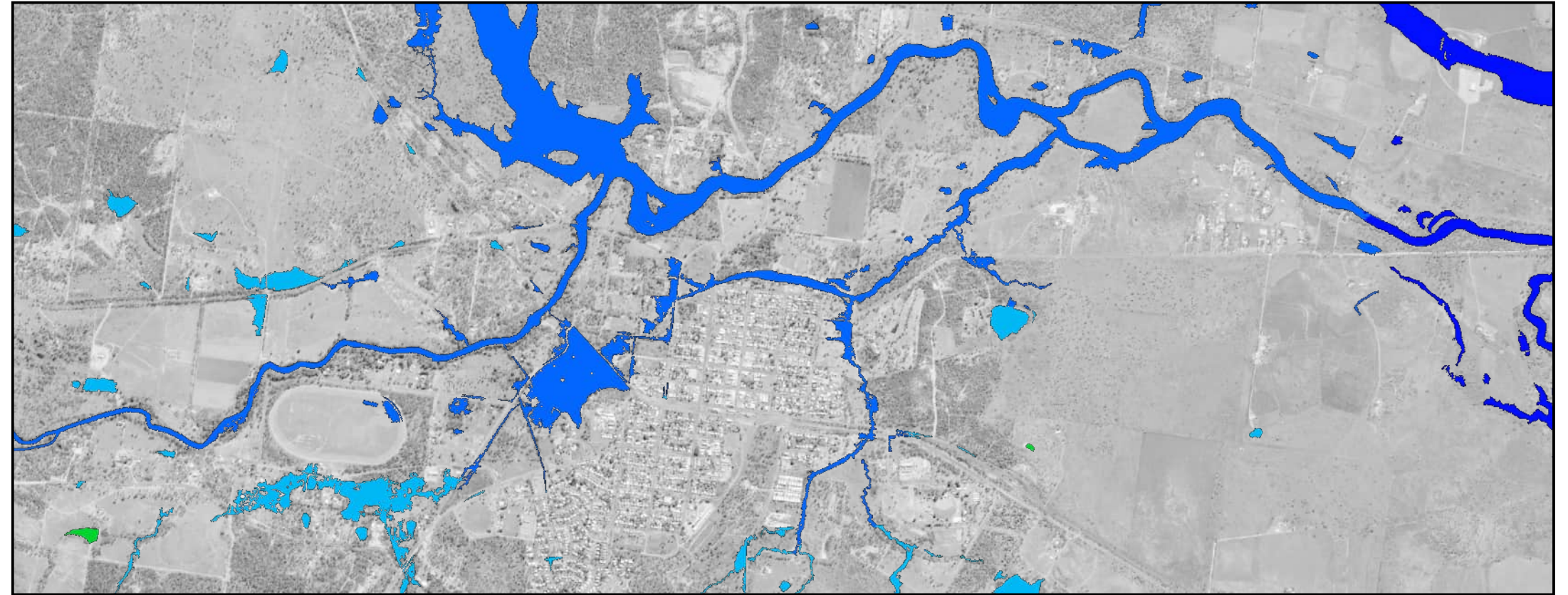
Appendix B: Annual Maximum Series

Table B-1 Sandy Creek at Clermont (130207A) Gauge Annual Maximum Series

Year	Flow (m ³ /s)	Year	Flow (m ³ /s)
1965	80	1995	50
1966	100	1996	343
1967	130	1997	58
1968	96	1998	57
1969	188	1999	261
1970	214	2000	116
1971	137	2003	154
1972	115	2004	130
1973	189	2005	66
1974	625	2006	26
1975	296	2007	53
1976	229	2008	697
1977	164	2009	48
1978	726	2010	85
1979	170	2011	50
1980	47	2012	209
1981	170	2014	53
1982	24	2016	104
1983	323	2017	54
1984	66	2018	56
1985	44	2019	234
1986	165	2020	57
1987	42	2021	338
1988	25	2022	217
1989	109	2023	186
1990	25	2024	10
1991	185	2025	56
1993	74	2026	483
1994	333		

The background of the slide is a photograph of the Upper Nogoia River. The river flows from the background towards the foreground, surrounded by dense green trees and vegetation. The water is a clear, vibrant blue. On the left side of the image, there are large, semi-transparent blue and yellow geometric shapes that overlap the river and the text.

Appendix C: Design Event Flood Mapping – Upper Nogoia River



LEGEND		
Peak Flood Levels (mAHd)		
■ <= 250	■ 280 - 290	■ 330 - 340
■ 250 - 260	■ 290 - 300	■ 340 - 350
■ 260 - 270	■ 300 - 310	■ >350
■ 270 - 280	■ 310 - 320	 Study Area
	■ 320 - 330	

Title:

50% AEP (2030) Event Peak Flood Levels Upper Nogoa River (Clermont)

Scale at A3
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While effort has been made to ensure the accuracy and completeness of the information presented, no guarantee is given, nor responsibility taken by KBR for any errors or omission.
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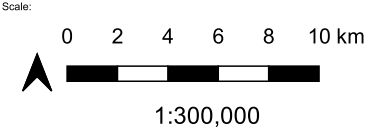
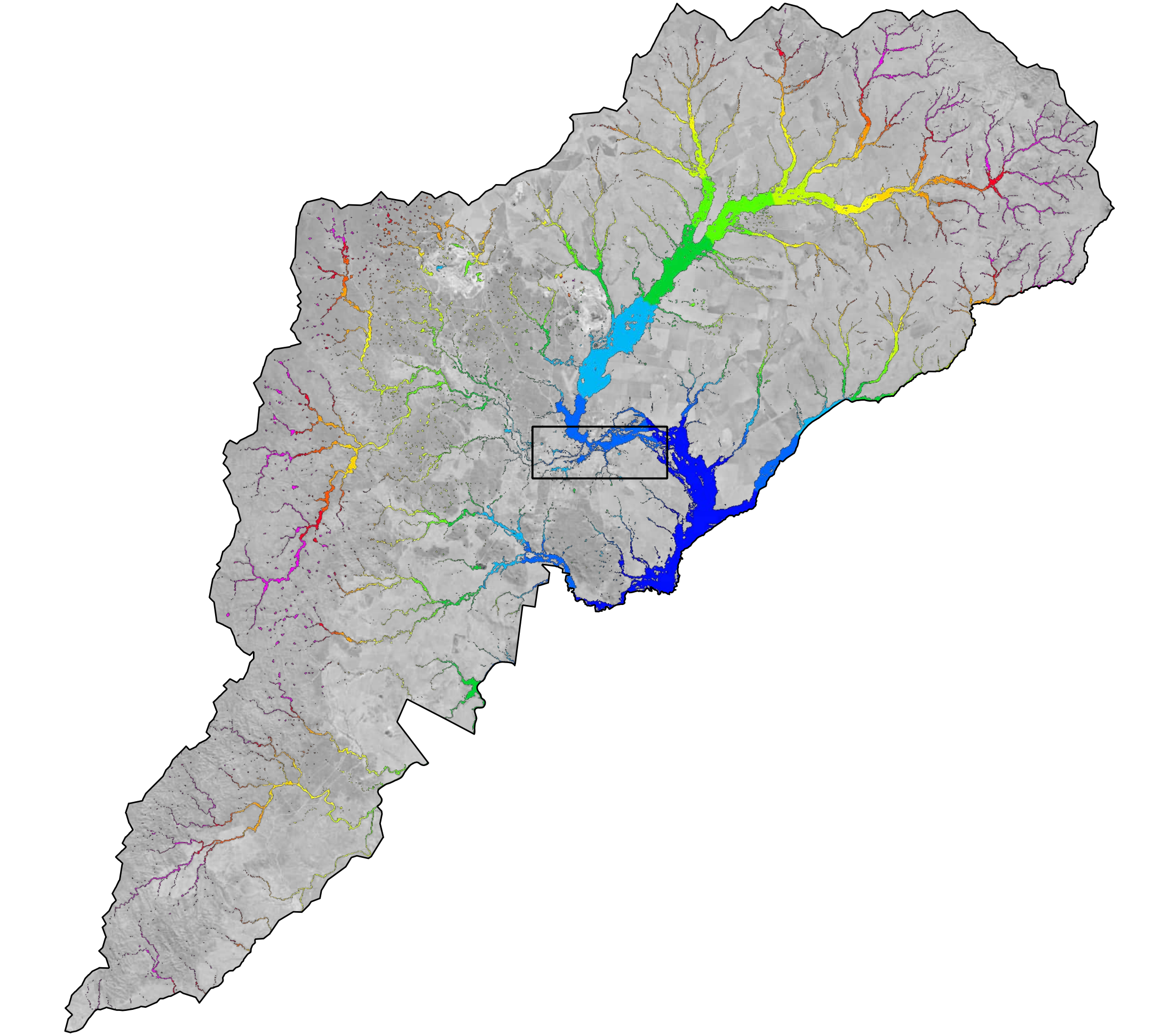
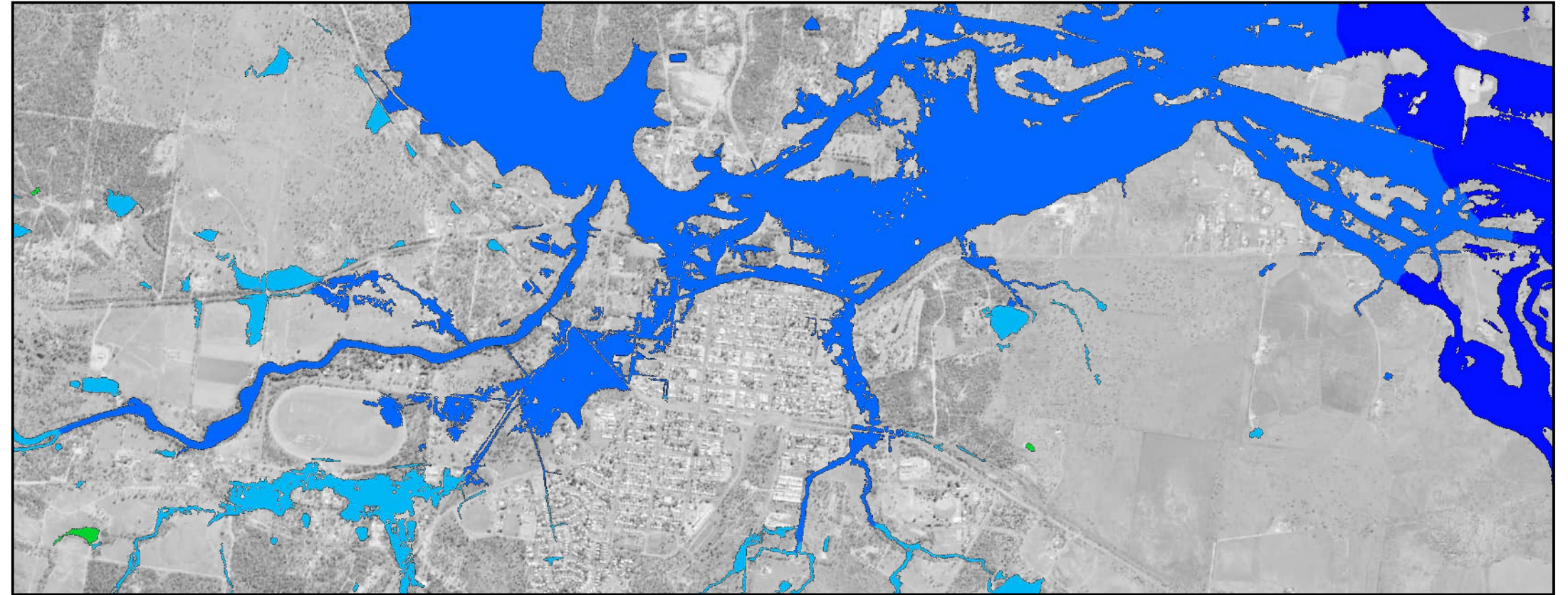


Figure:	Rev:
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LEGEND			
Peak Flood Levels (mAHD)			
 <= 250	 280 - 290	 330 - 340	
 250 - 260	 290 - 300	 340 - 350	
 260 - 270	 300 - 310	 >350	
 270 - 280	 310 - 320	 Study Area	
	 320 - 330		

Title:

20% AEP (2030) Event Peak Flood Levels Upper Nogoa River (Clermont)

Scale at A3
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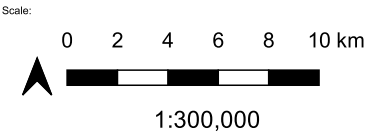
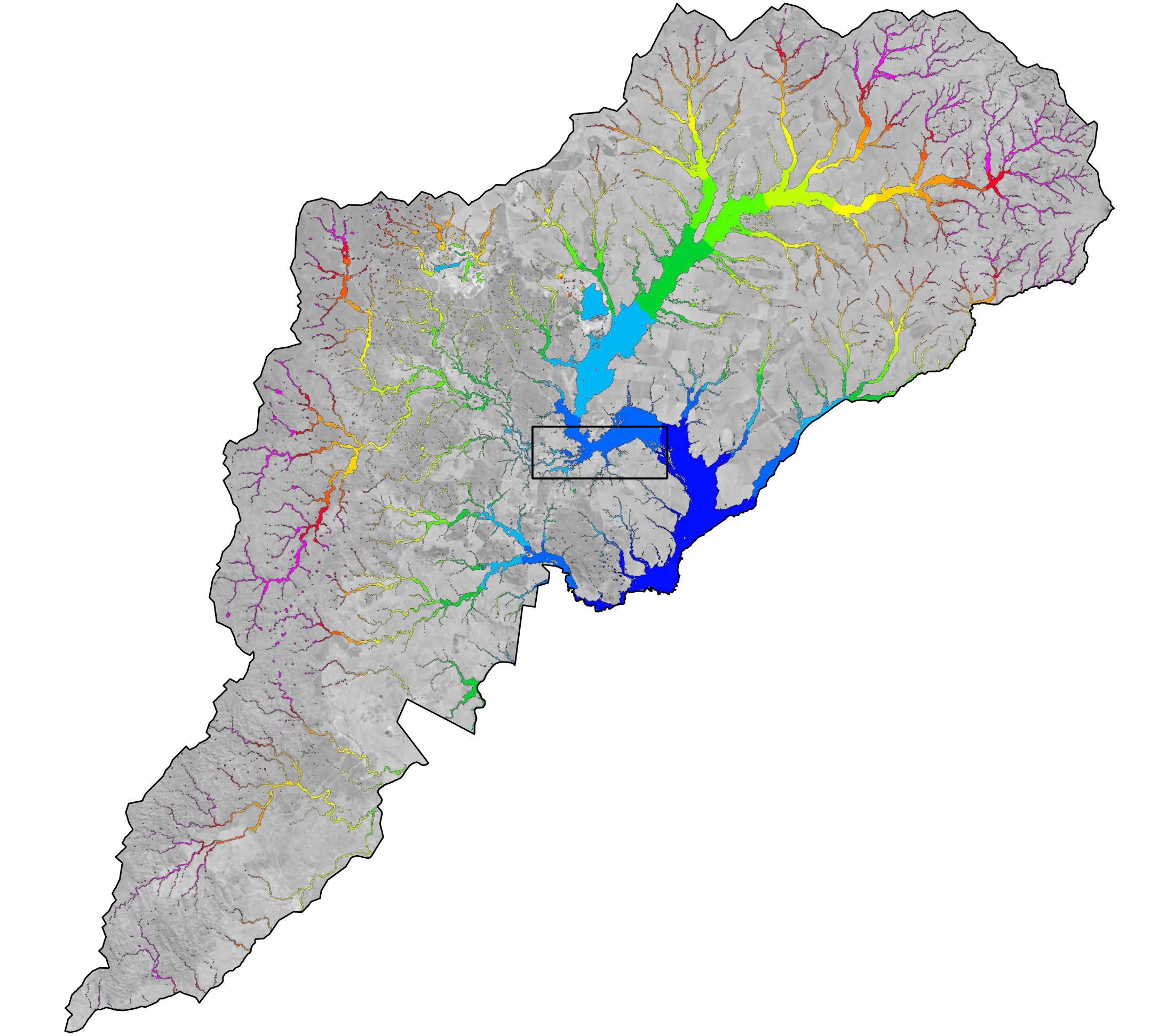


Figure:	Rev:
C-2	0





LEGEND		
Peak Flood Levels (mAHd)		
 <= 250	 280 - 290	 330 - 340
 250 - 260	 290 - 300	 340 - 350
 260 - 270	 300 - 310	 >350
 270 - 280	 310 - 320	 Study Area
	 320 - 330	

Title:

5% AEP (2030) Event Peak Flood Levels Upper Nogoa River (Clermont)

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While effort has been made to ensure the accuracy and completeness of the information presented, no guarantee is given, nor responsibility taken by KBR for any errors or omission.
File: \\profile001\data\$\Water_Resources\Projects\BEW571 - Upper Nogoa and Mackenzie\G - GIS\Workspaces\260630_Mapping_Atlas.qgz

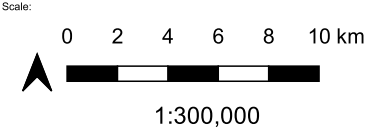
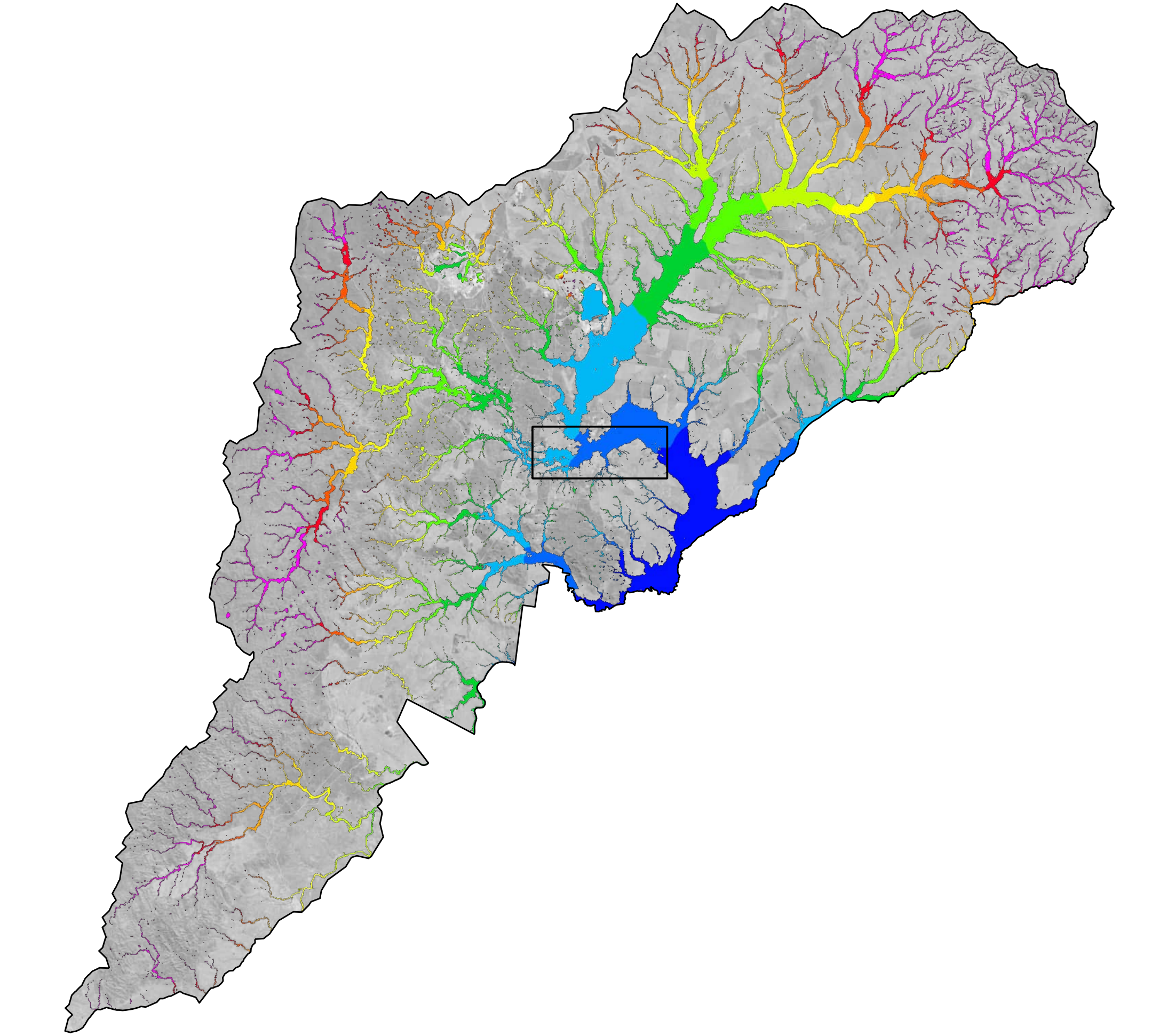


Figure: **C-3** Rev: **0**





LEGEND		
Peak Flood Levels (mAHN)		
 <= 250	 280 - 290	 330 - 340
 250 - 260	 290 - 300	 340 - 350
 260 - 270	 300 - 310	 >350
 270 - 280	 310 - 320	 Study Area
	 320 - 330	

Title:

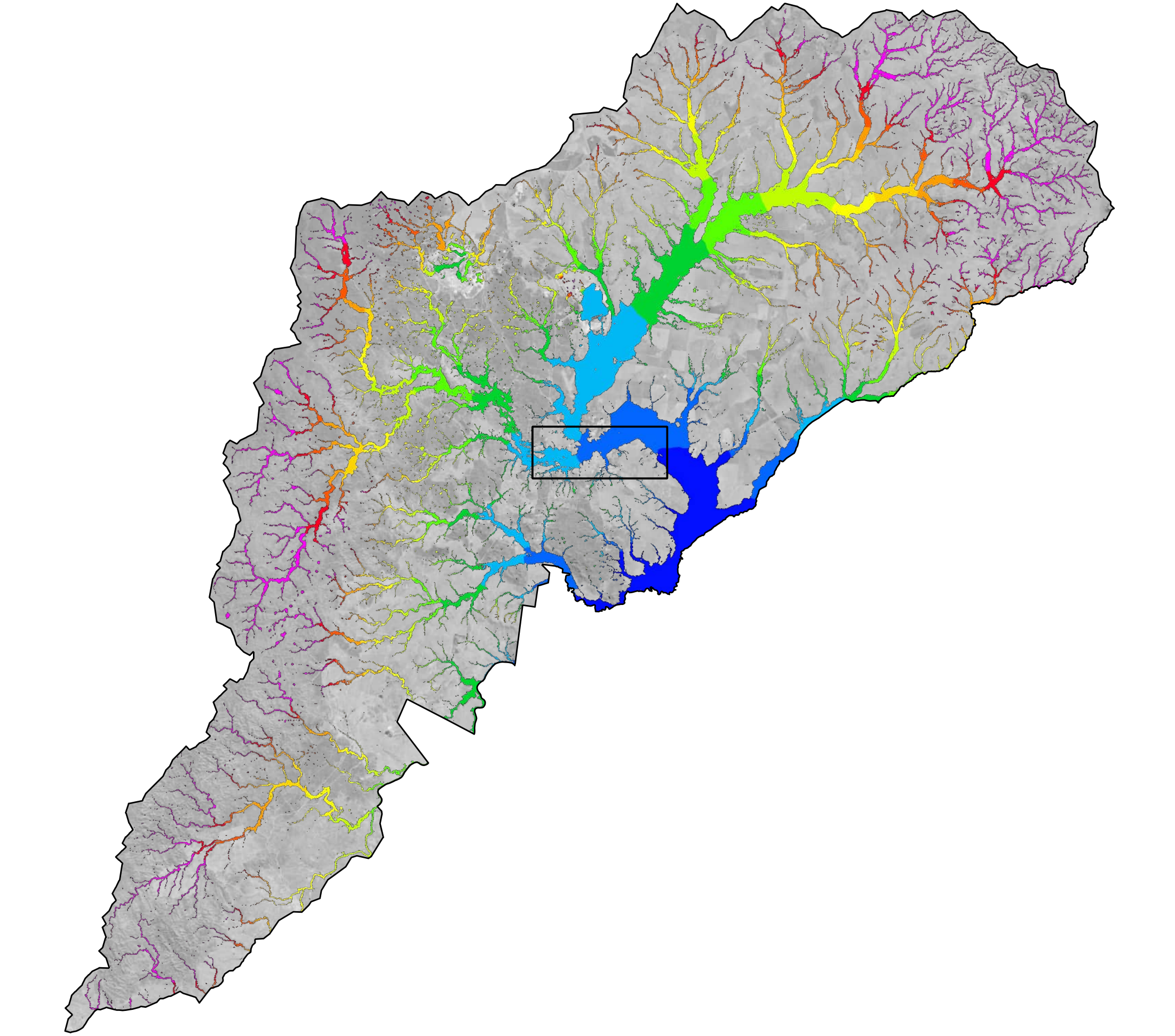
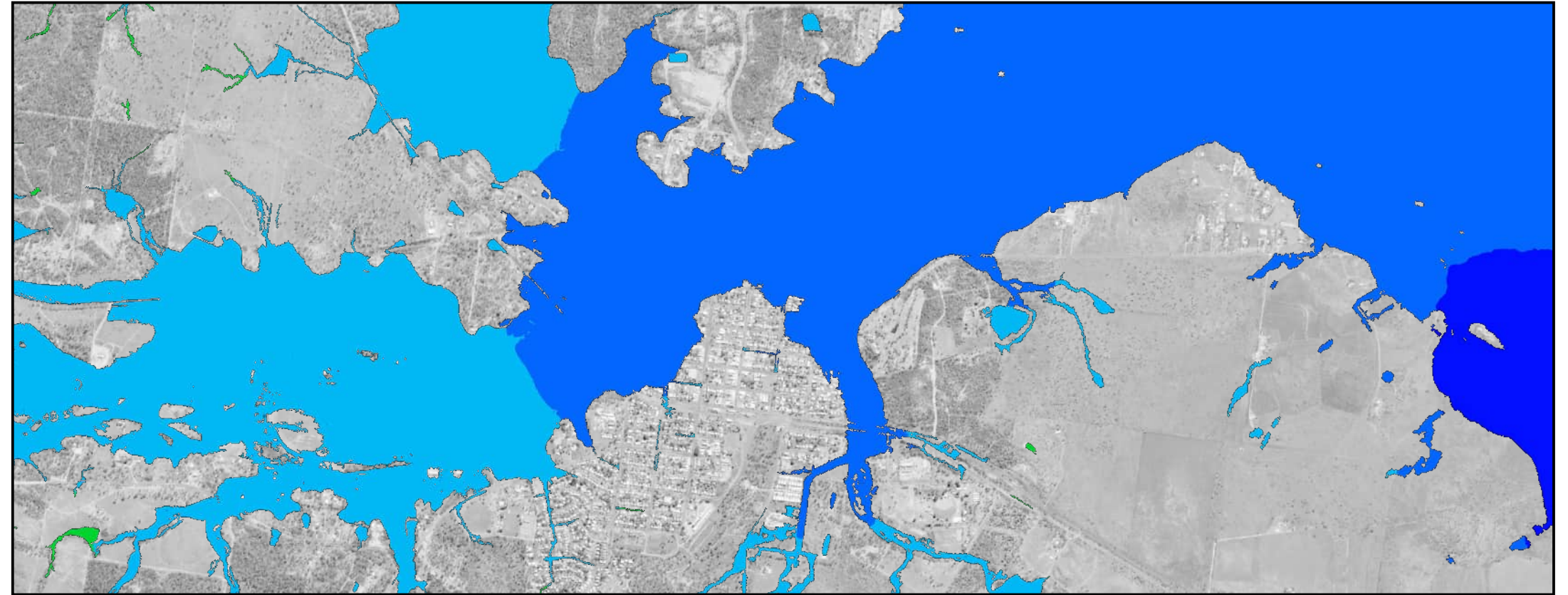
1% AEP (2030) Event Peak Flood Levels Upper Nogoa River (Clermont)

Scale at A3
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Figure: **C-5** Rev: **0**





LEGEND		
Peak Flood Levels (mAHN)		
 <= 250	 280 - 290	 330 - 340
 250 - 260	 290 - 300	 340 - 350
 260 - 270	 300 - 310	 >350
 270 - 280	 310 - 320	 Study Area
	 320 - 330	

Title:

0.5% AEP (2030) Event Peak Flood Levels Upper Nogoa River (Clermont)

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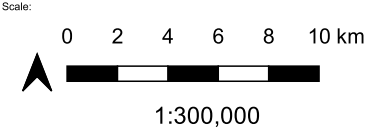
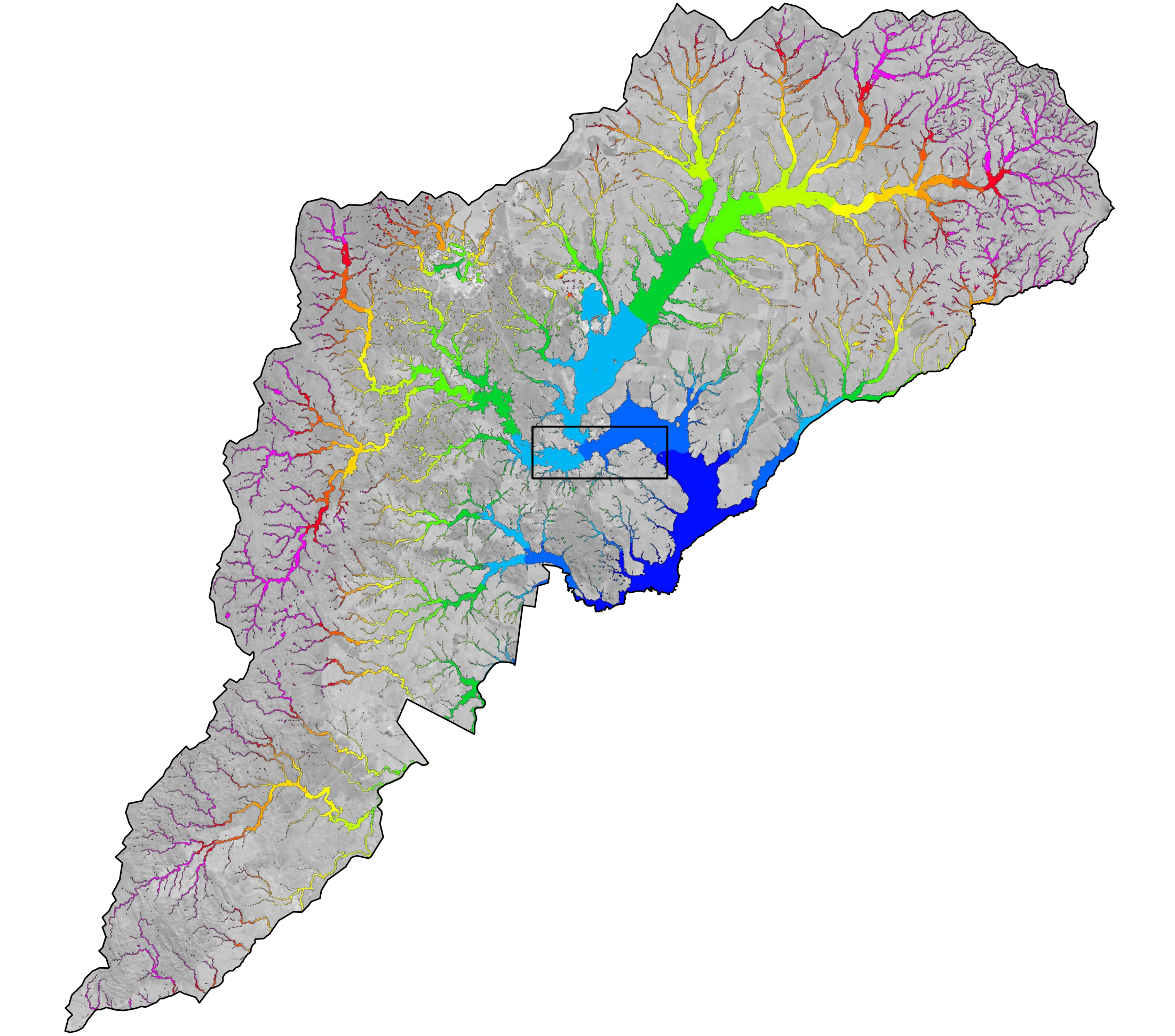


Figure:	Rev:
C-6	0





LEGEND			
Peak Flood Levels (mAHd)			
	<= 250		280 - 290
	250 - 260		290 - 300
	260 - 270		300 - 310
	270 - 280		310 - 320
			320 - 330
			330 - 340
			340 - 350
			>350
			Study Area

Title:

0.2% AEP (2030) Event Peak Flood Levels Upper Nogoa River (Clermont)

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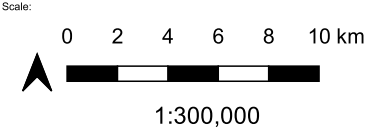
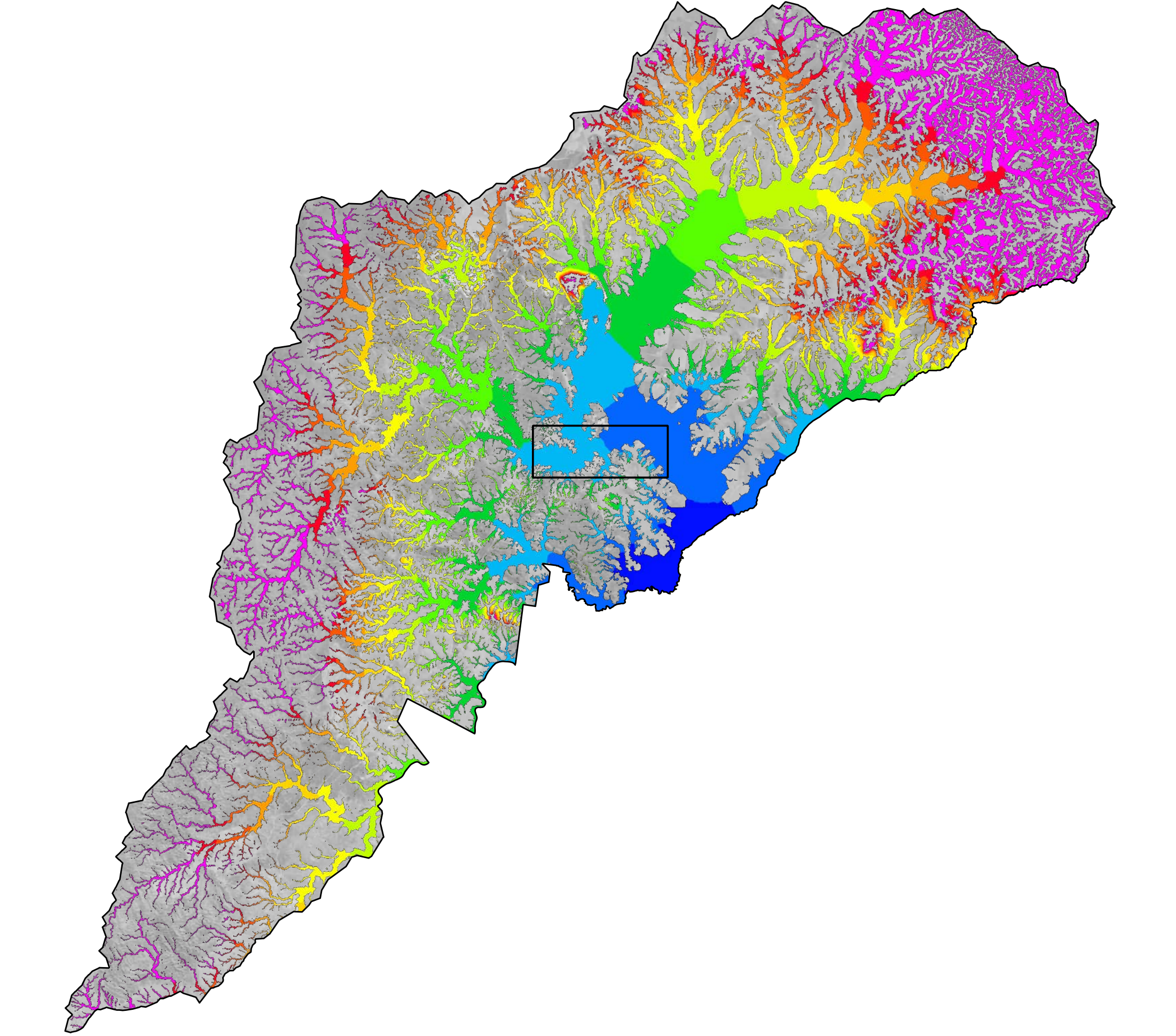
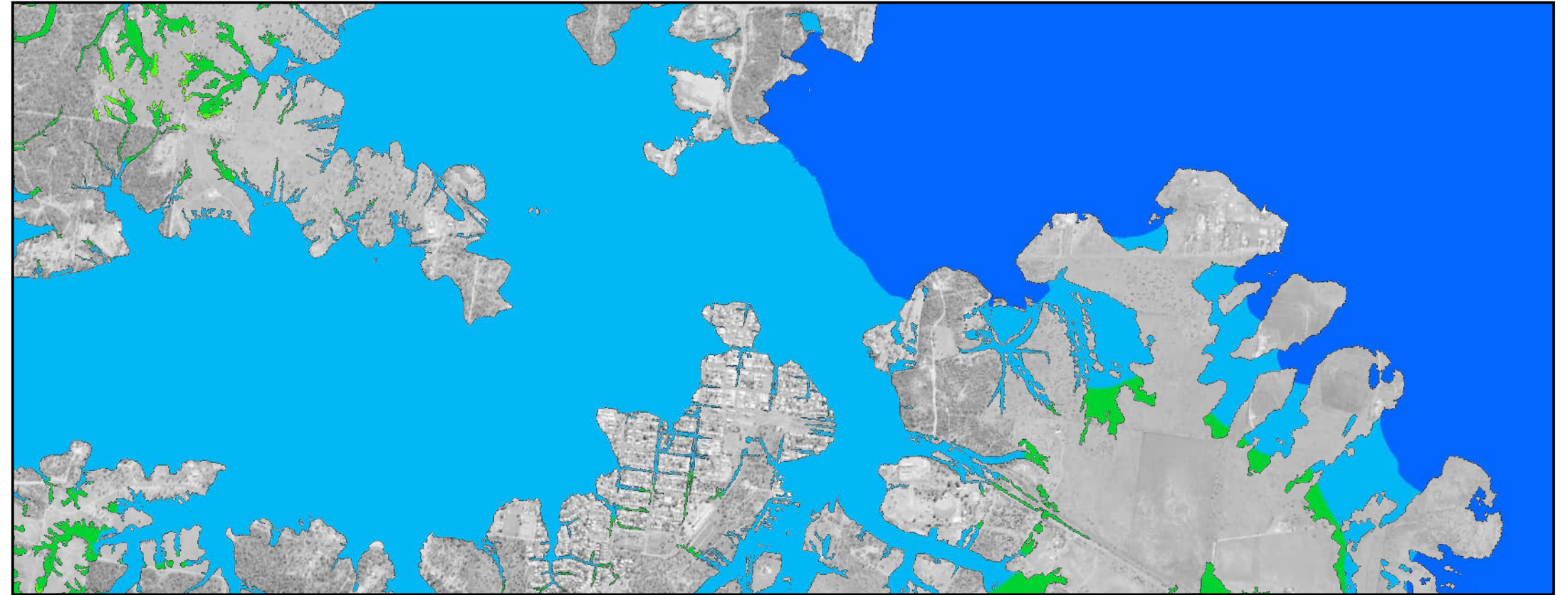


Figure:	Rev:
C-7	0





LEGEND

Peak Flood Levels (mAHD)

<= 250

250 - 260

260 - 270

270 - 280

280 - 290

290 - 300

300 - 310

310 - 320

320 - 330

330 - 340

340 - 350

>350

Study Area

Title:

**PMF Event (2030) Peak Flood Levels
Upper Nogoa River (Clermont)**

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Scale:

0

2

4

6

8

10 km

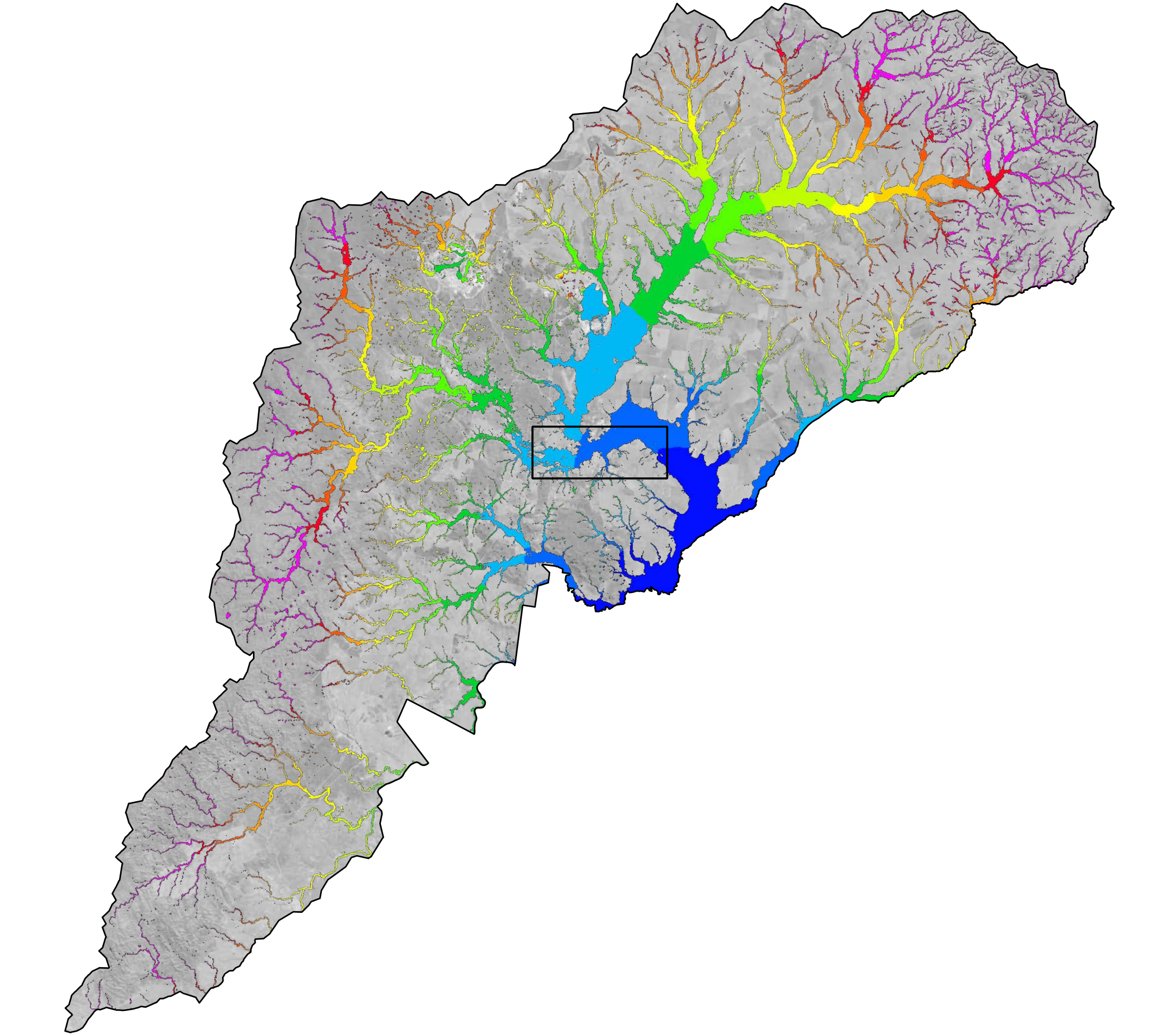
1:300,000

Figure:

C-8

Rev:

0



LEGEND

Peak Flood Levels (mAHN)

<= 250

250 - 260

260 - 270

270 - 280

280 - 290

290 - 300

300 - 310

310 - 320

320 - 330

330 - 340

340 - 350

>350

Study Area

Title:

1% AEP (2100) Event Peak Flood Levels Upper Nogoa River (Clermont)

Scale at A3
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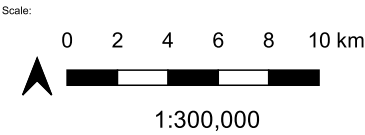
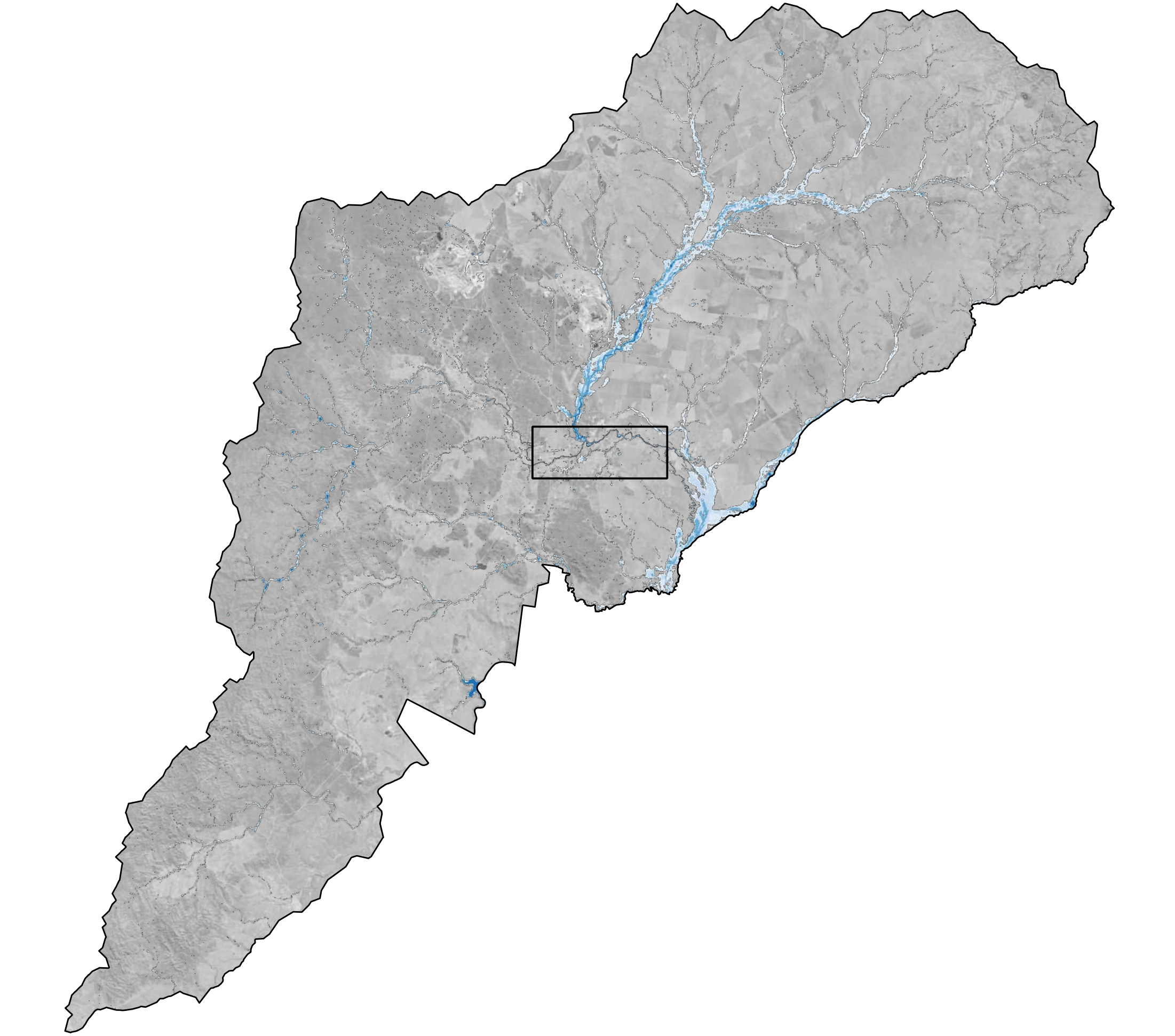
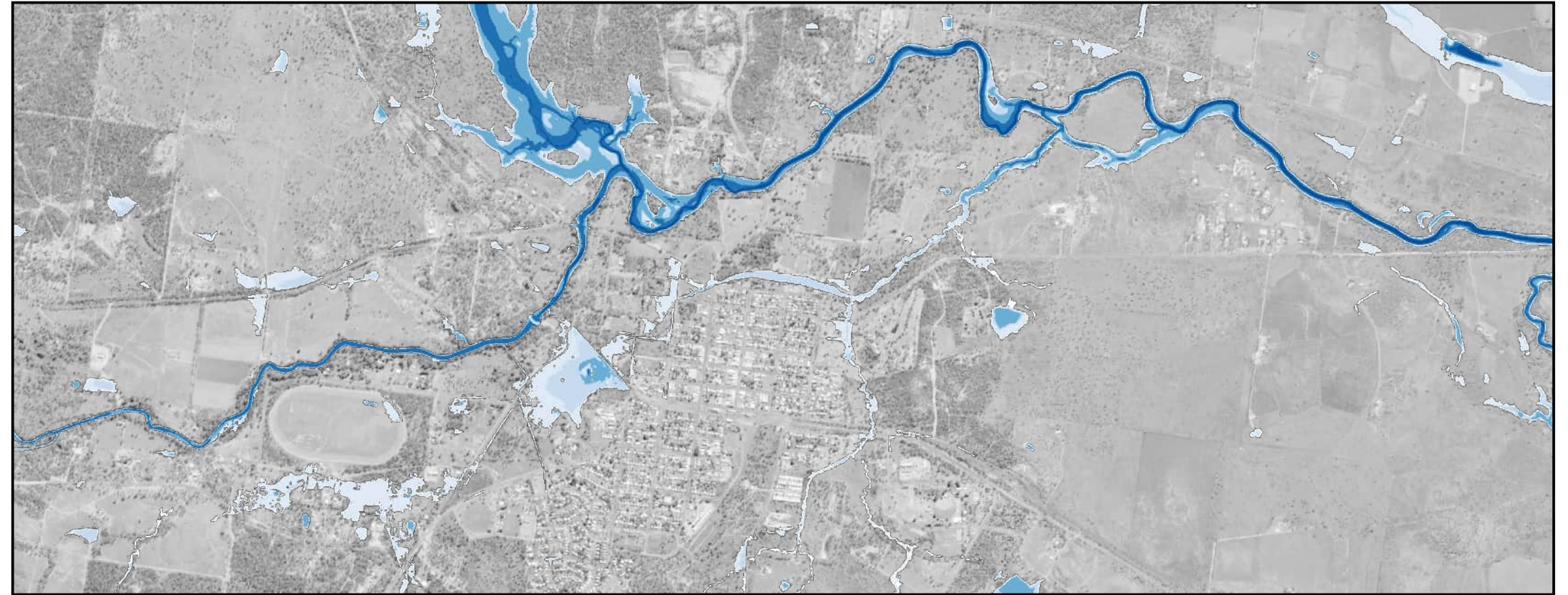


Figure:	Rev:
C-9	0





LEGEND

Peak Flood Depths (m)

<= 0.1

0.1 - 0.5

0.5 - 1.0

1.0 - 2.5

2.5 - 5.0

5.0 - 10.0

> 10.0

Study Area

Title:

**50% AEP (2030) Event Peak Flood Depths
Upper Nogoa River (Clermont)**

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File: \\perfile001\data\$\Water_Resources\Projects\BEW571 - Upper Nogoa and Mackenzie\G - GIS\Workspaces\260630_Mapping_Atlas.qgz

Scale:

0246810 km

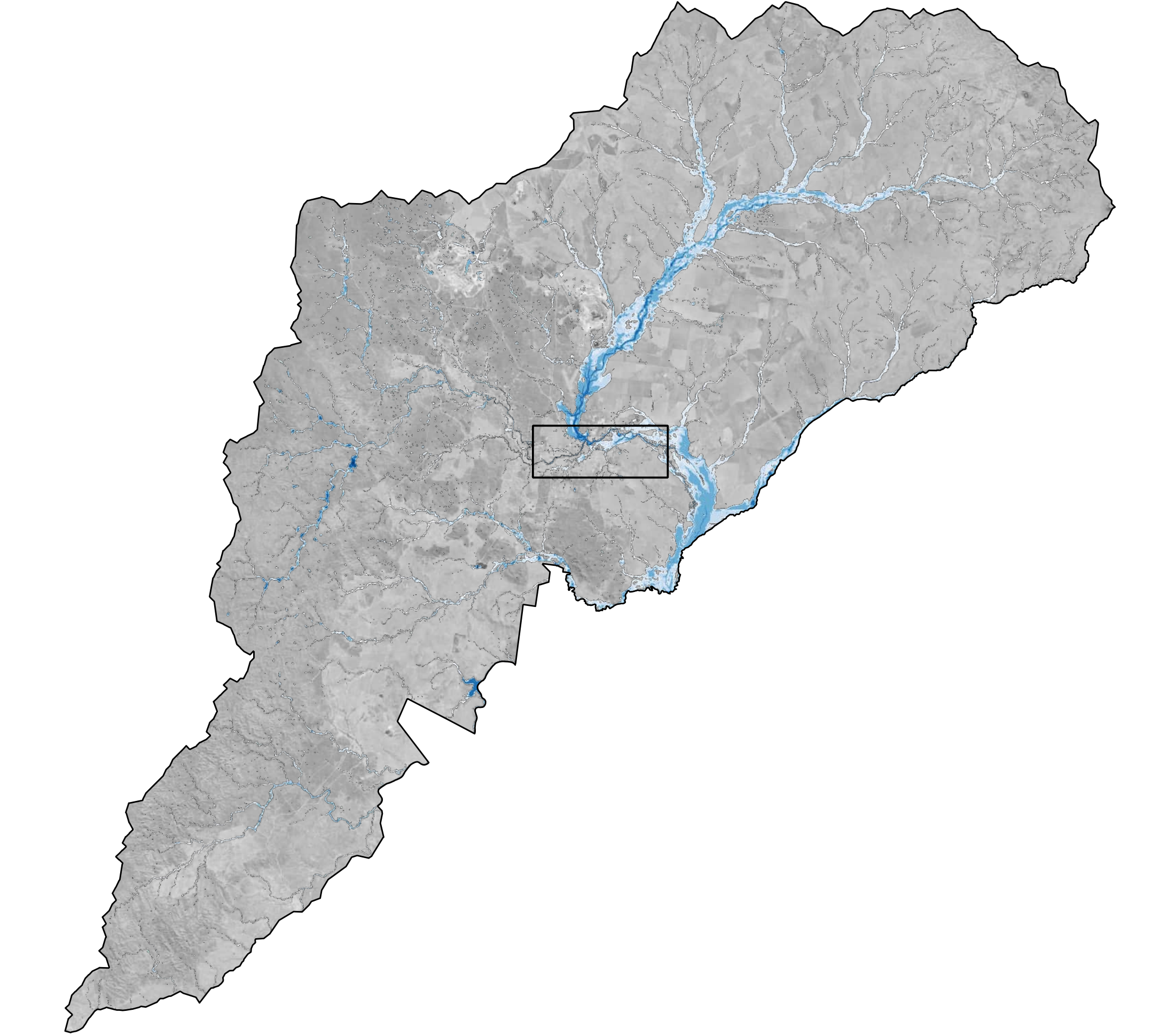
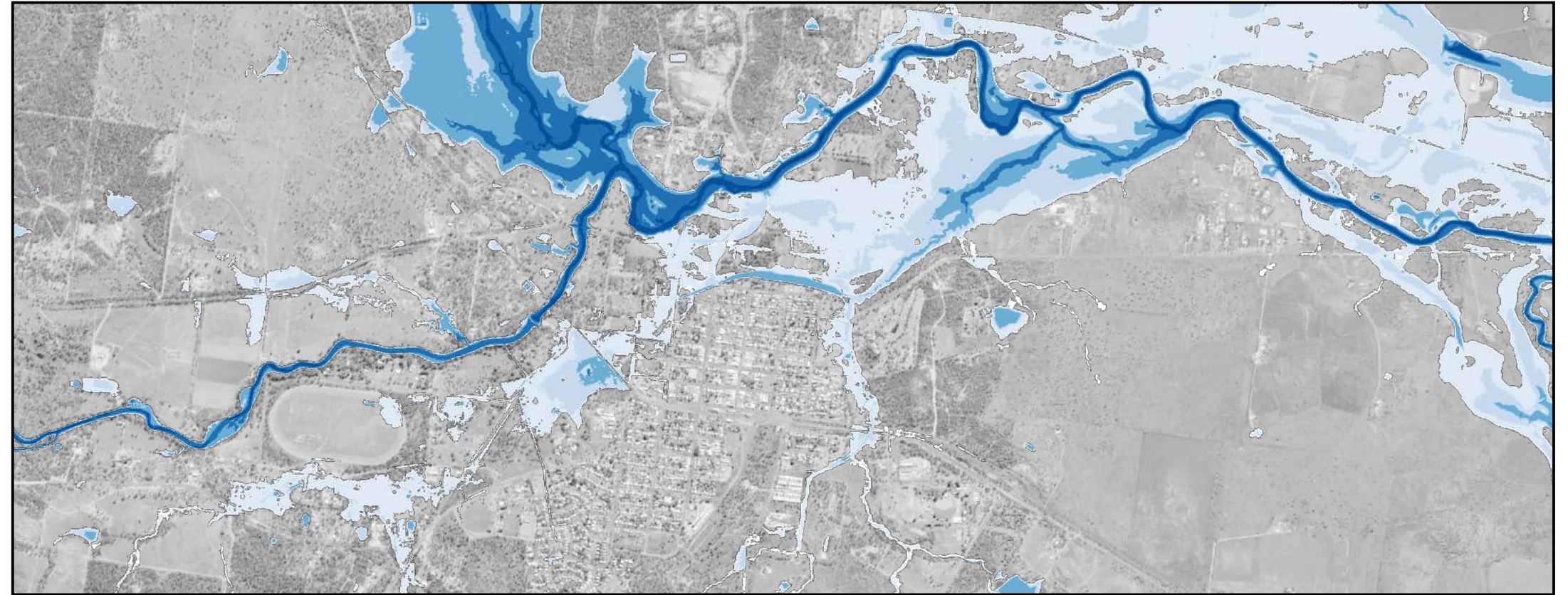
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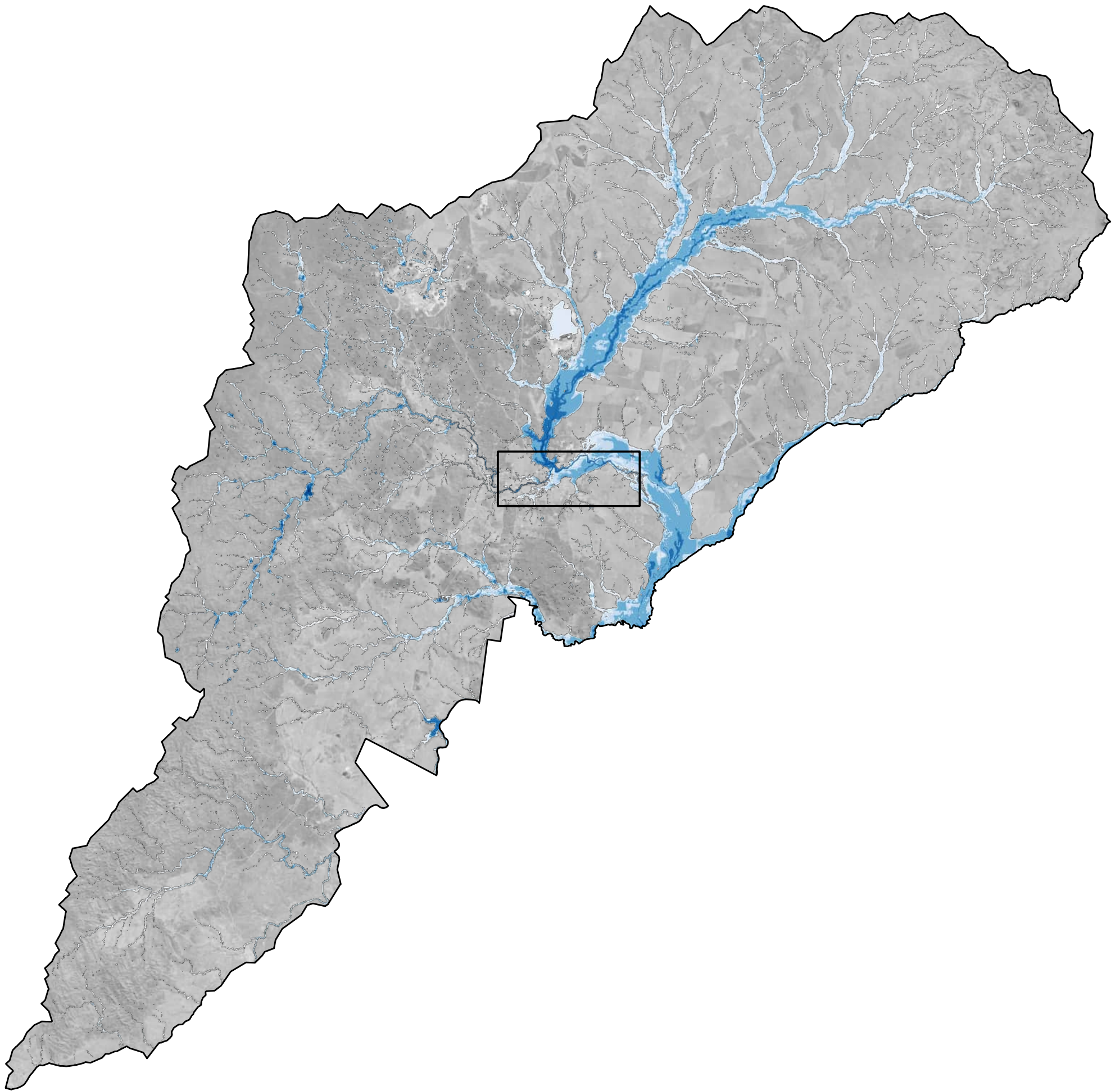
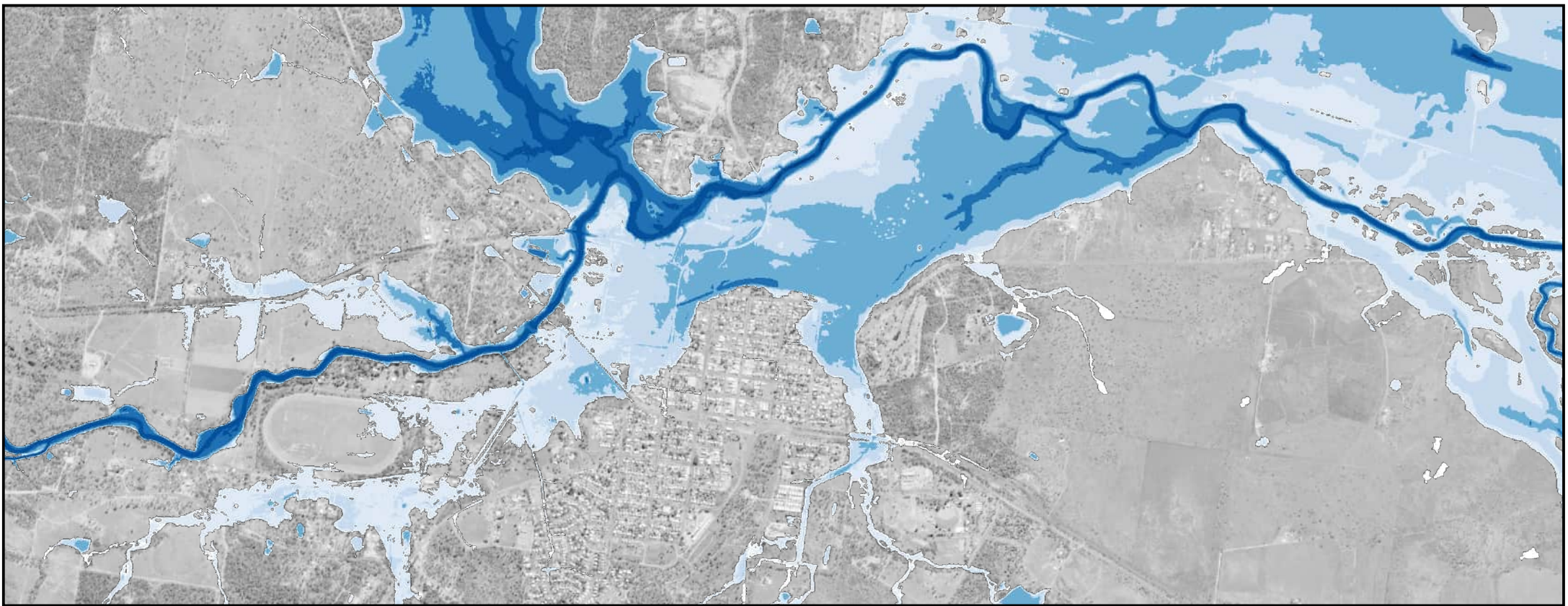
C-10

Rev:

0

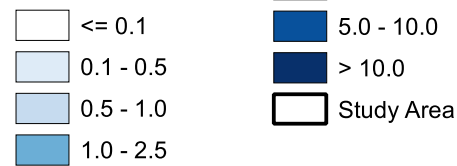


LEGEND Peak Flood Depths (m) <= 0.1 0.1 - 0.5 0.5 - 1.0 1.0 - 2.5 2.5 - 5.0 5.0 - 10.0 > 10.0 Study Area	Title: 20% AEP (2030) Event Peak Flood Depths Upper Nogoa River (Clermont)	Figure: C-11	Rev: 0	
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LEGEND

Peak Flood Depths (m)



5% AEP (2030) Event Peak Flood Depths Upper Nogoia River (Clermont)

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C-12

O

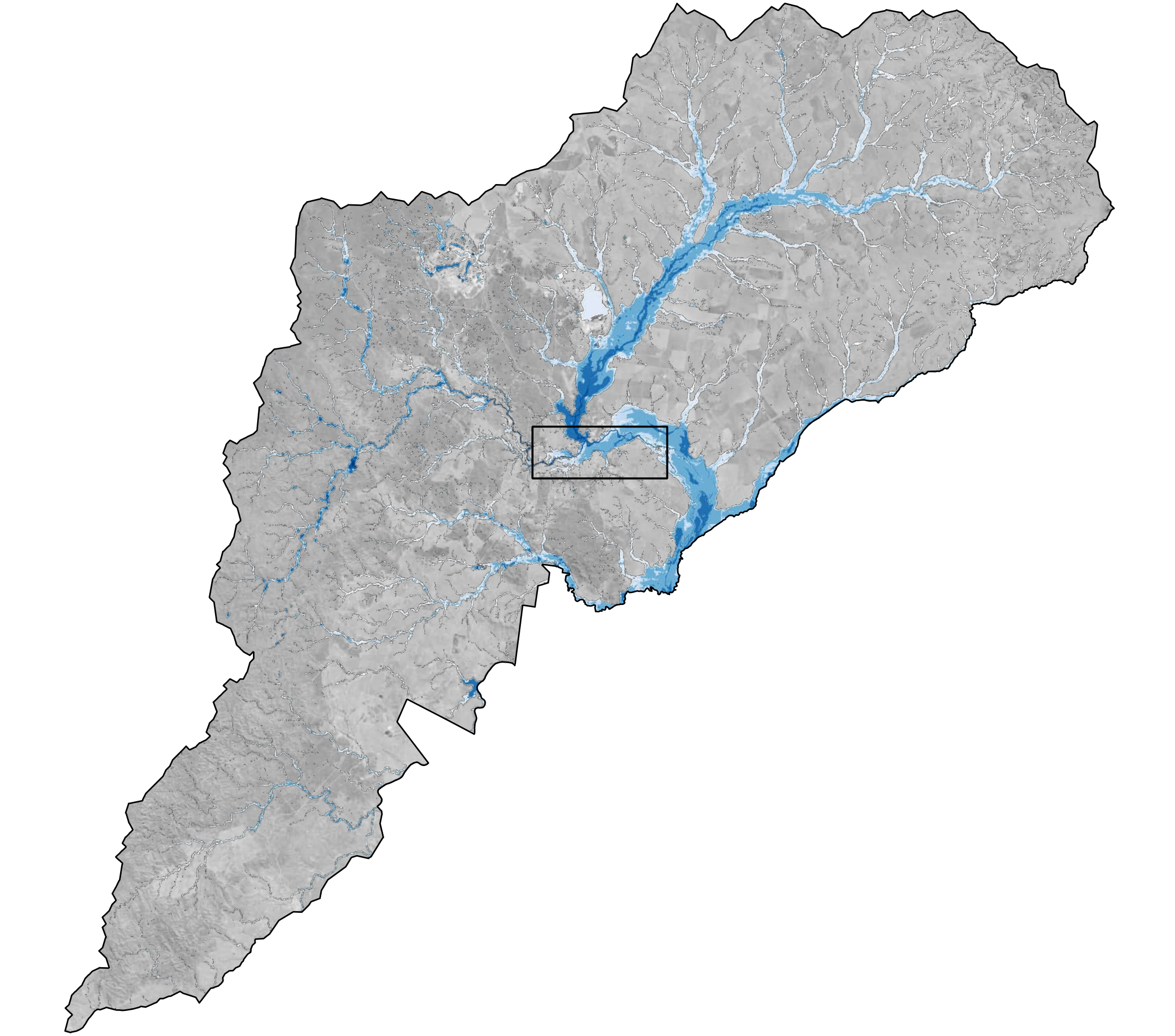
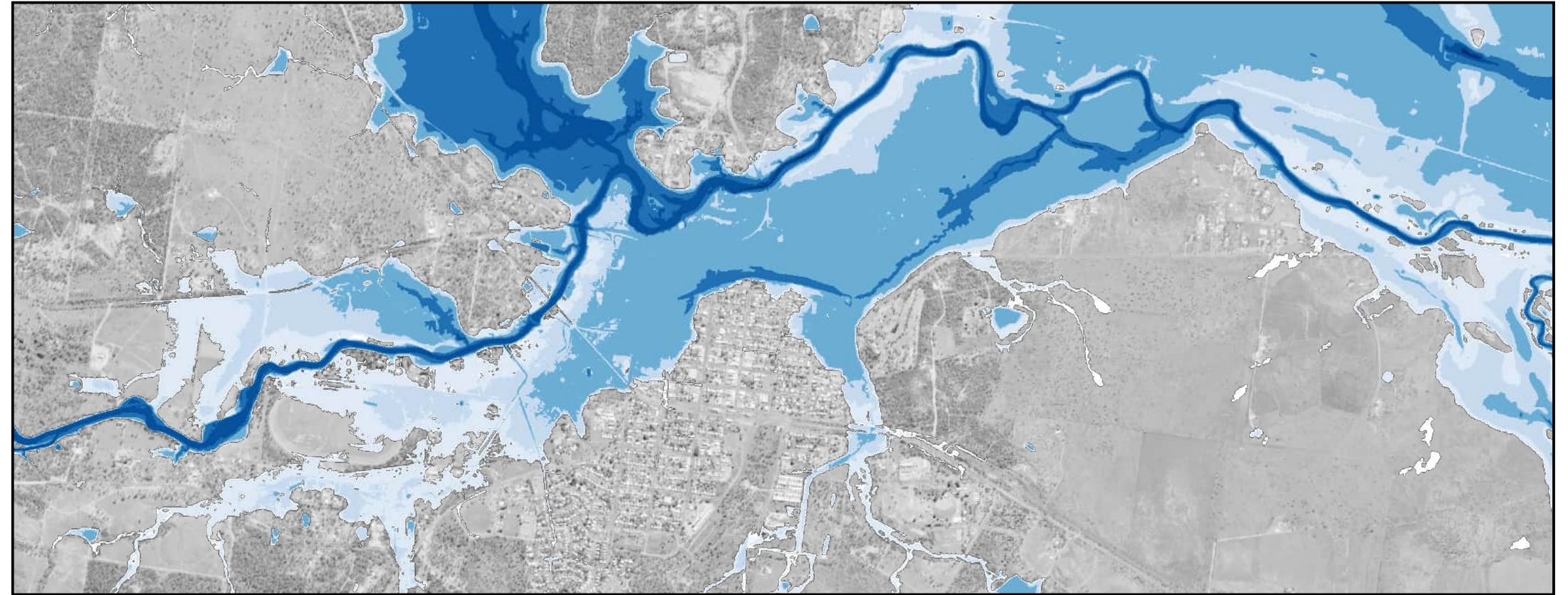


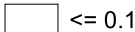
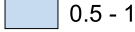
Scale:



0 2 4 6 8 10 km

1:300,000



LEGEND	
Peak Flood Depths (m)	
	<= 0.1
	0.1 - 0.5
	0.5 - 1.0
	1.0 - 2.5
	2.5 - 5.0
	5.0 - 10.0
	> 10.0
	Study Area

Title:

2% AEP (2030) Event Peak Flood Depths Upper Nogoa River (Clermont)

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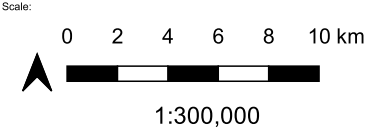
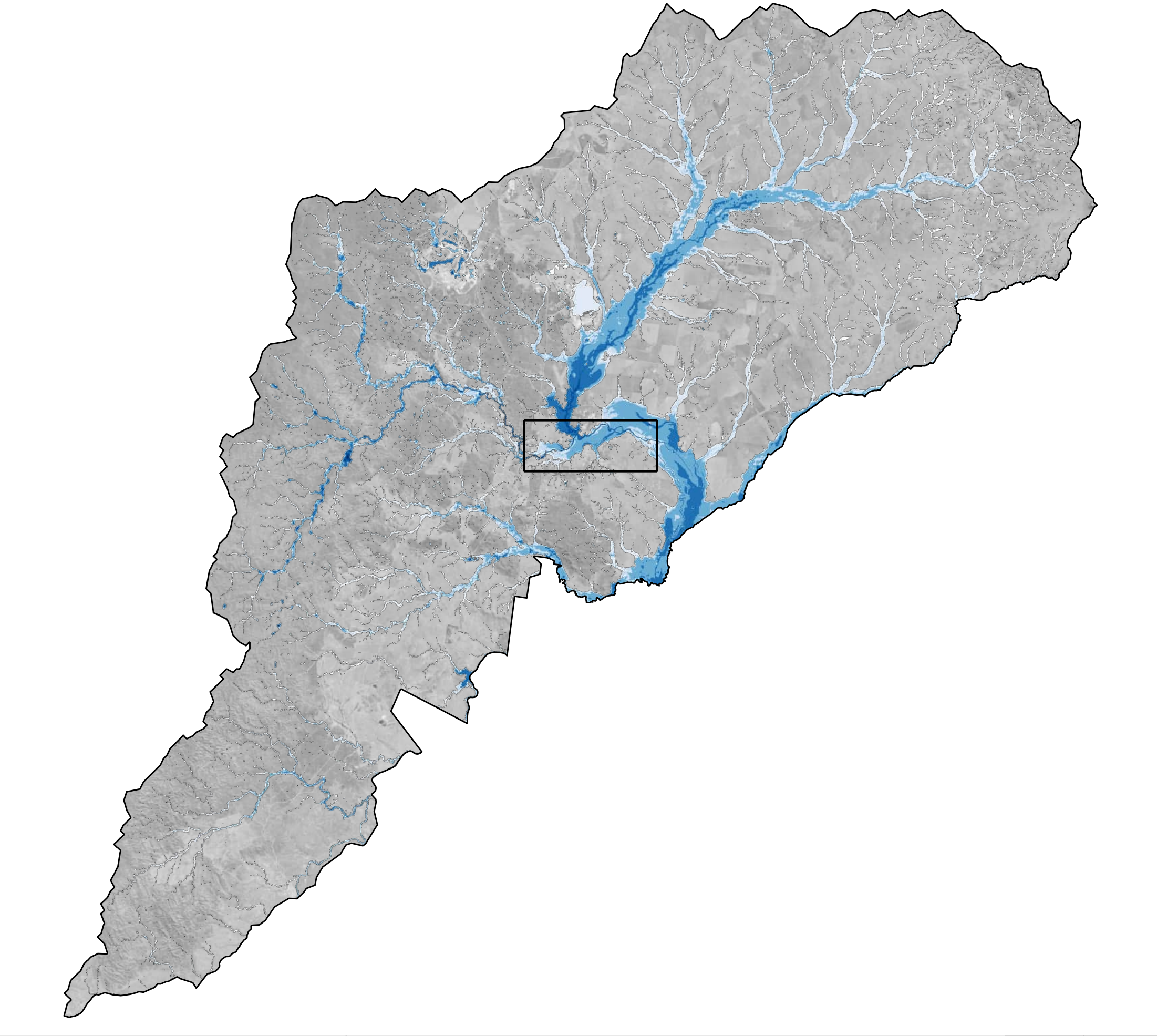
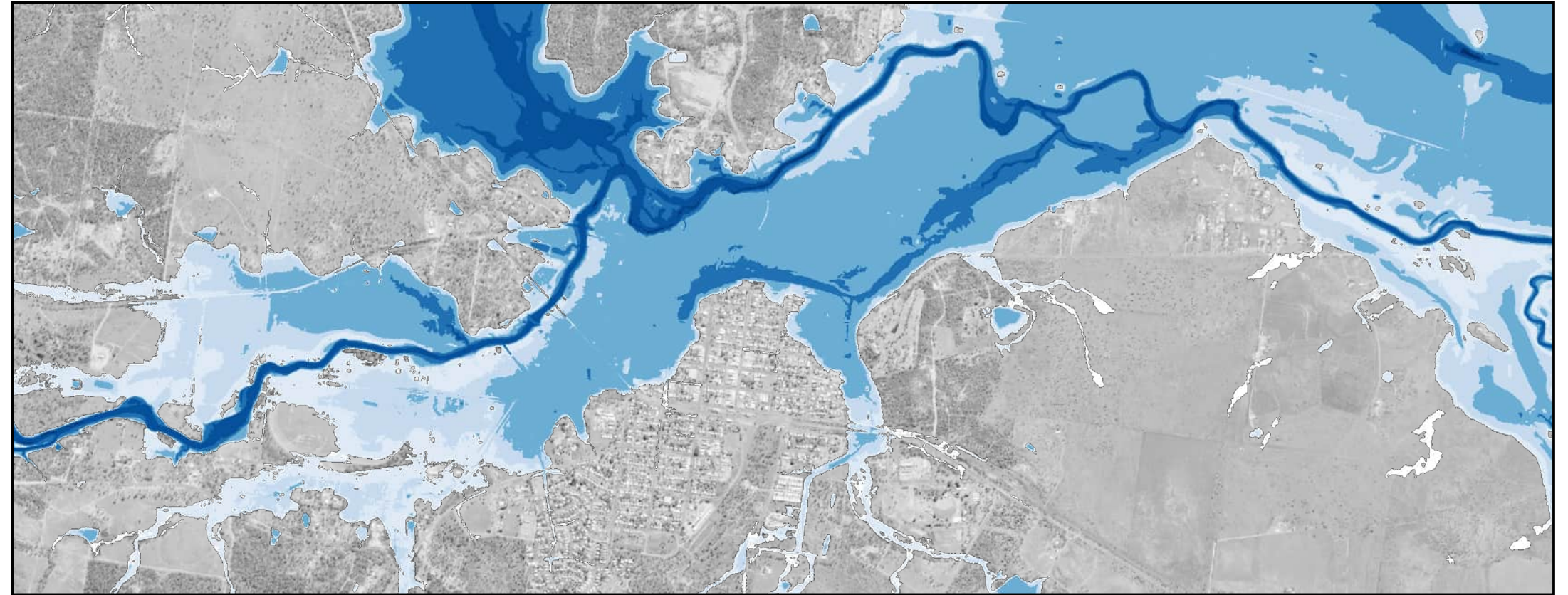
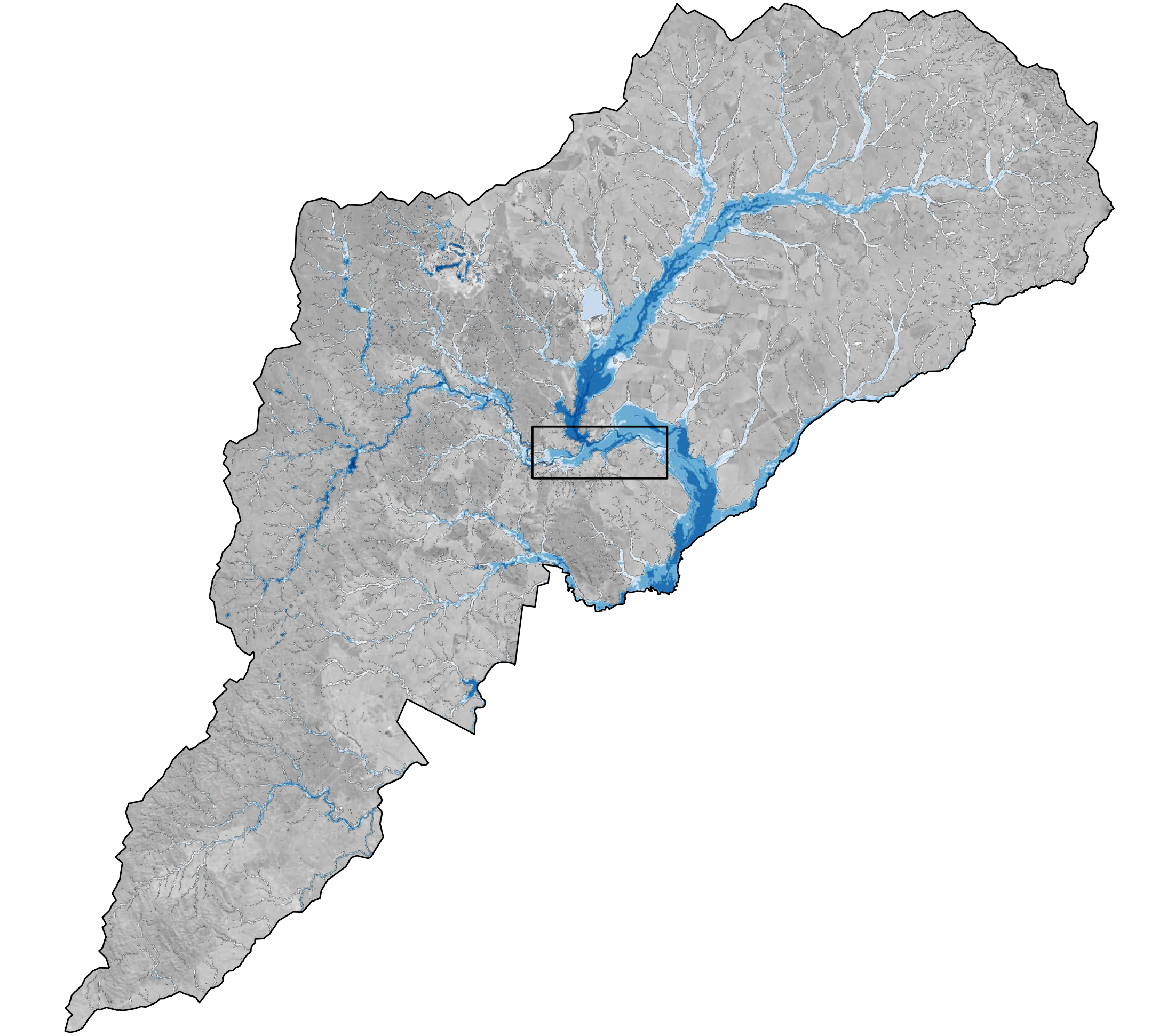
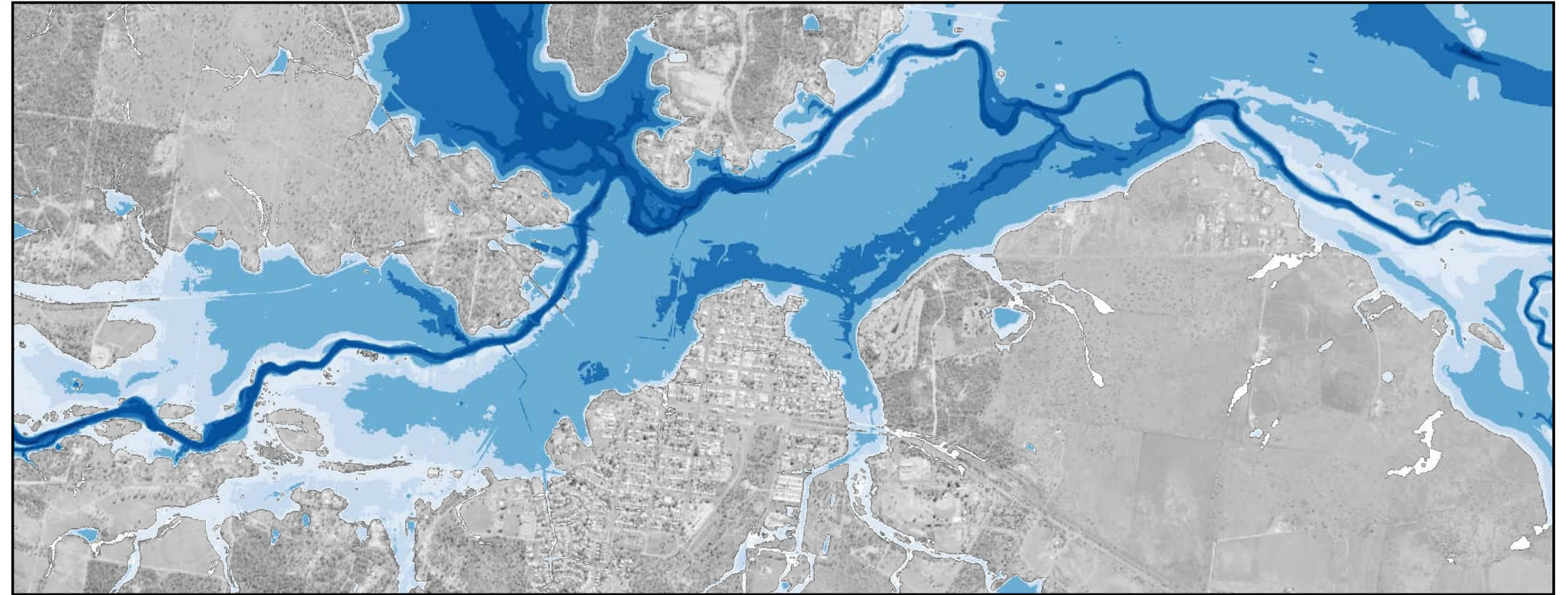


Figure:	Rev:
C-13	0





LEGEND Peak Flood Depths (m) <= 0.1 0.1 - 0.5 0.5 - 1.0 1.0 - 2.5 2.5 - 5.0 5.0 - 10.0 > 10.0 Study Area	Title: 1% AEP (2030) Event Peak Flood Depths Upper Nogoa River (Clermont)	Figure: C-14	Rev: 0
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LEGEND

Peak Flood Depths (m)

<= 0.1

0.1 - 0.5

0.5 - 1.0

1.0 - 2.5

2.5 - 5.0

5.0 - 10.0

> 10.0

Study Area

Title:

**0.5% AEP (2030) Event Peak Flood Depths
Upper Nogoa River (Clermont)**

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Scale:

0246810 km

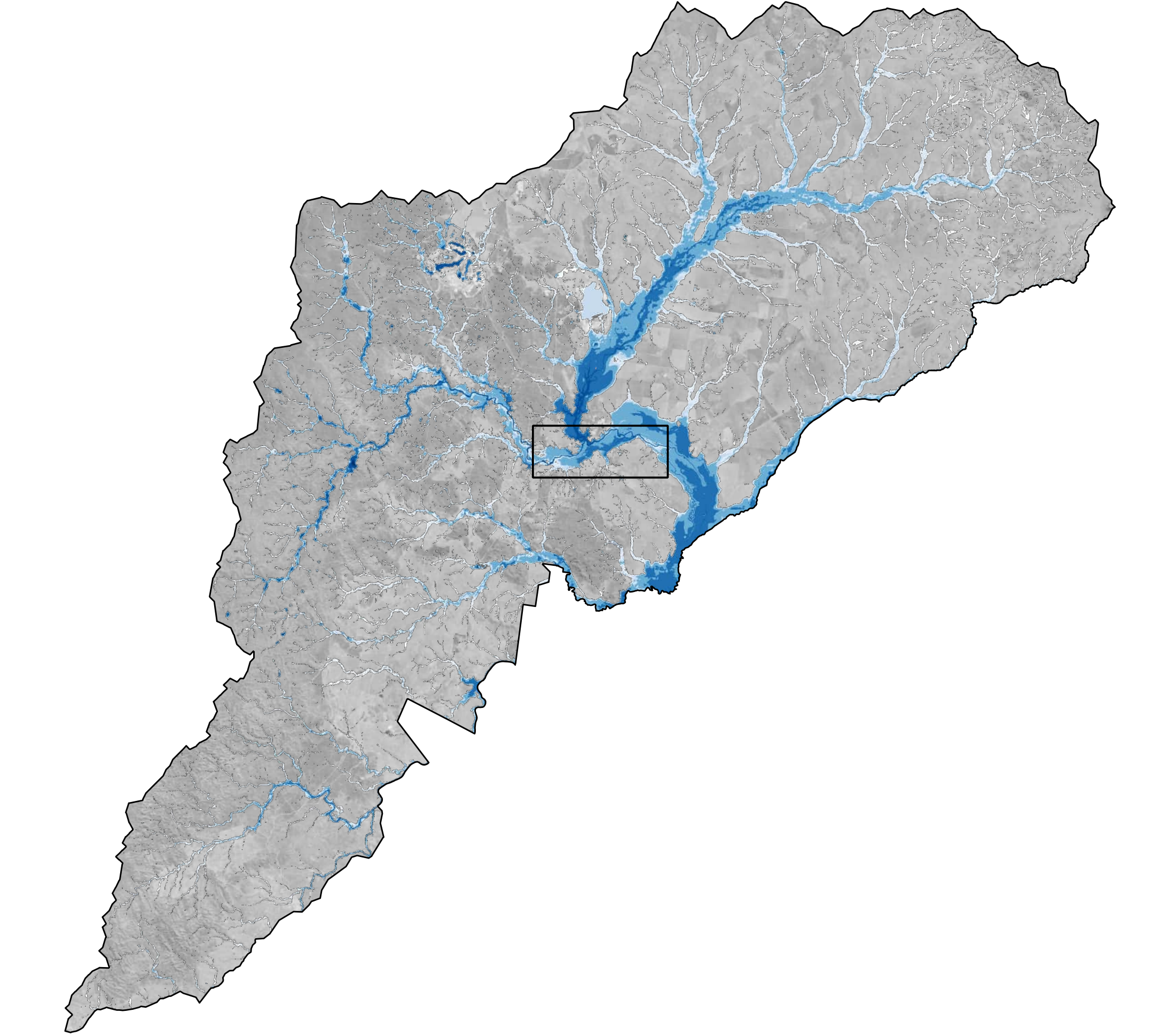
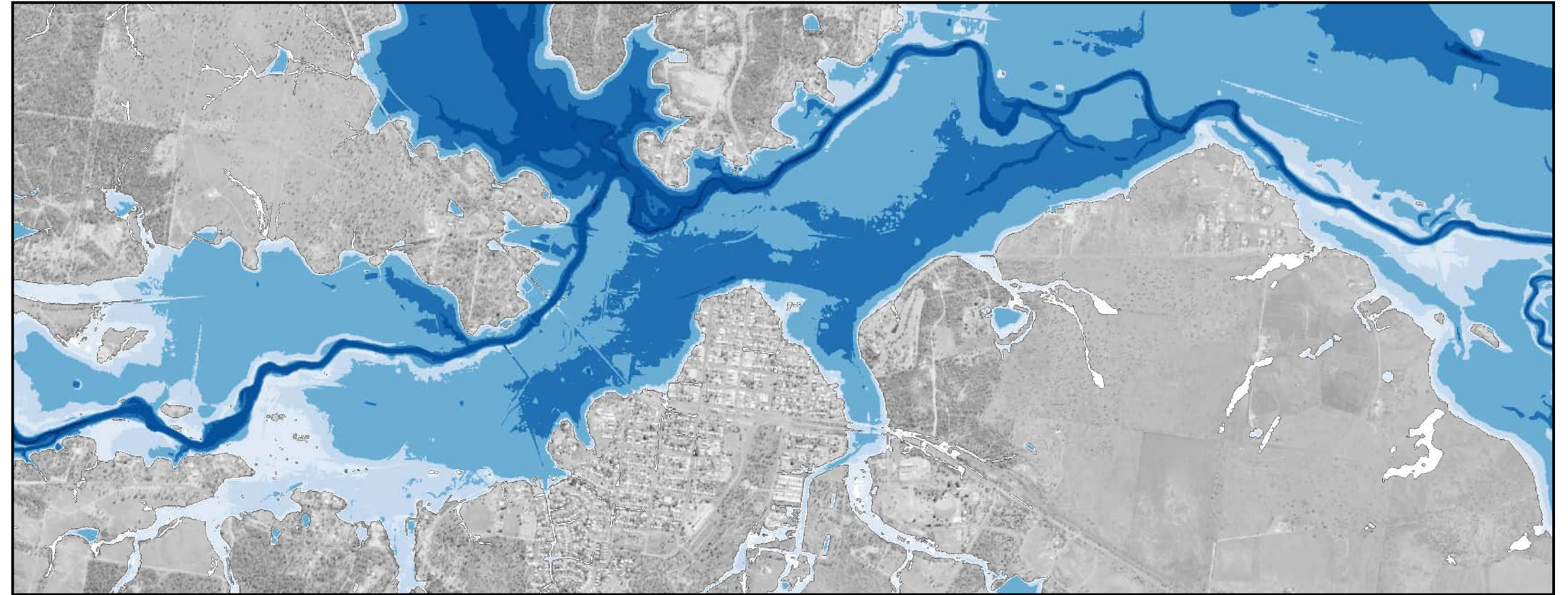
1:300,000

Figure:

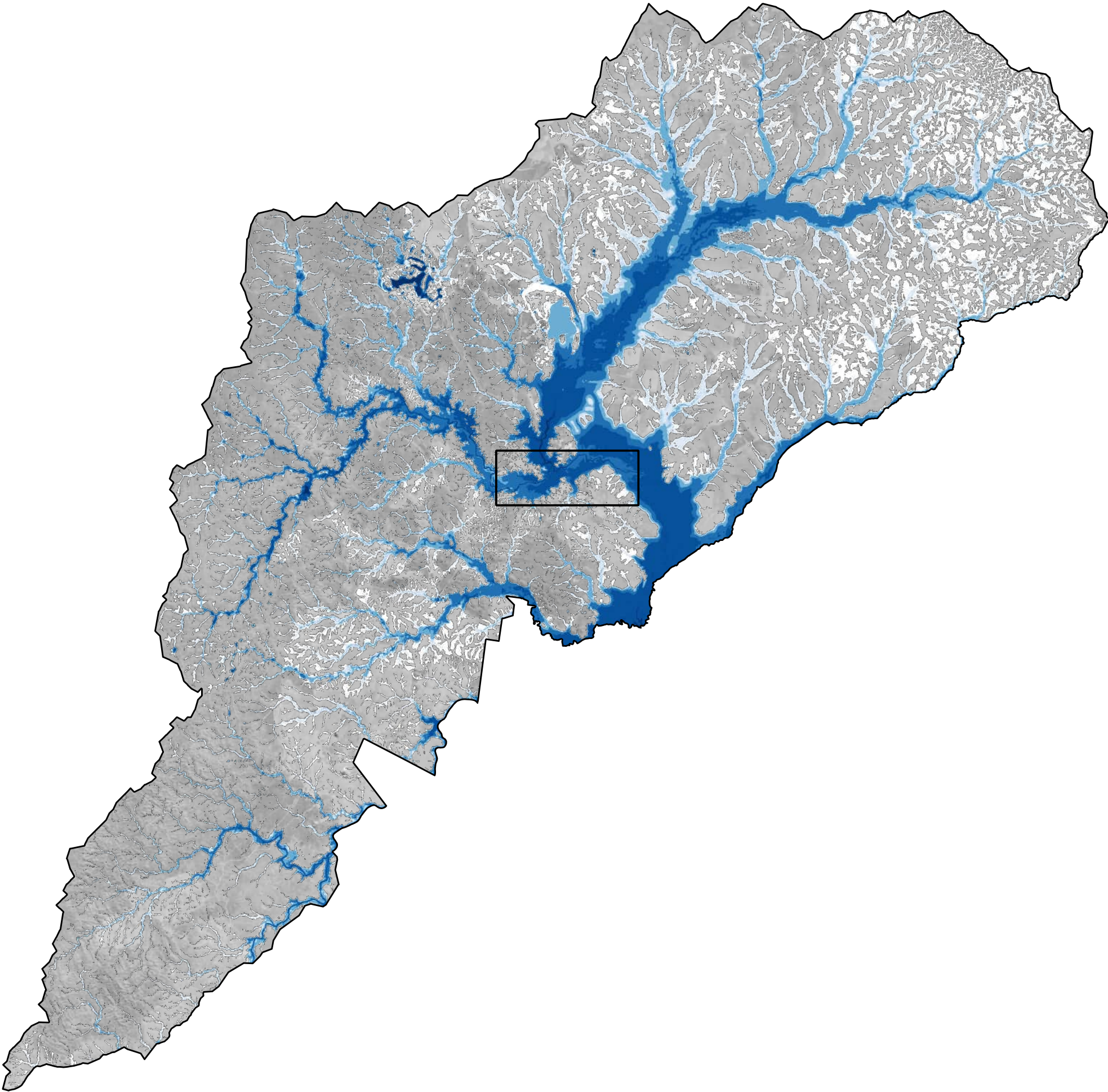
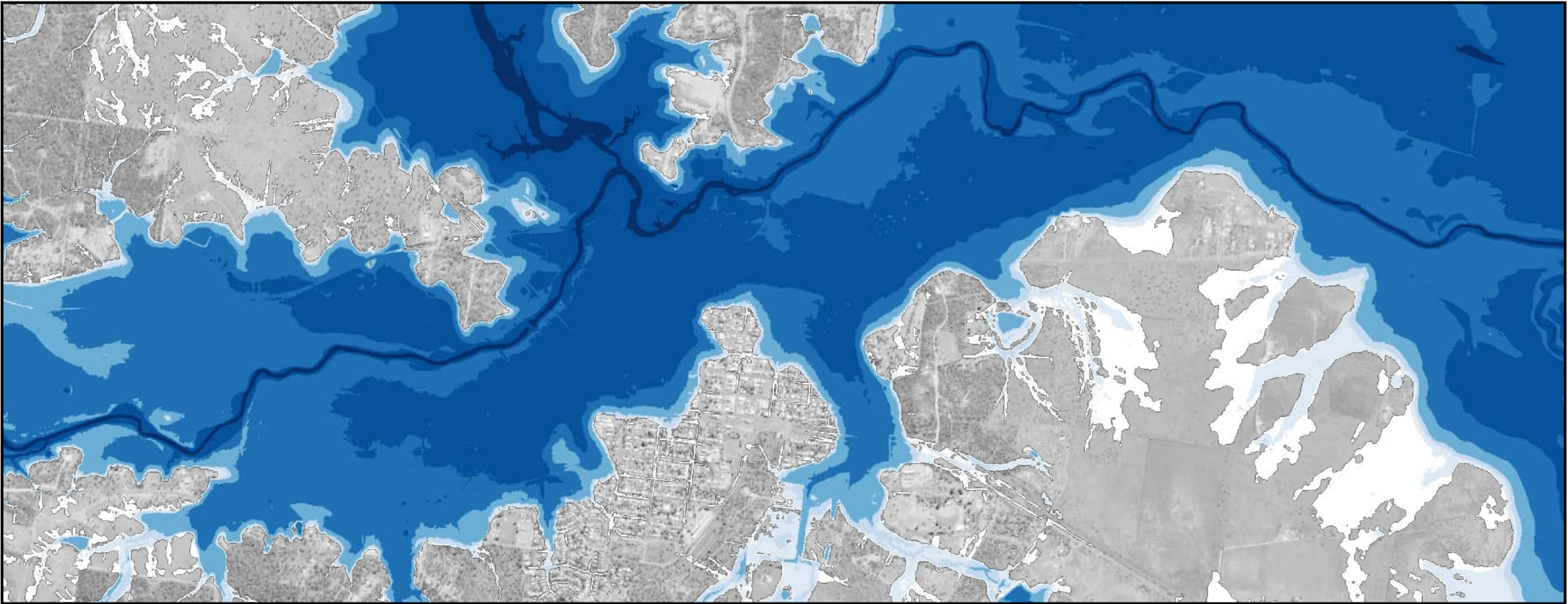
C-15

Rev:

0



LEGEND Peak Flood Depths (m) <= 0.1 0.1 - 0.5 0.5 - 1.0 1.0 - 2.5 2.5 - 5.0 5.0 - 10.0 > 10.0 Study Area	0.2% AEP (2030) Event Peak Flood Depths Upper Nogoa River (Clermont)	Figure: C-16	Rev: 0
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LEGEND

Peak Flood Depths (m)

	<= 0.1		2.5 - 5.0
	0.1 - 0.5		5.0 - 10.0
	0.5 - 1.0		> 10.0
	1.0 - 2.5		Study Area

Title:

PMF Event (2030) Peak Flood Depths Upper Nogoa River (Clermont)

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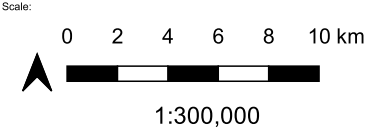
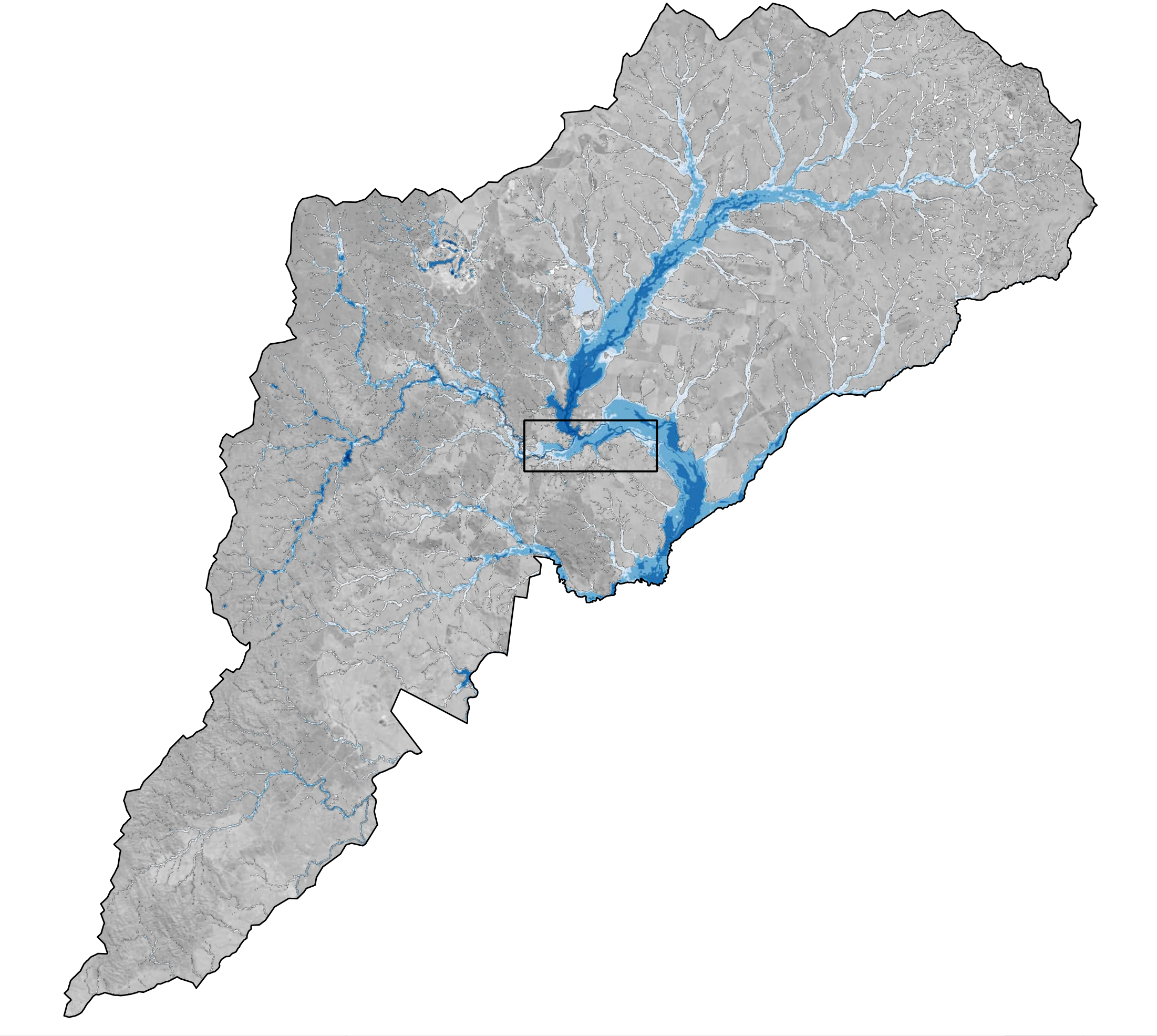
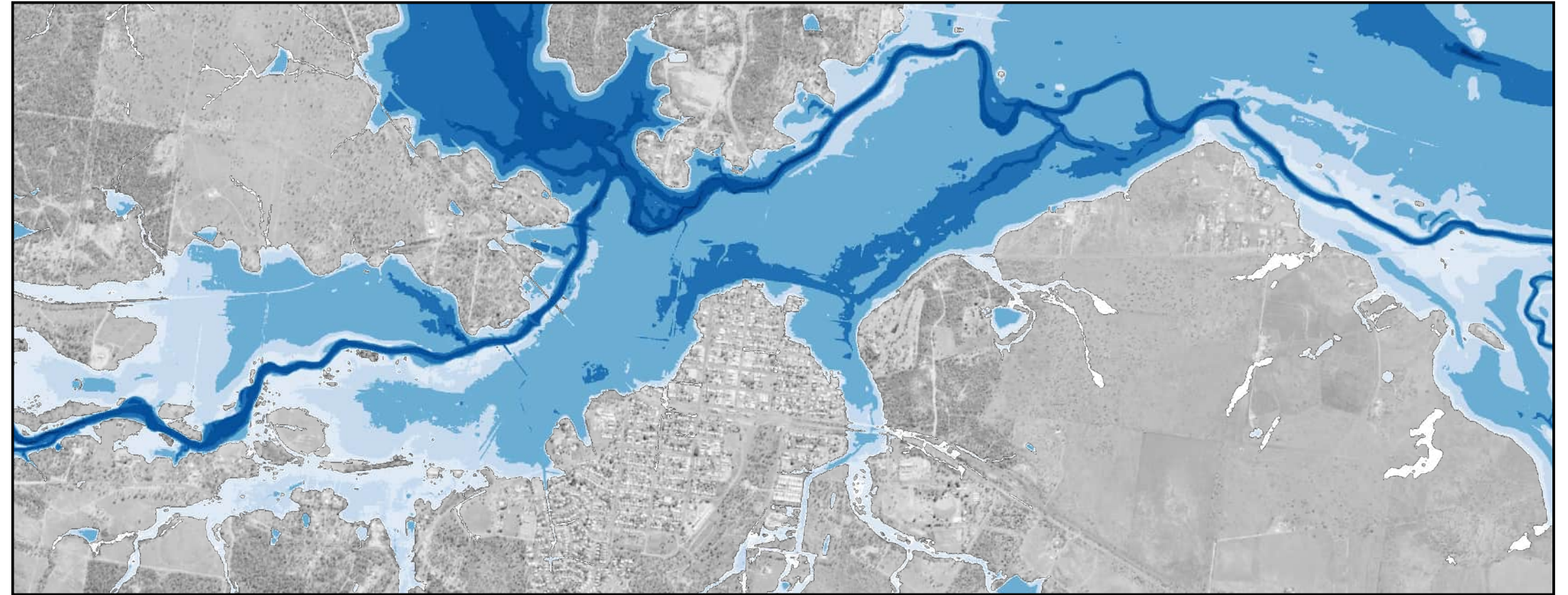
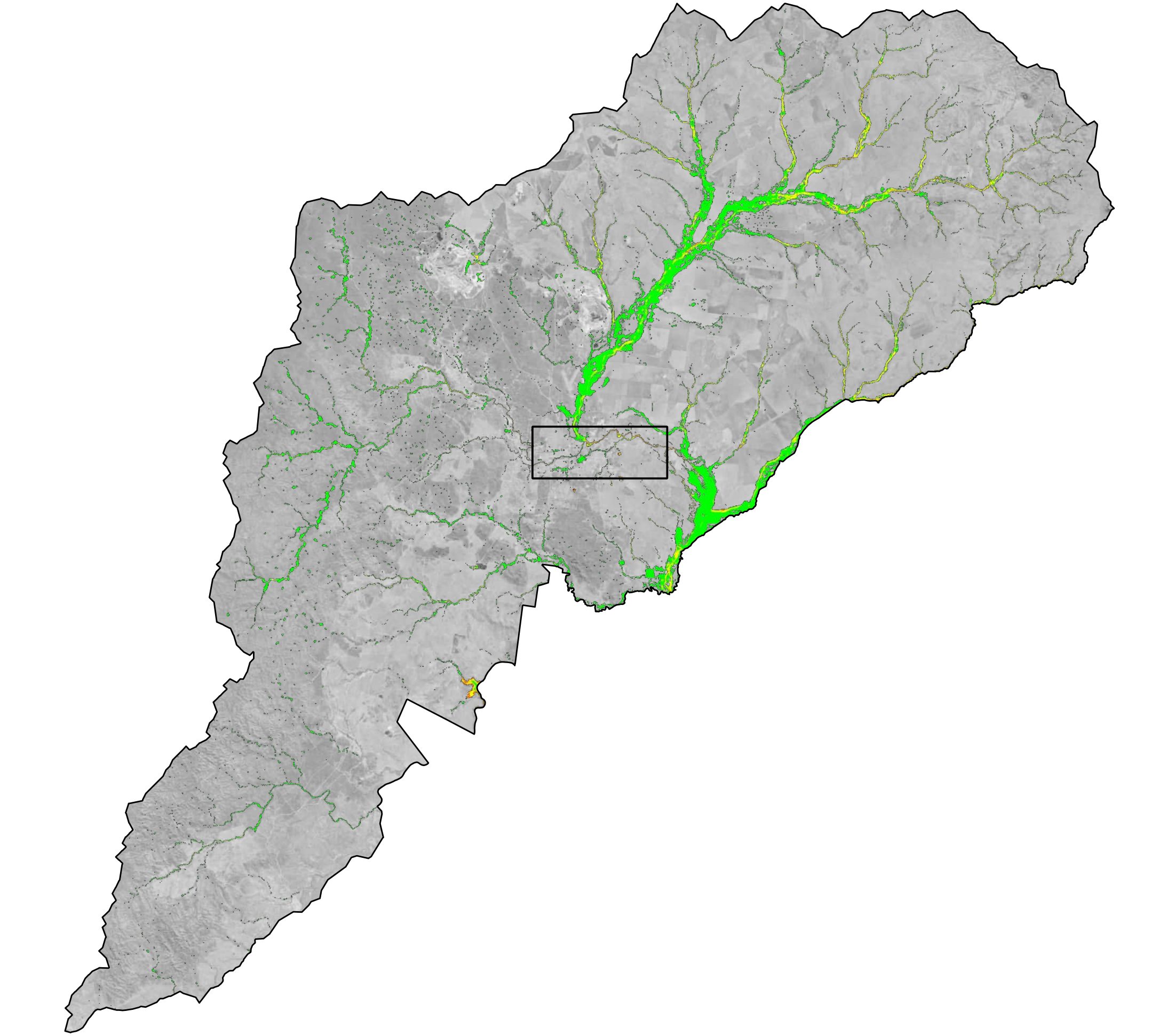
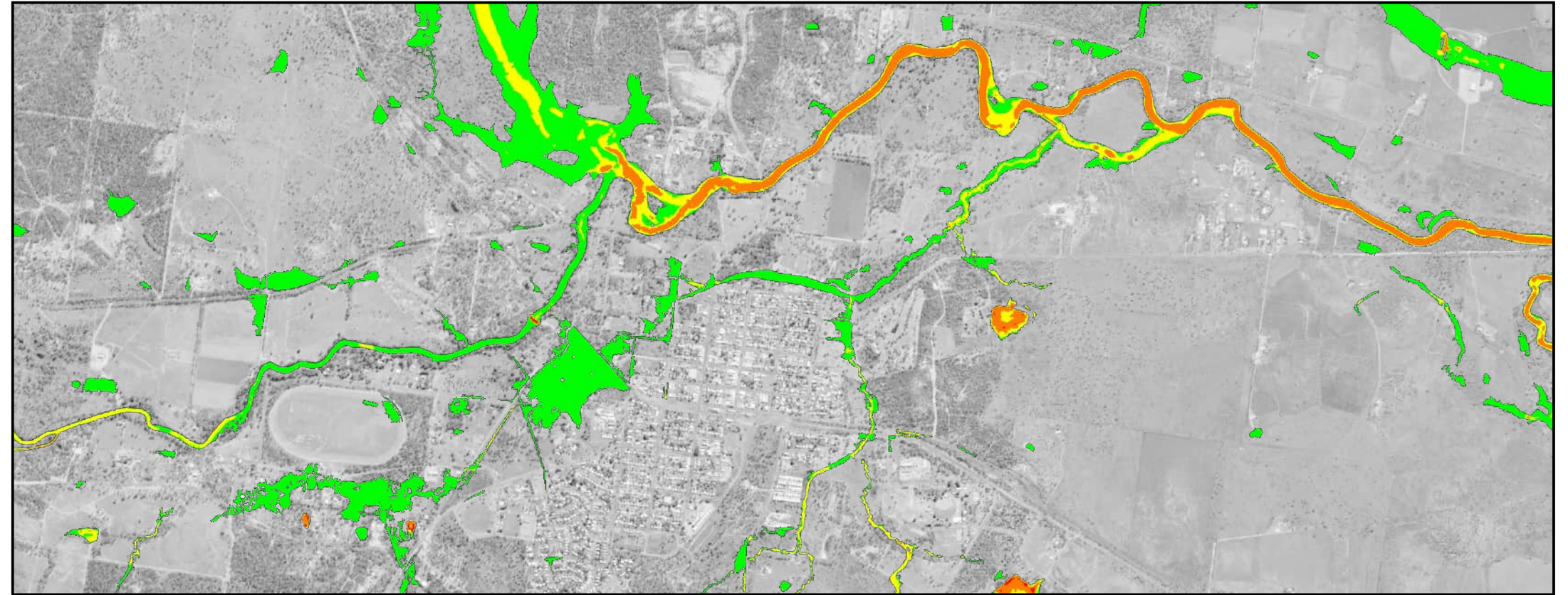


Figure:	C-17	Rev:	0



LEGEND Peak Flood Depths (m) <= 0.1 0.1 - 0.5 0.5 - 1.0 1.0 - 2.5 2.5 - 5.0 5.0 - 10.0 > 10.0 Study Area	Title: 1% AEP (2100) Event Peak Flood Depths Upper Nogoa River (Clermont)	Figure: C-18	Rev: 0
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LEGEND

Peak Flood Velocities (m/s)

<= 0.5

0.5 - 1.0

1.0 - 2.0

2.0 - 4.0

> 4.0

Study Area

Title:

**50% AEP (2030) Event Peak Flood Velocities
Upper Nogoa River (Clermont)**

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Scale:

0

2

4

6

8

10 km

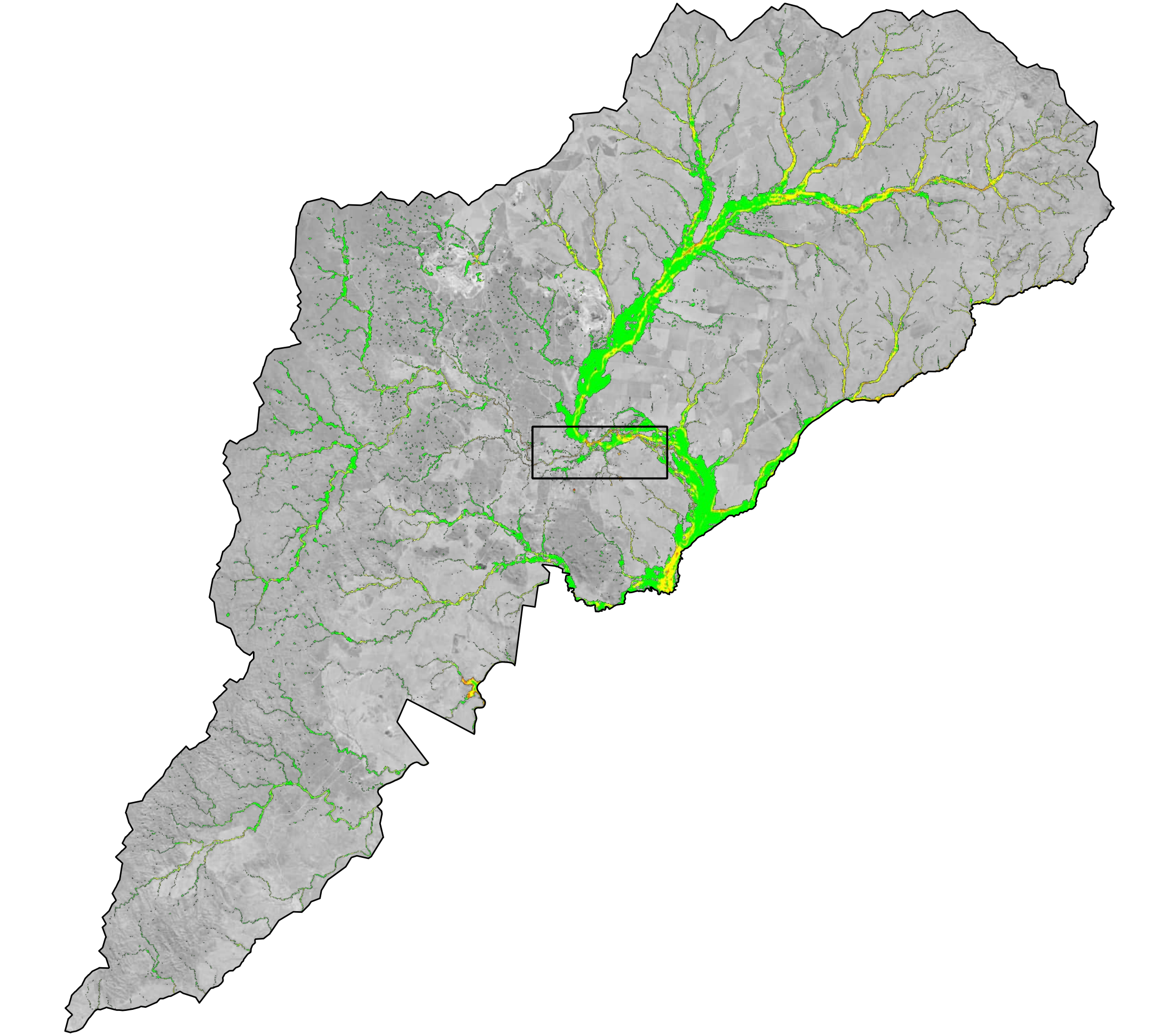
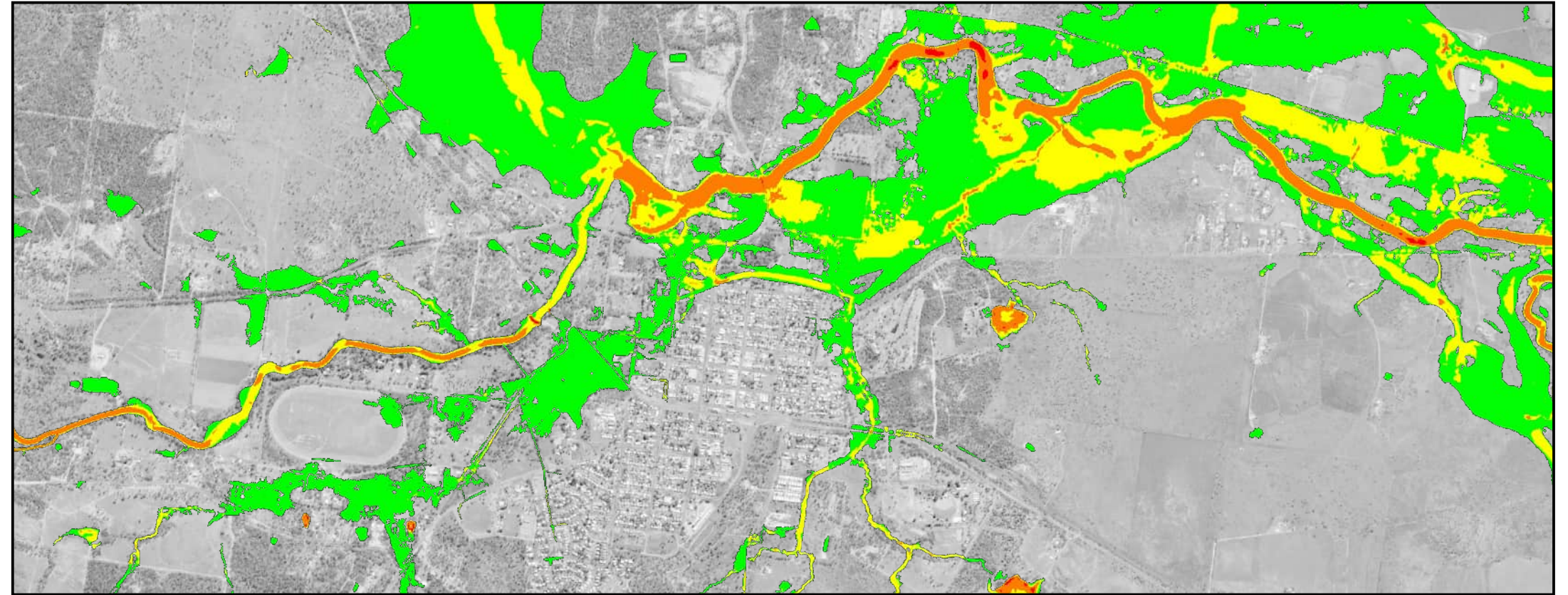
1:300,000

Figure:

C-19

Rev:

0



LEGEND

Peak Flood Velocities (m/s)

<= 0.5

0.5 - 1.0

1.0 - 2.0

2.0 - 4.0

> 4.0

Study Area

Title:

20% AEP (2030) Event Peak Flood Velocities
Upper Nogoa River (Clermont)

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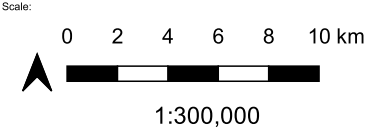
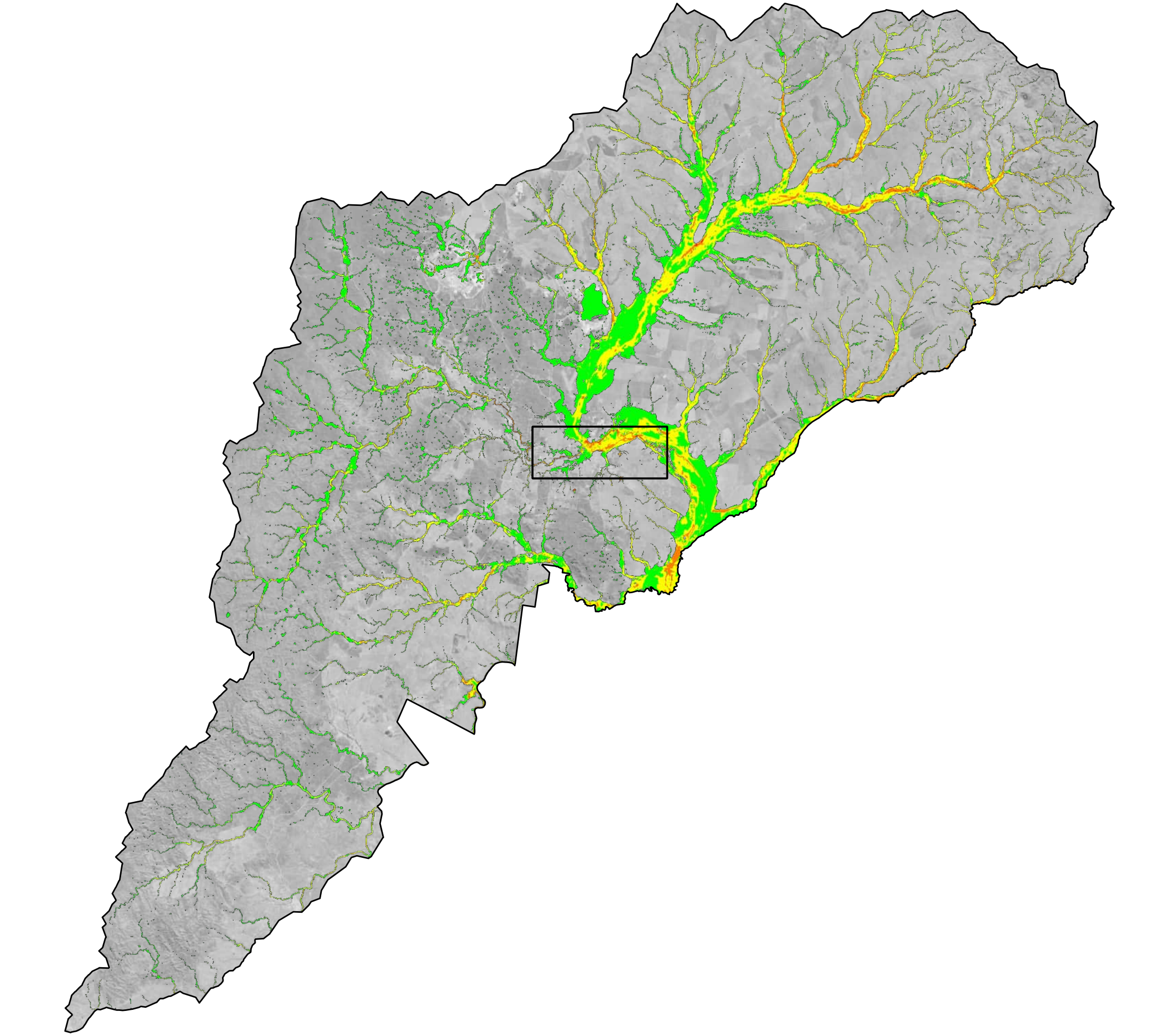
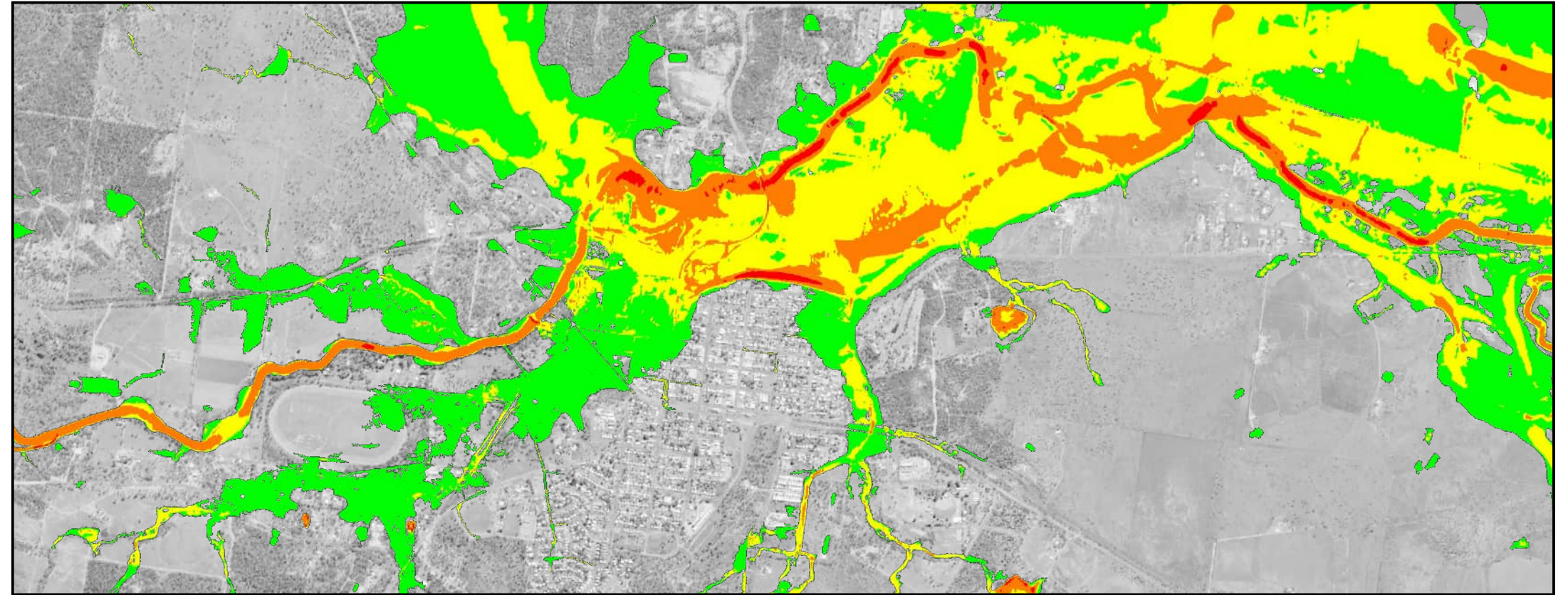


Figure:

C-20

Rev:

0



LEGEND

Peak Flood Velocities (m/s)

	≤ 0.5		2.0 - 4.0
	0.5 - 1.0		> 4.0
	1.0 - 2.0		Study Area

Title:

5% AEP (2030) Event Peak Flood Velocities Upper Nogoa River (Clermont)

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File: \\profile001\data\$\Water_Resources\Projects\BEW571 - Upper Nogoa and Mackenzie\G - GIS\Workspaces\260630_Mapping_Atlas.qgz

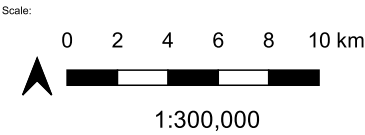
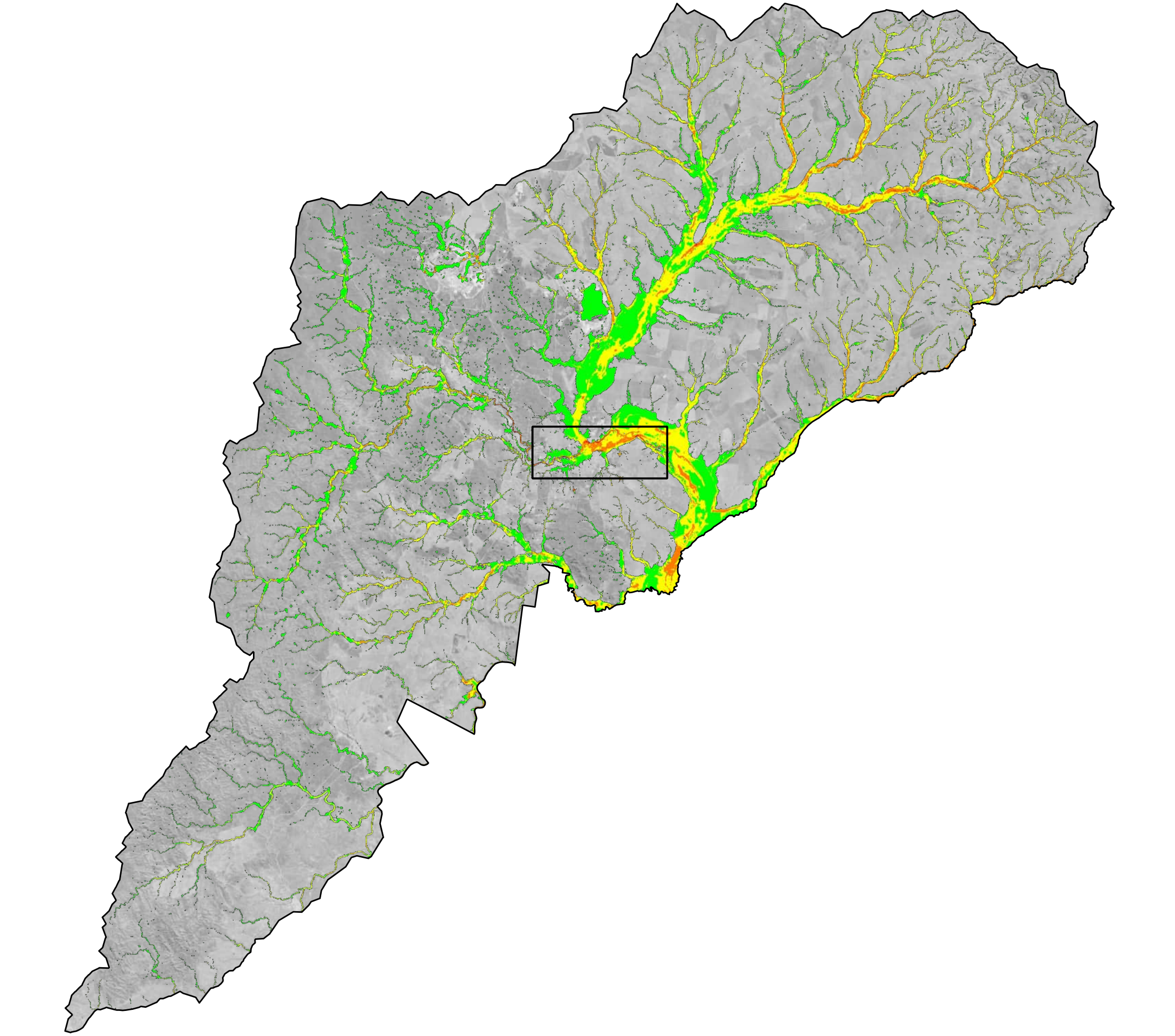
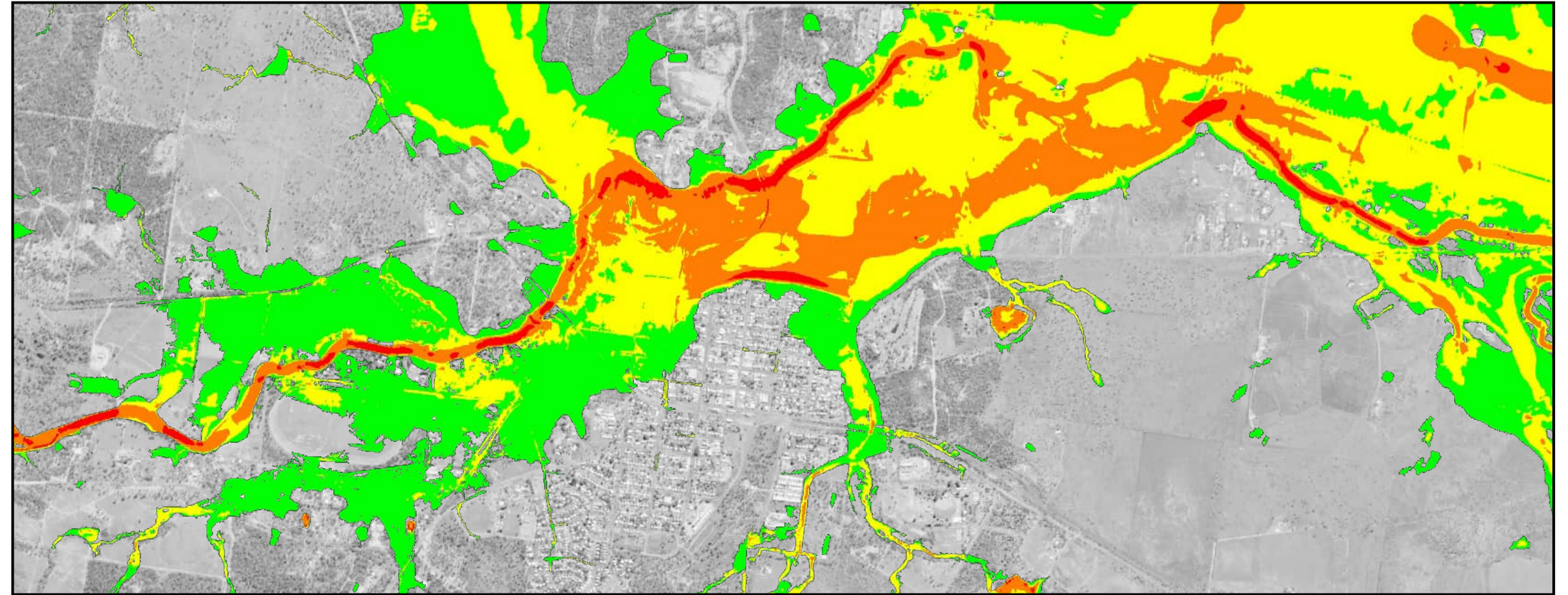


Figure:	Rev:
C-21	0





LEGEND

Peak Flood Velocities (m/s)

	<= 0.5		2.0 - 4.0
	0.5 - 1.0		> 4.0
	1.0 - 2.0		Study Area

Title:

2% AEP (2030) Event Peak Flood Velocities Upper Nogoa River (Clermont)

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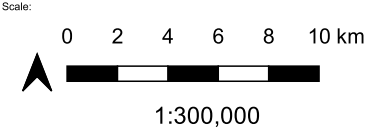
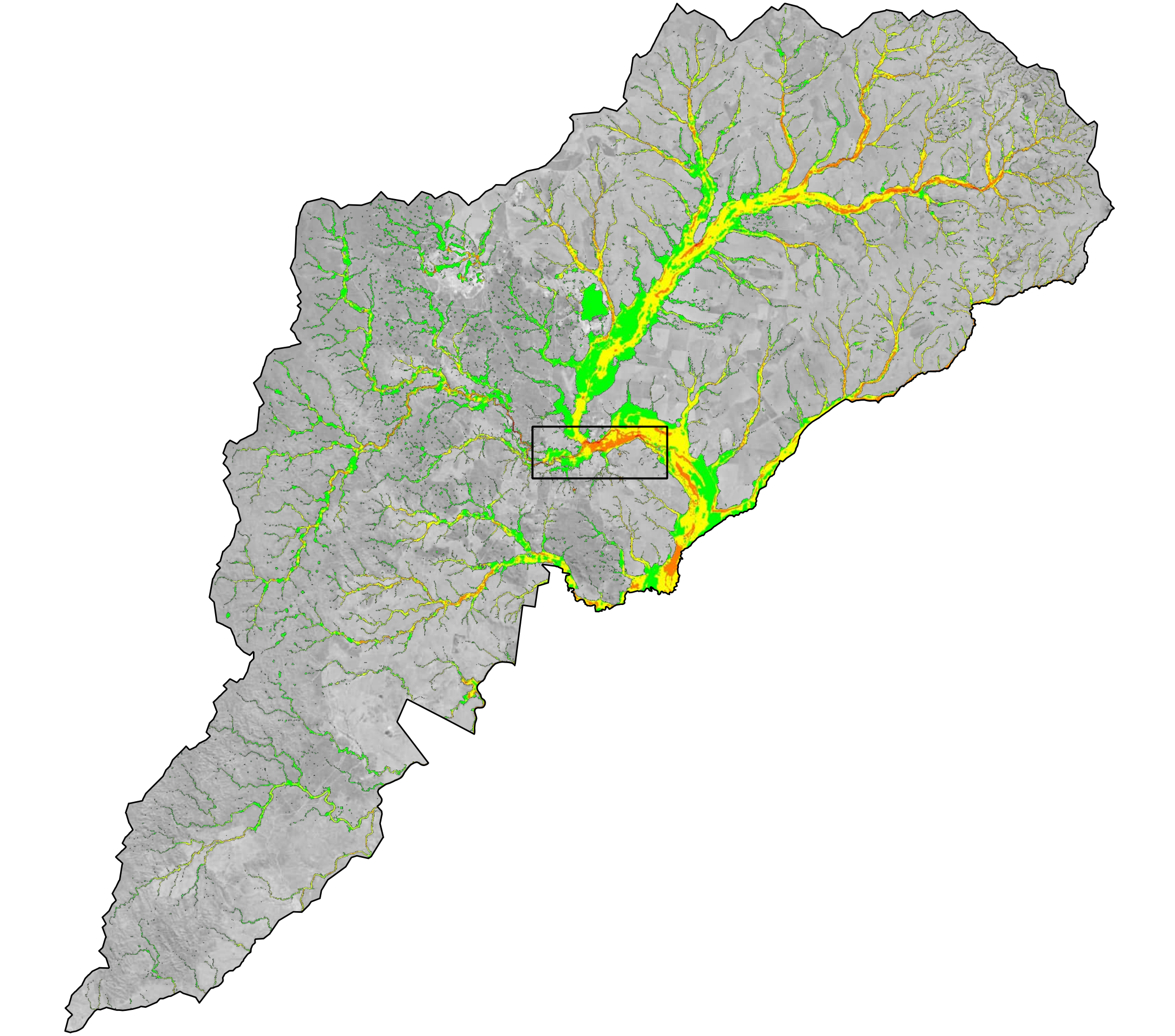
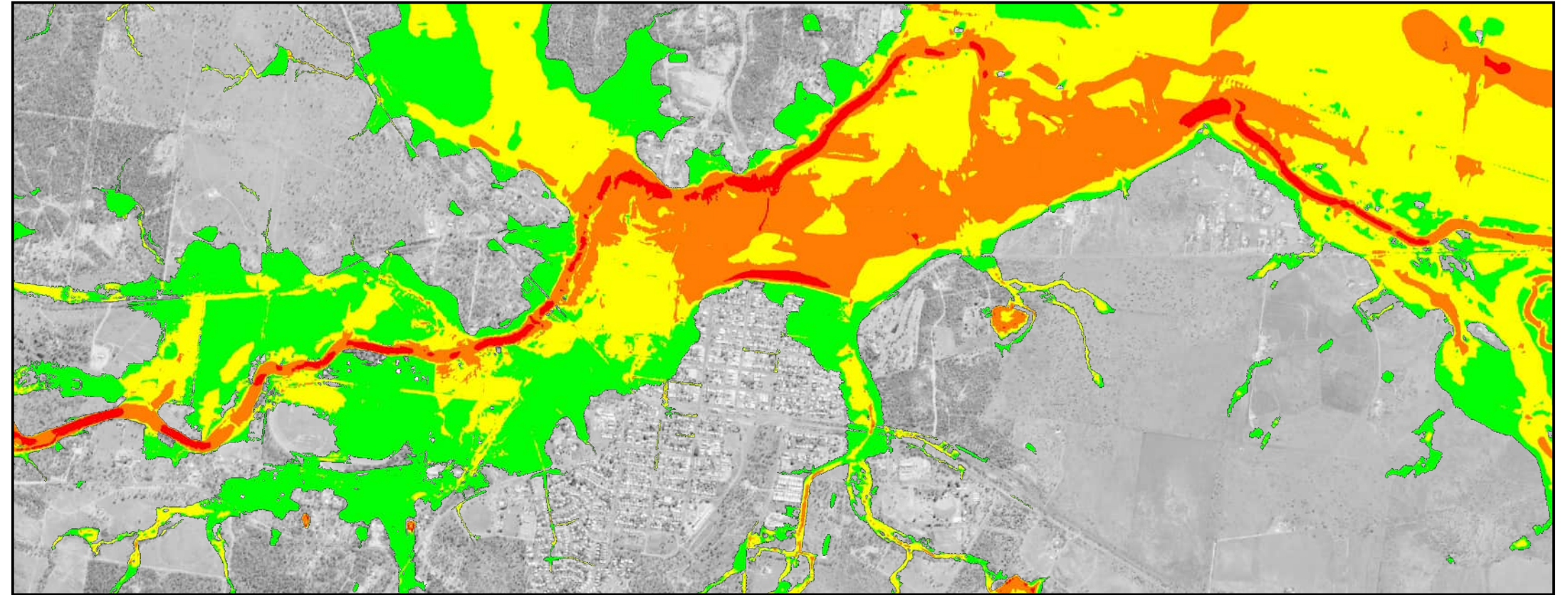


Figure:	Rev:
C-22	0
	



LEGEND

Peak Flood Velocities (m/s)

	≤ 0.5		2.0 - 4.0
	0.5 - 1.0		> 4.0
	1.0 - 2.0		Study Area

Title:

1% AEP (2030) Event Peak Flood Velocities Upper Nogoa River (Clermont)

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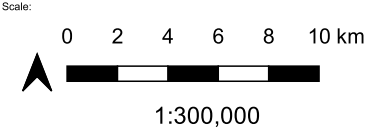


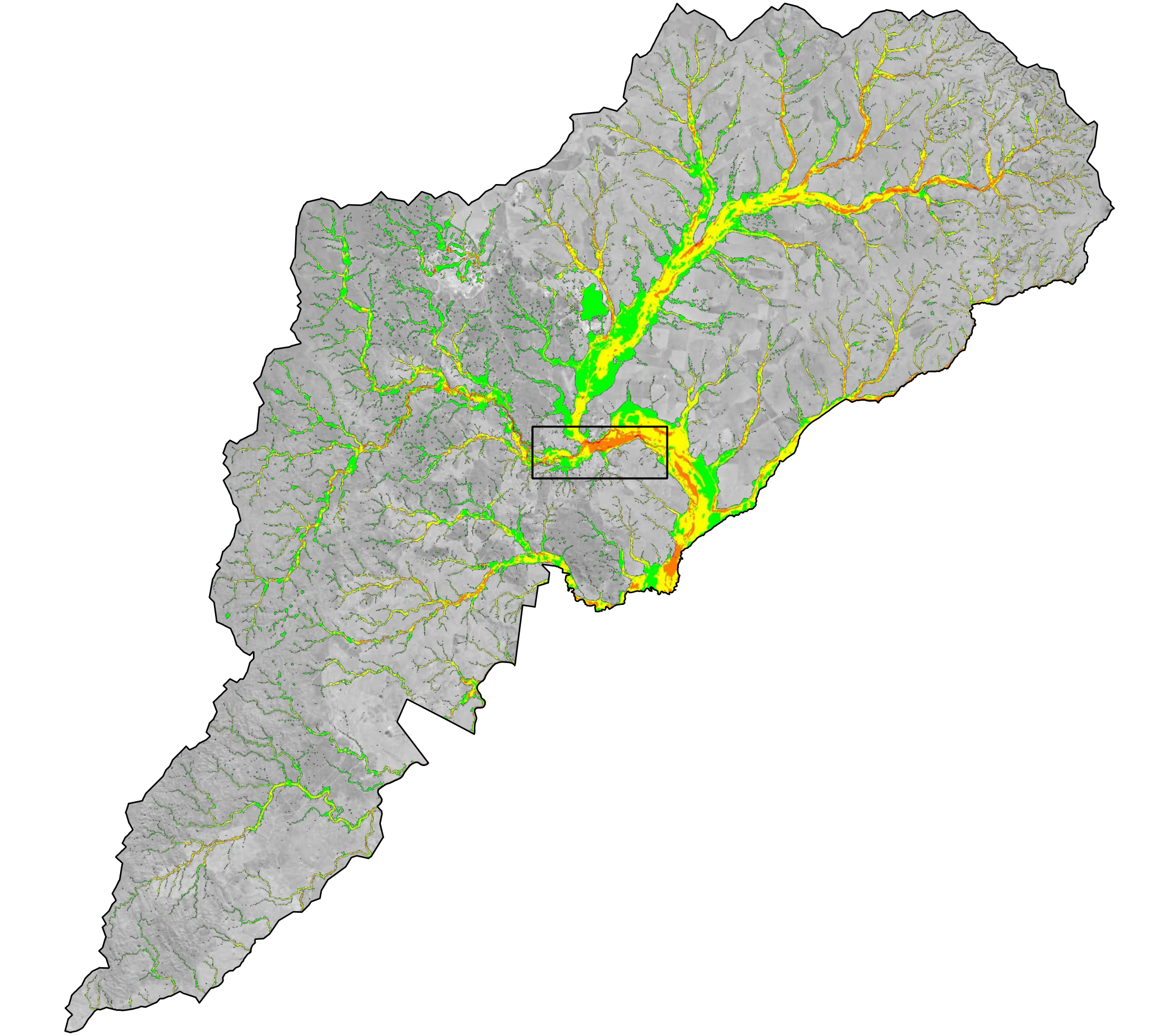
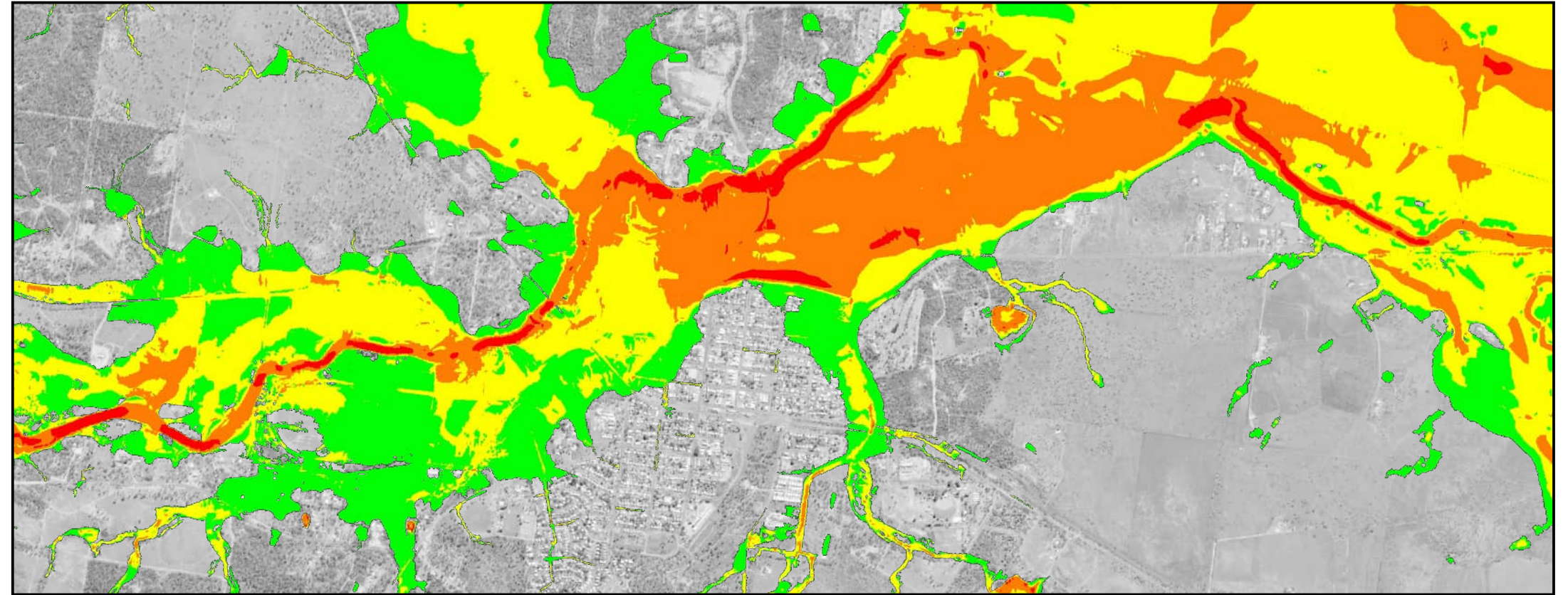
Figure:

C-23

Rev:

0





LEGEND

Peak Flood Velocities (m/s)

	<= 0.5		2.0 - 4.0
	0.5 - 1.0		> 4.0
	1.0 - 2.0		Study Area

Title:

**0.5% AEP (2030) Event Peak Flood Velocities
Upper Nogoa River (Clermont)**

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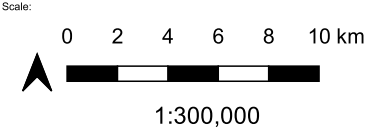
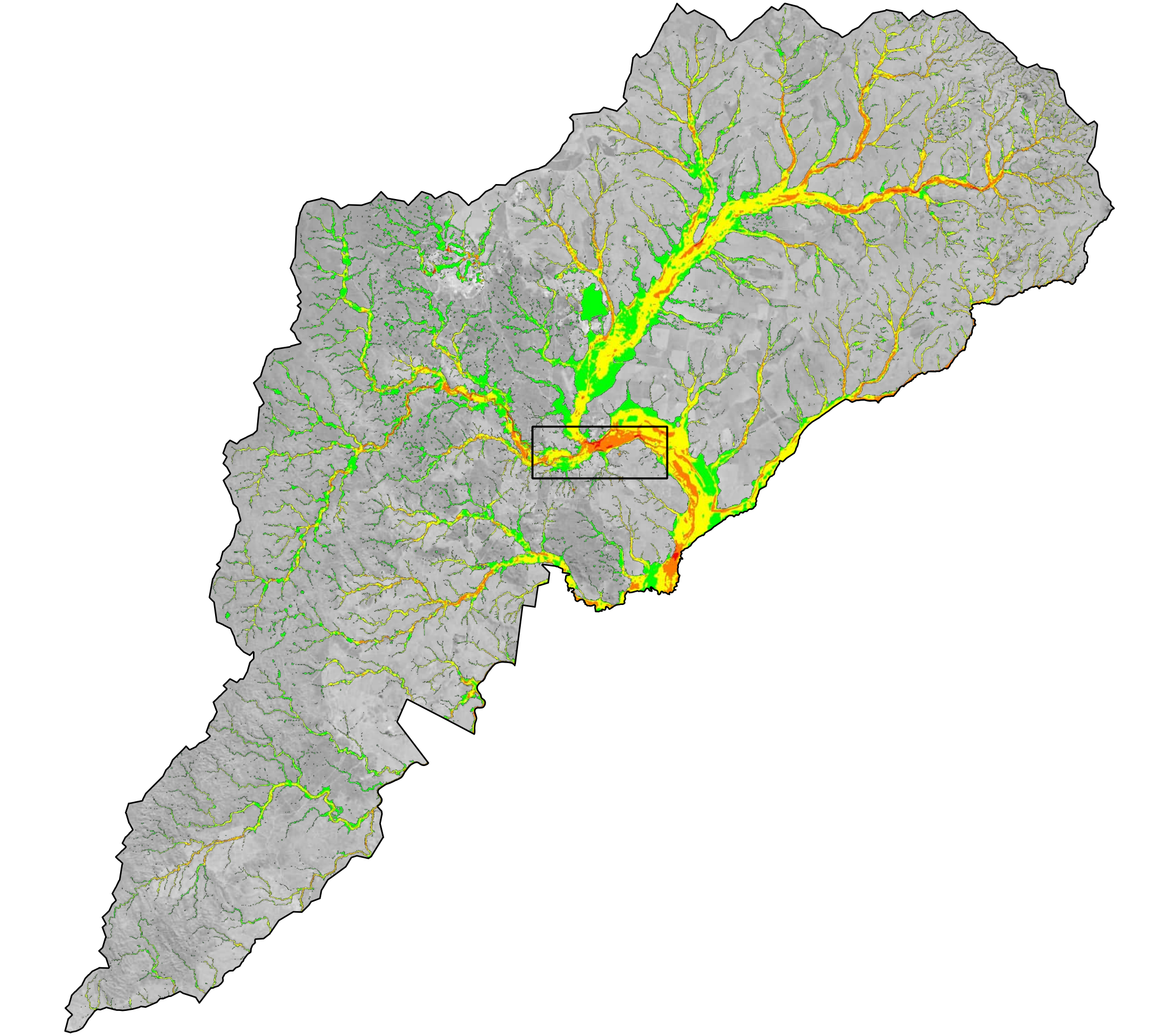
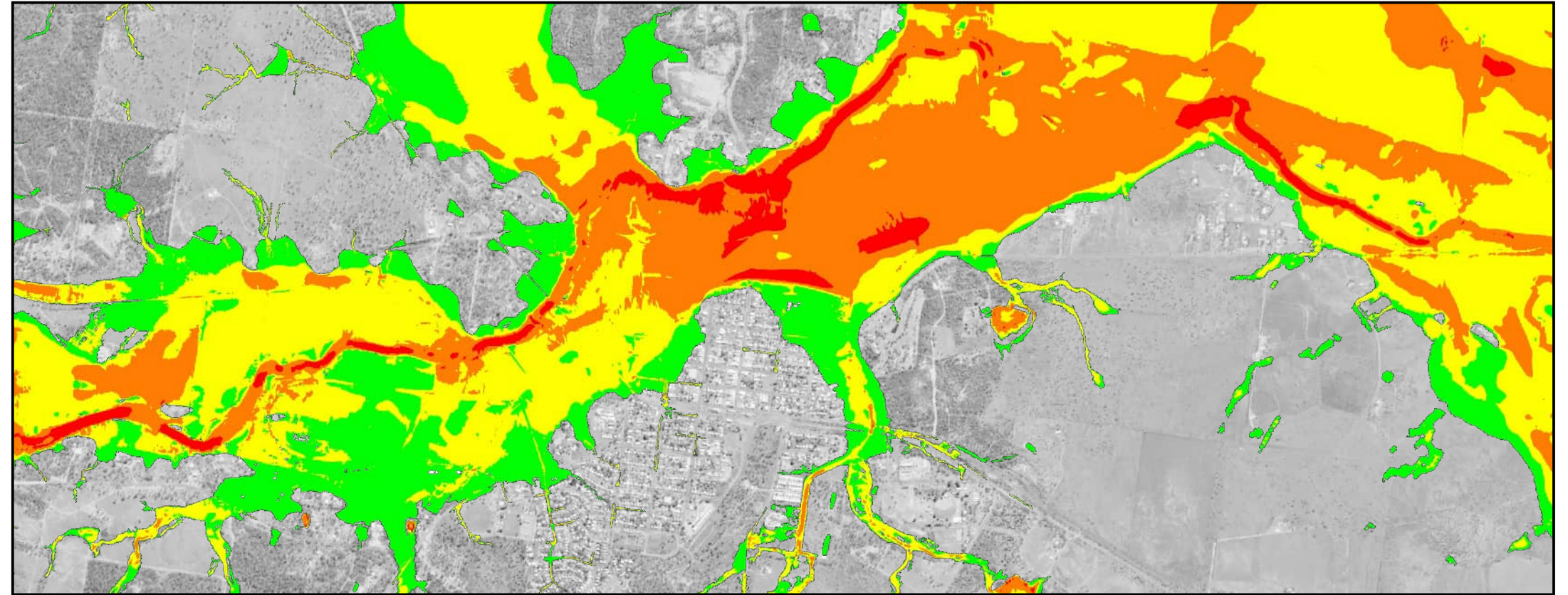


Figure:	Rev:
C-24	0



LEGEND

Peak Flood Velocities (m/s)

	≤ 0.5		2.0 - 4.0
	0.5 - 1.0		> 4.0
	1.0 - 2.0		Study Area

Title:

0.2% AEP (2030) Event Peak Flood Velocities Upper Nogoa River (Clermont)

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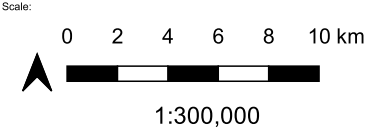
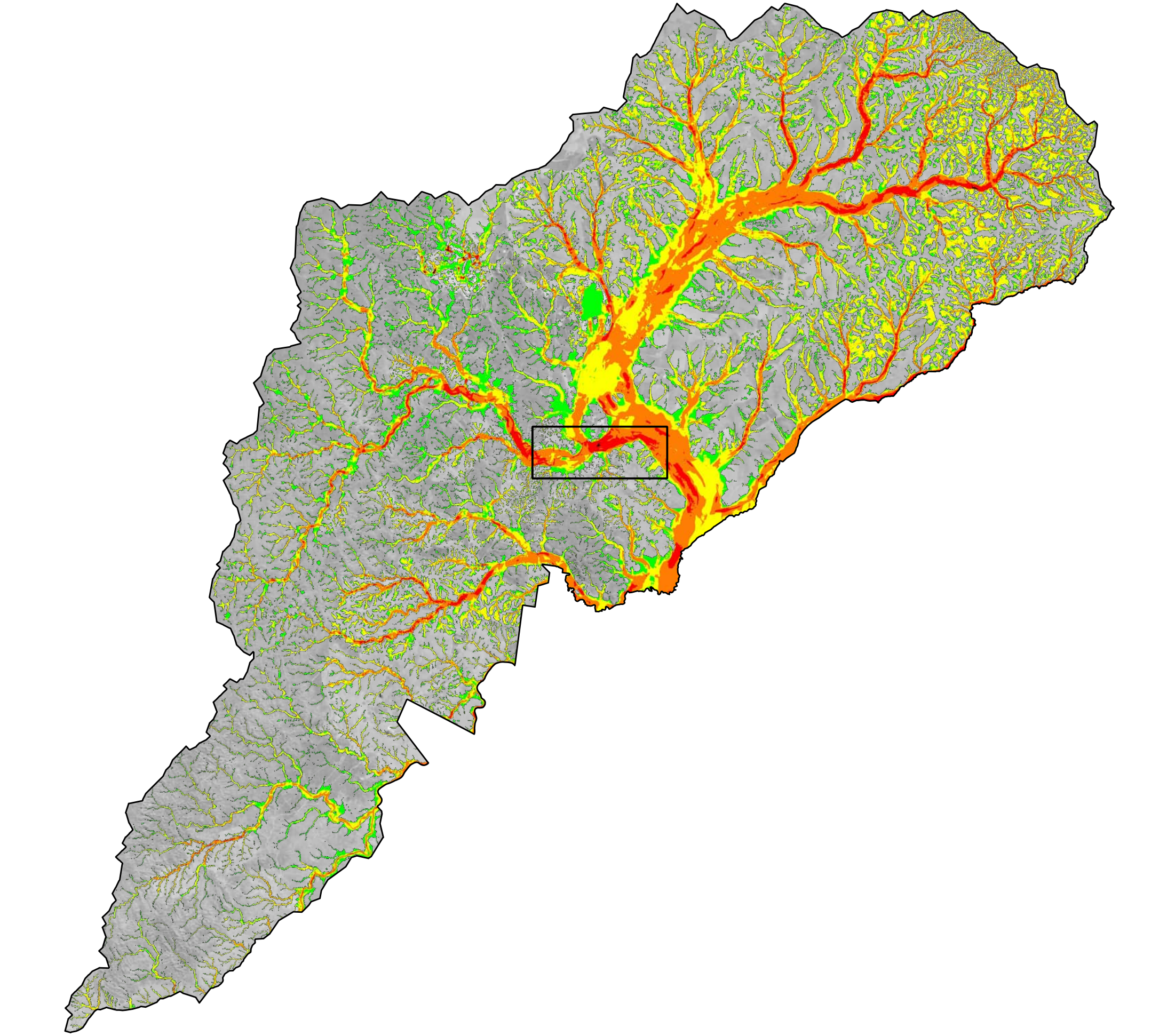
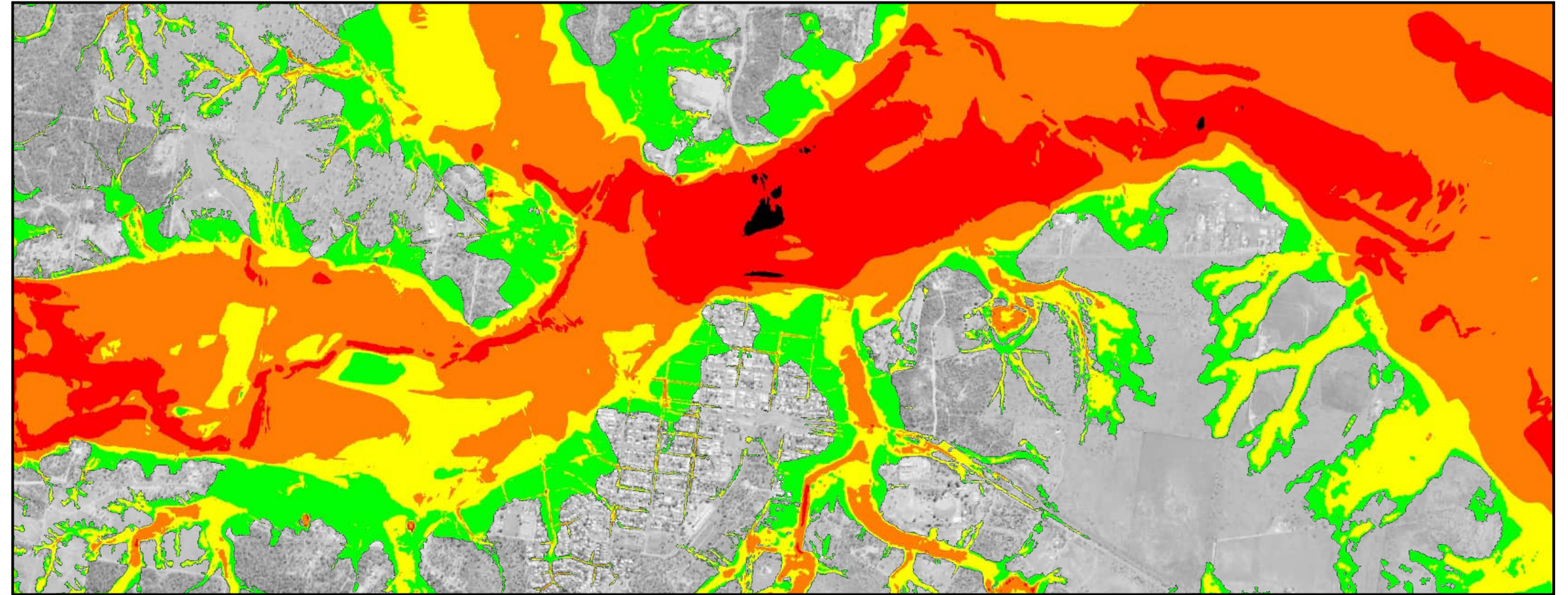


Figure:	Rev:
C-25	0





LEGEND

Peak Flood Velocities (m/s)

	<= 0.5		2.0 - 4.0
	0.5 - 1.0		> 4.0
	1.0 - 2.0		Study Area

Title:

PMF Event (2030) Peak Flood Velocities Upper Nogoa River (Clermont)

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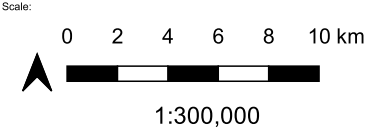
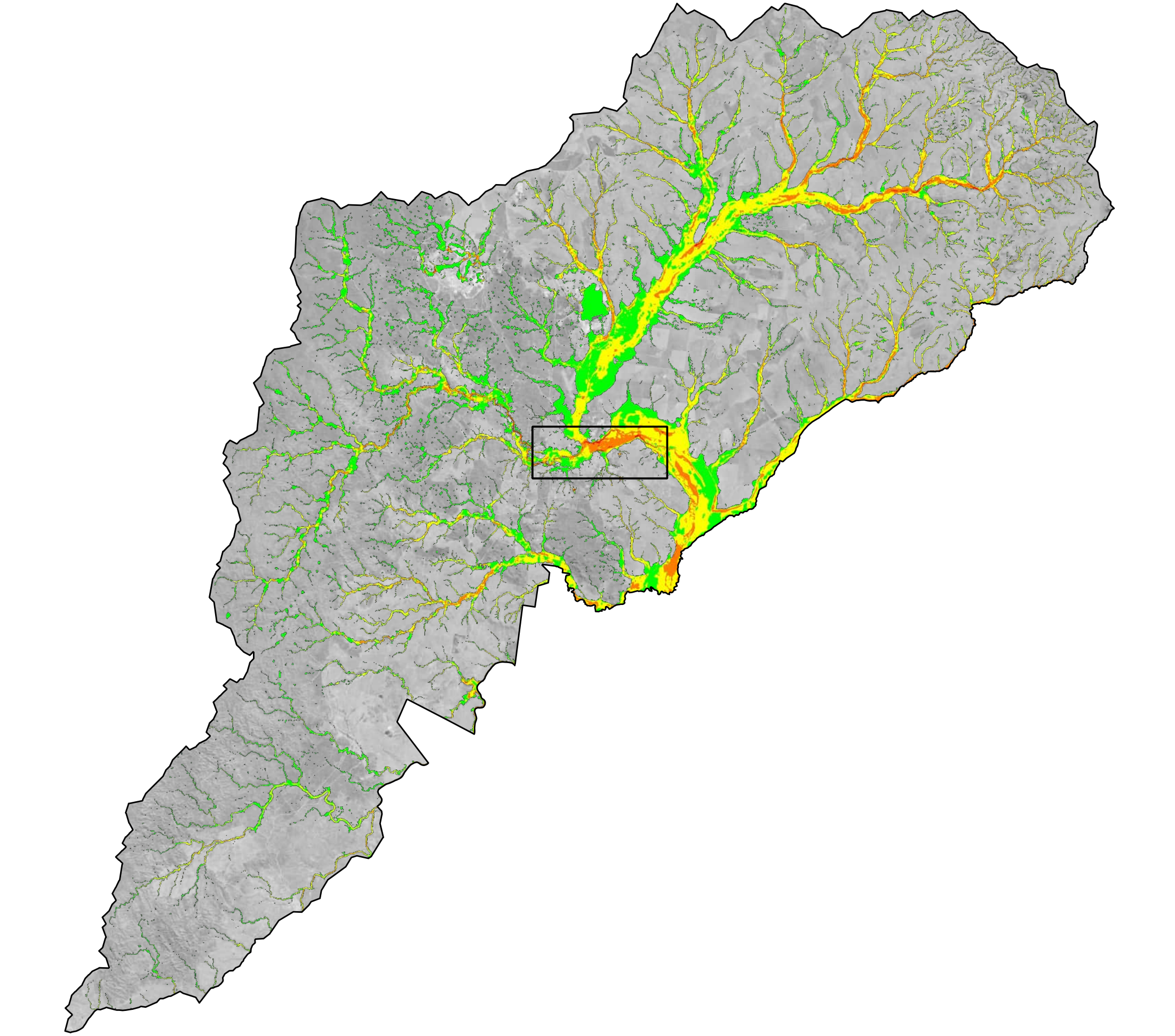
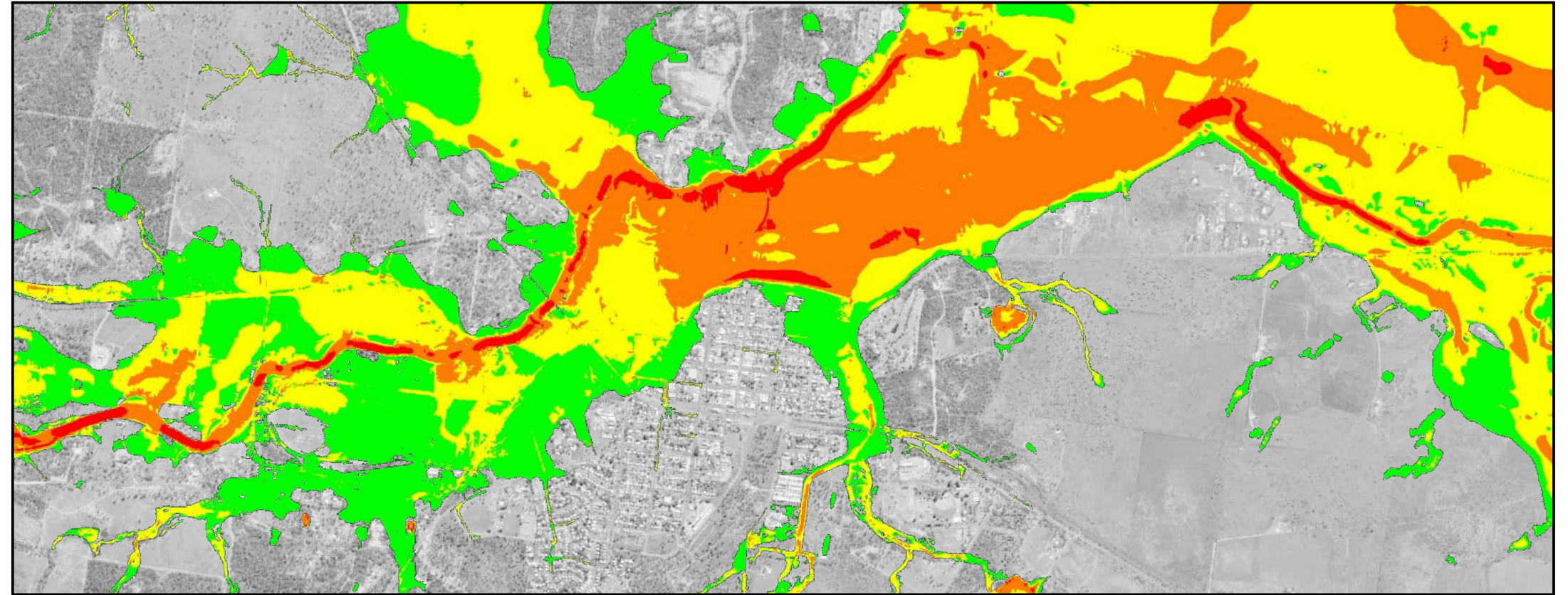


Figure:	Rev:
C-26	0





LEGEND

Peak Flood Velocities (m/s)

	≤ 0.5		2.0 - 4.0
	0.5 - 1.0		> 4.0
	1.0 - 2.0		Study Area

Title:

1% AEP (2100) Event Peak Flood Velocities Upper Nogoa River (Clermont)

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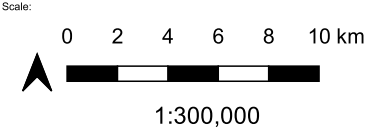
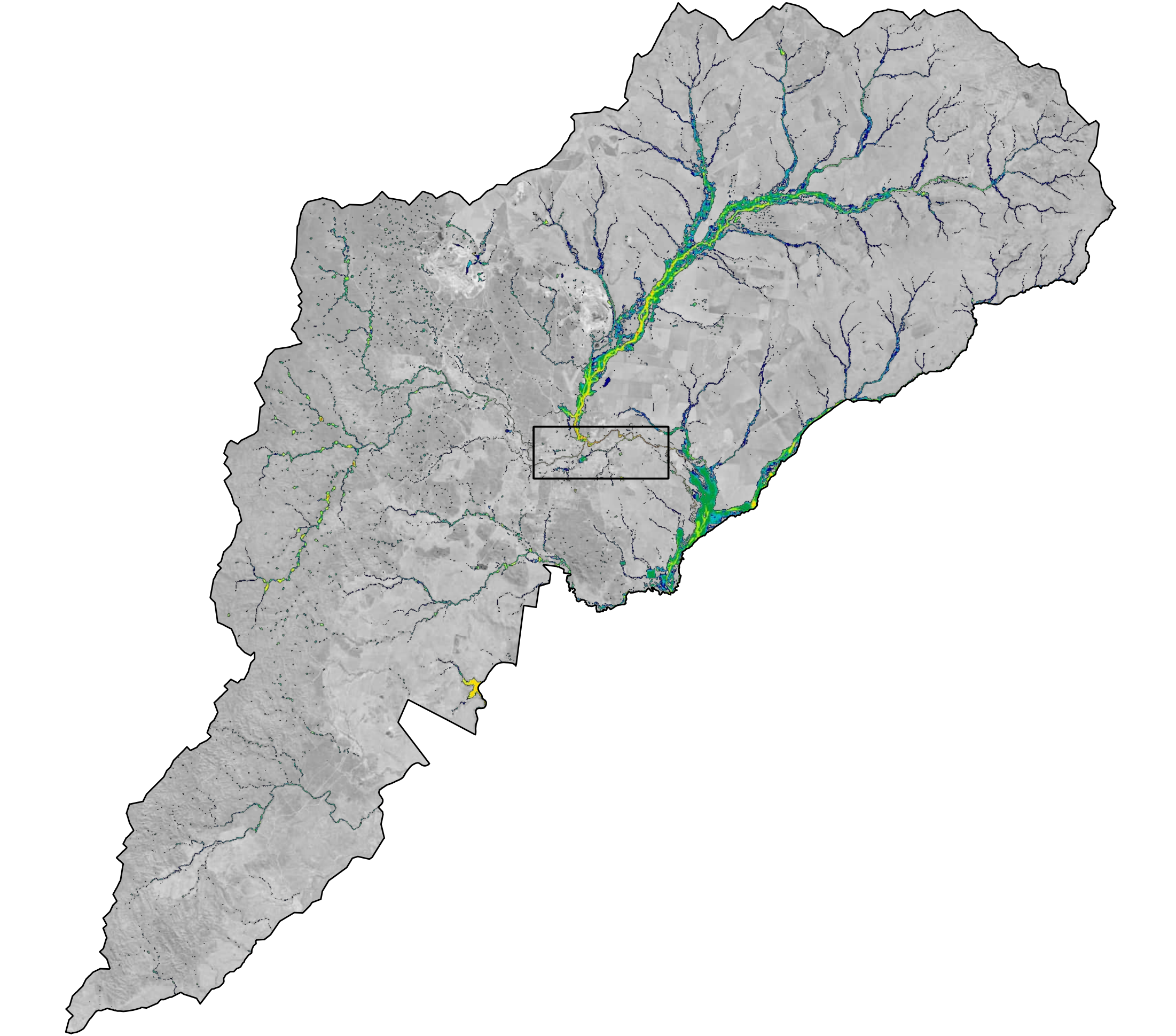
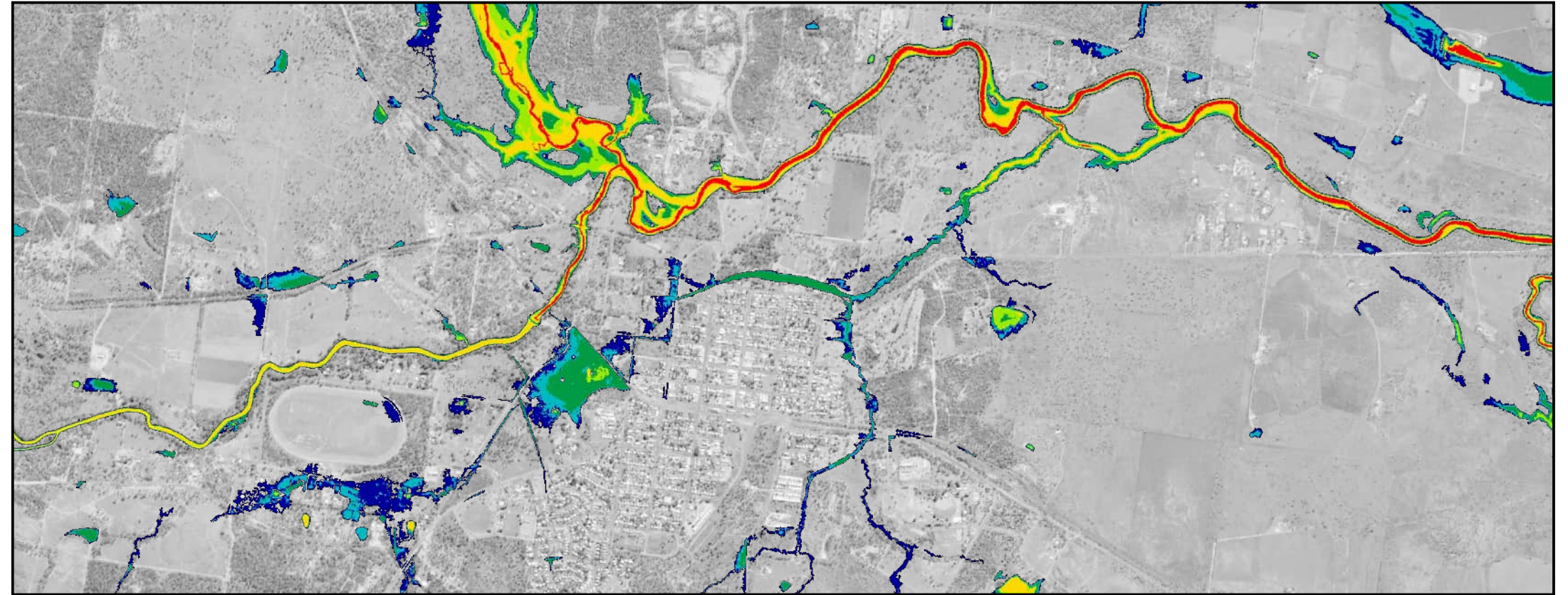


Figure:	Rev:
C-27	0





LEGEND

Flood Hazards (AIDR)

	H1		H4
	H2		H5
	H3		H6
	Study Area		

Title:

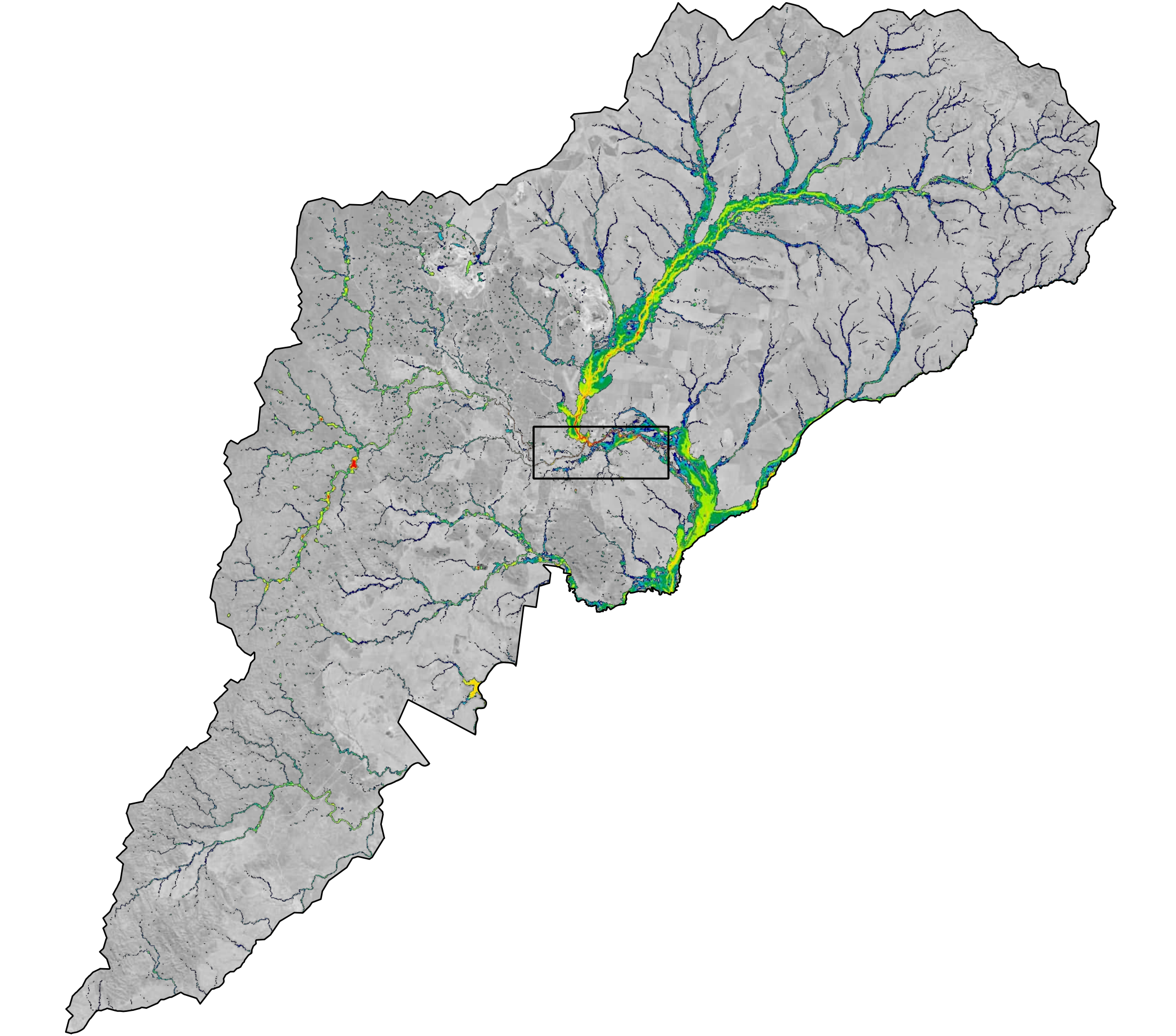
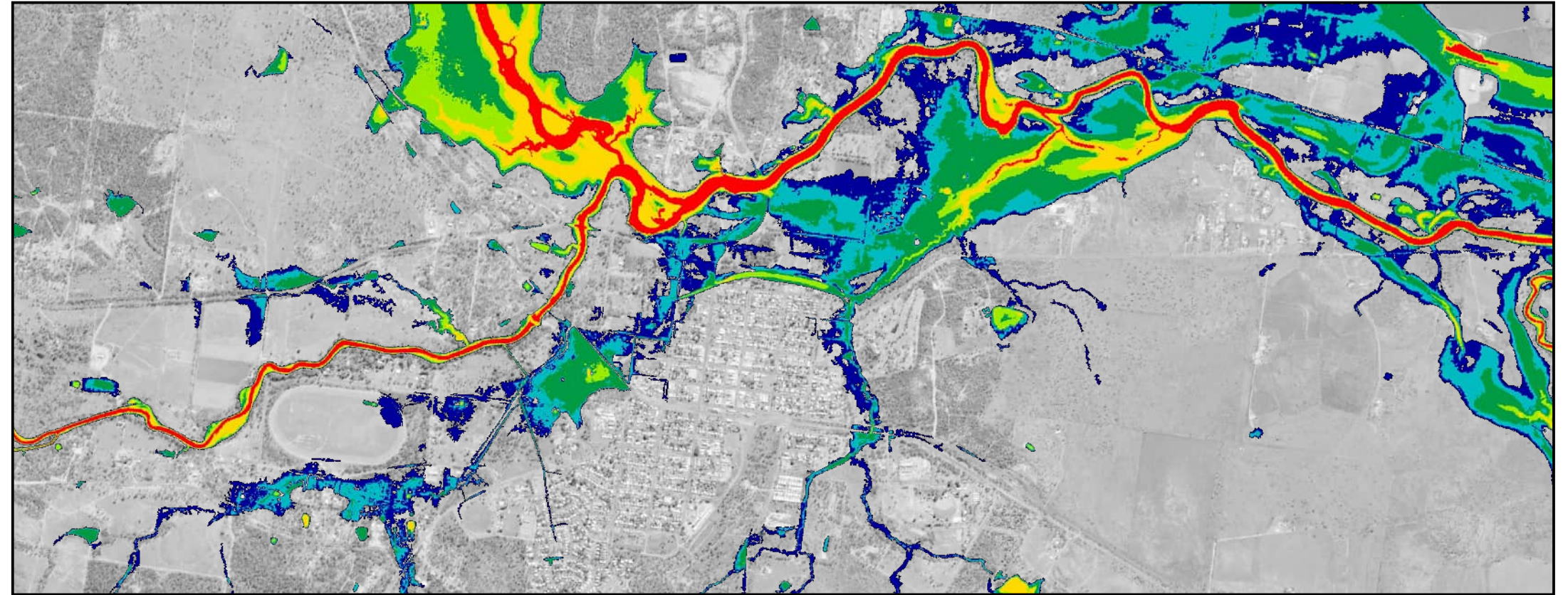
50% AEP (2030) Event Peak Flood Hazards (AIDR) Upper Nogoa River (Clermont)

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Figure:	Rev:
C-28	0





LEGEND

Flood Hazards (AIDR)

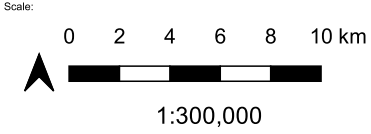
H1	H4
H2	H5
H3	H6
	Study Area

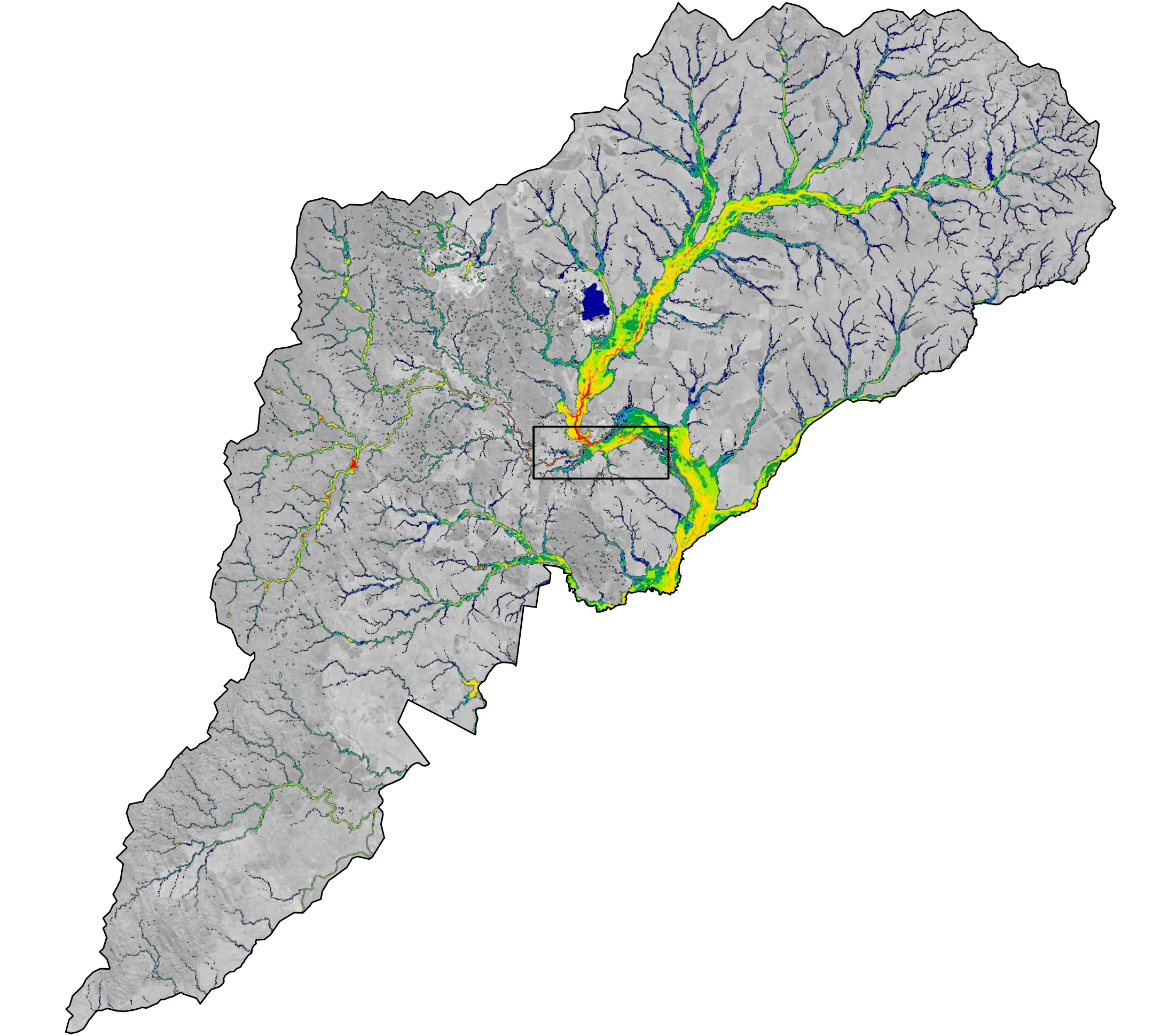
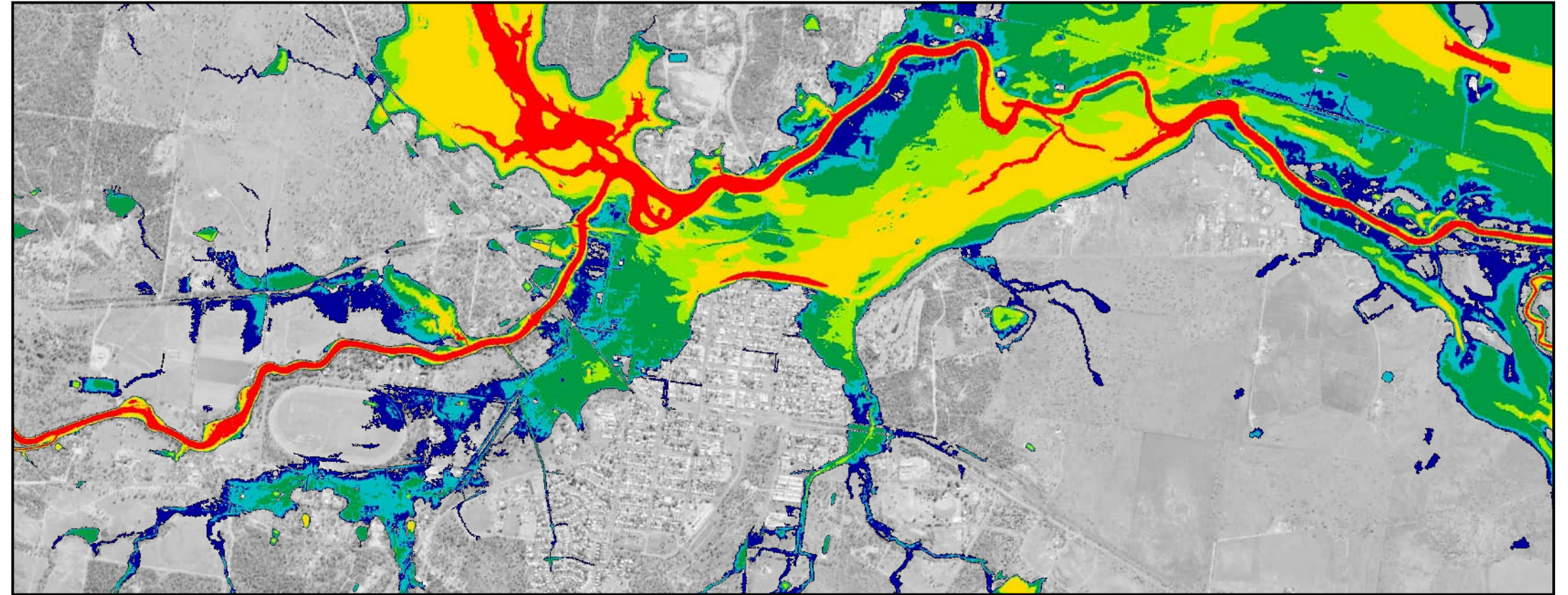
Title:

20% AEP (2030) Event Peak Flood Hazards (AIDR)

Upper Nogoa River (Clermont)

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LEGEND

Flood Hazards (AIDR)

	H1		H4
	H2		H5
	H3		H6
	Study Area		

Title:

5% AEP (2030) Event Peak Flood Hazards (AIDR) Upper Nogoa River (Clermont)

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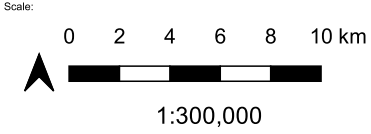
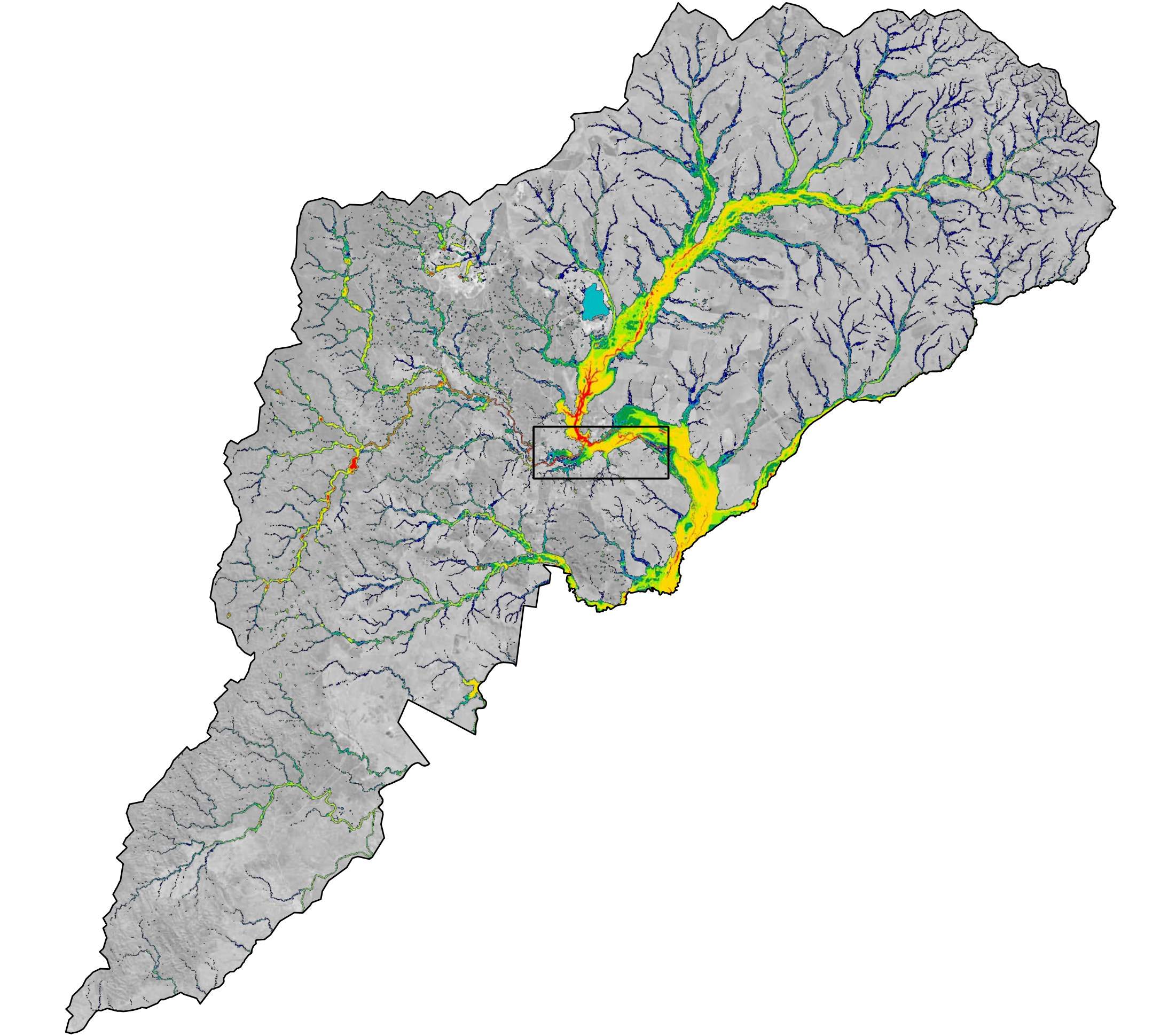
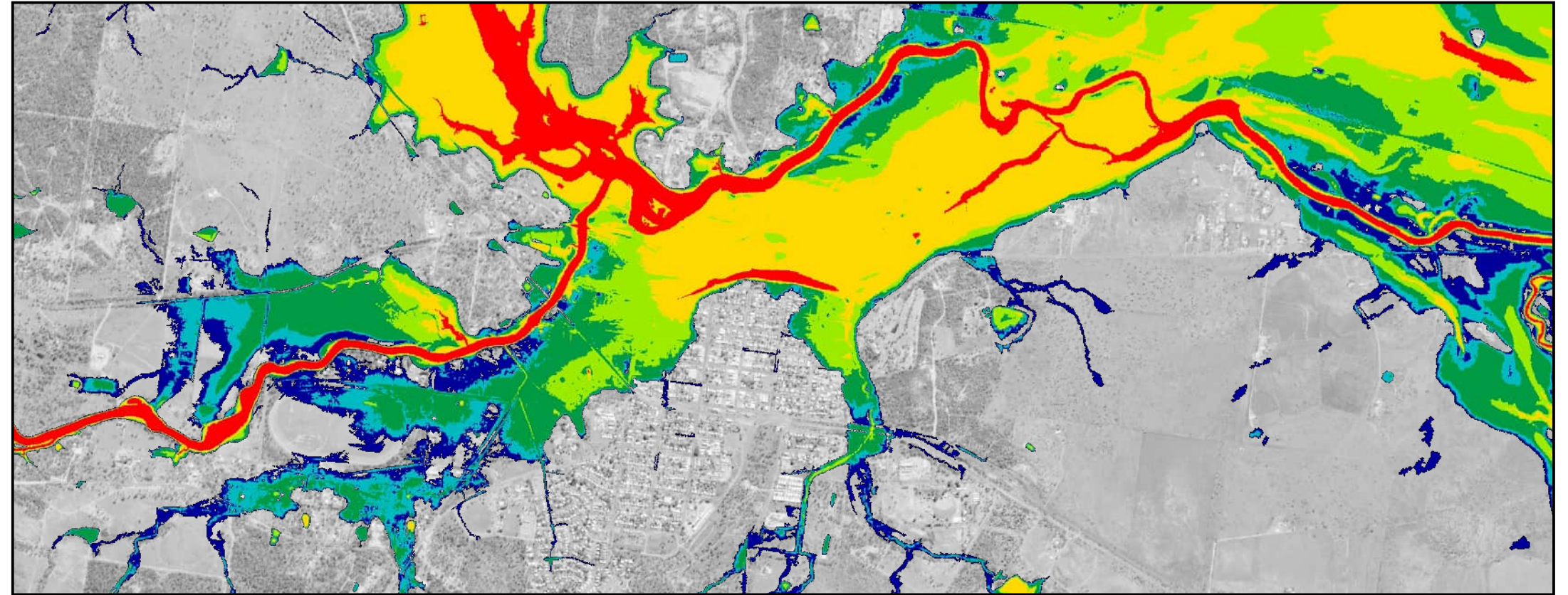


Figure:	C-30	Rev:	0
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LEGEND

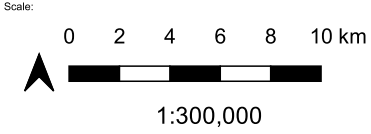
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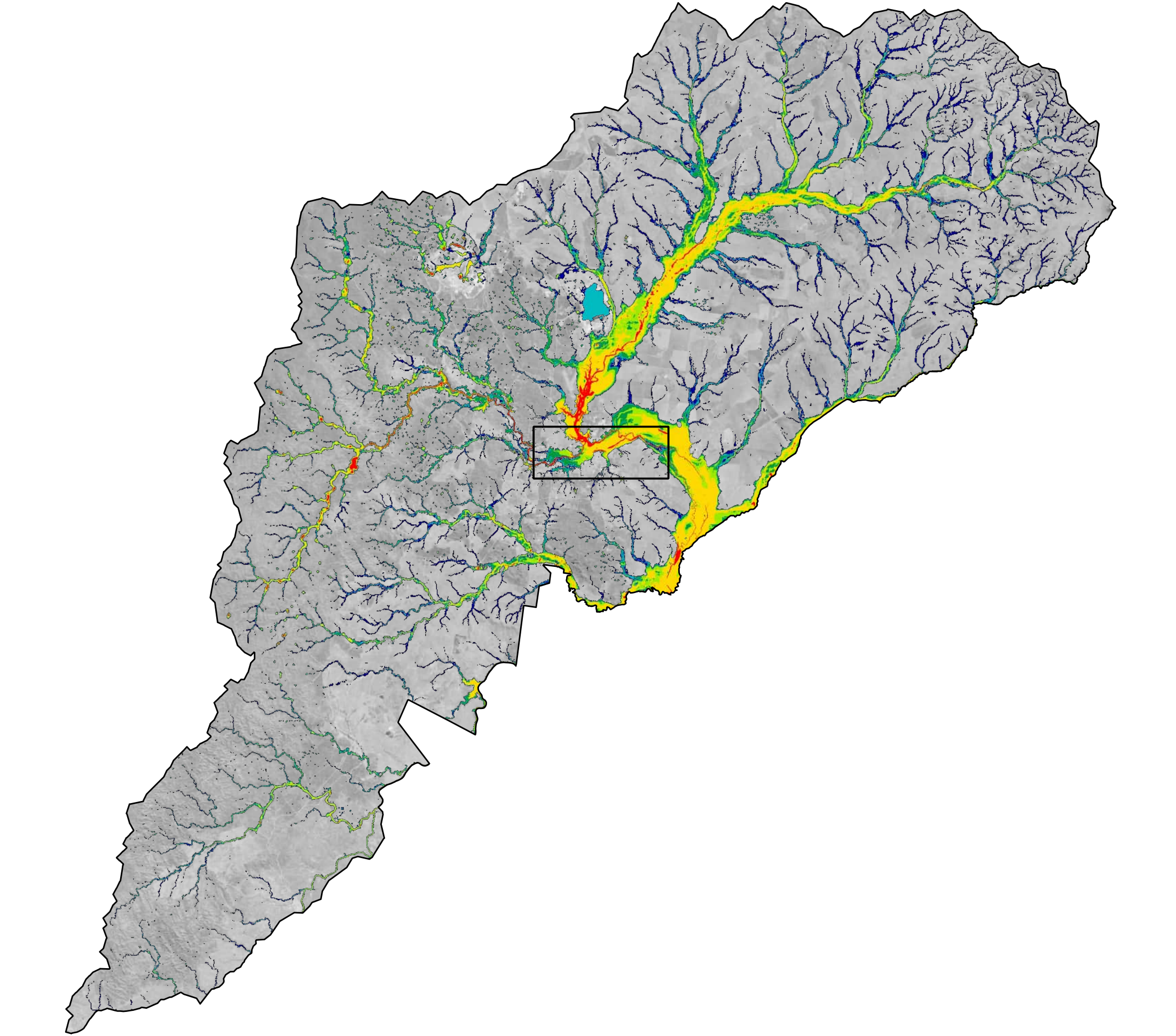
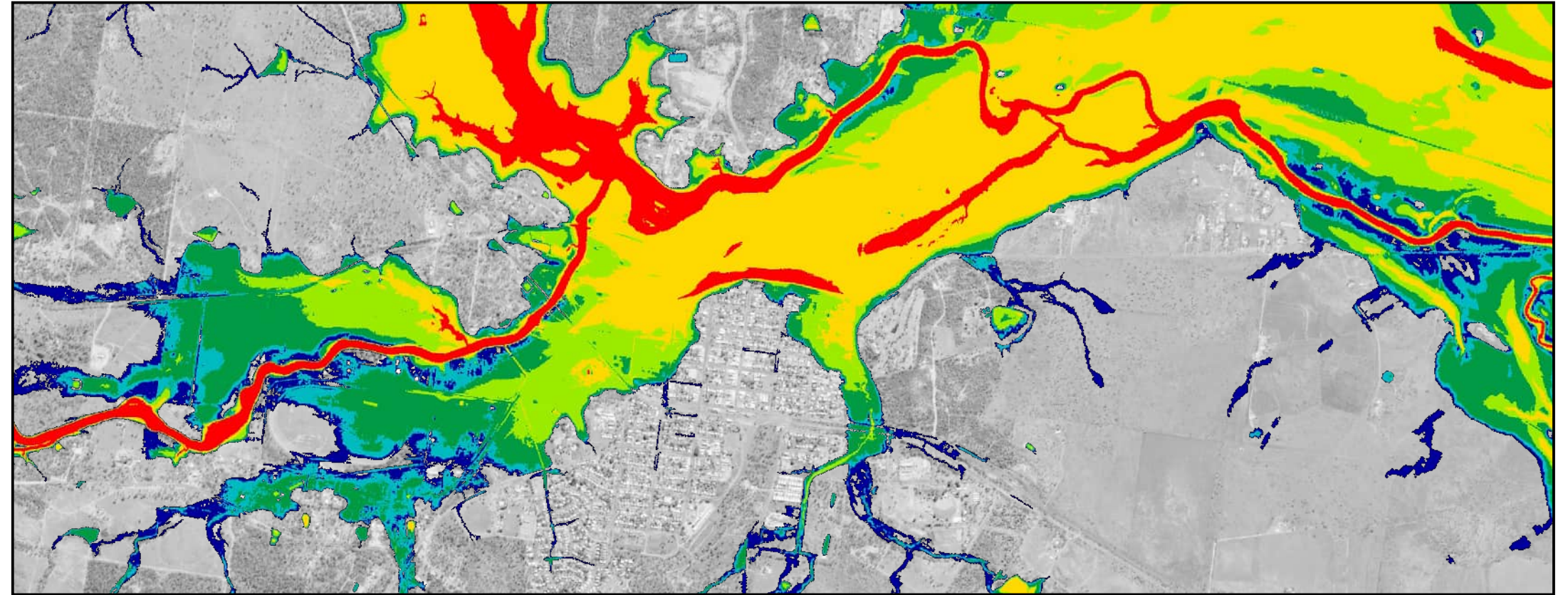
H1	H4
H2	H5
H3	H6
	Study Area

Title:

2% AEP (2030) Event Peak Flood Hazards (AIDR) Upper Nogoa River (Clermont)

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LEGEND

Flood Hazards (AIDR)

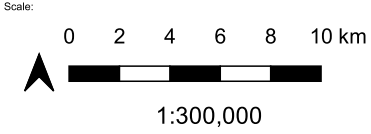
H1	H4
H2	H5
H3	H6
Study Area	

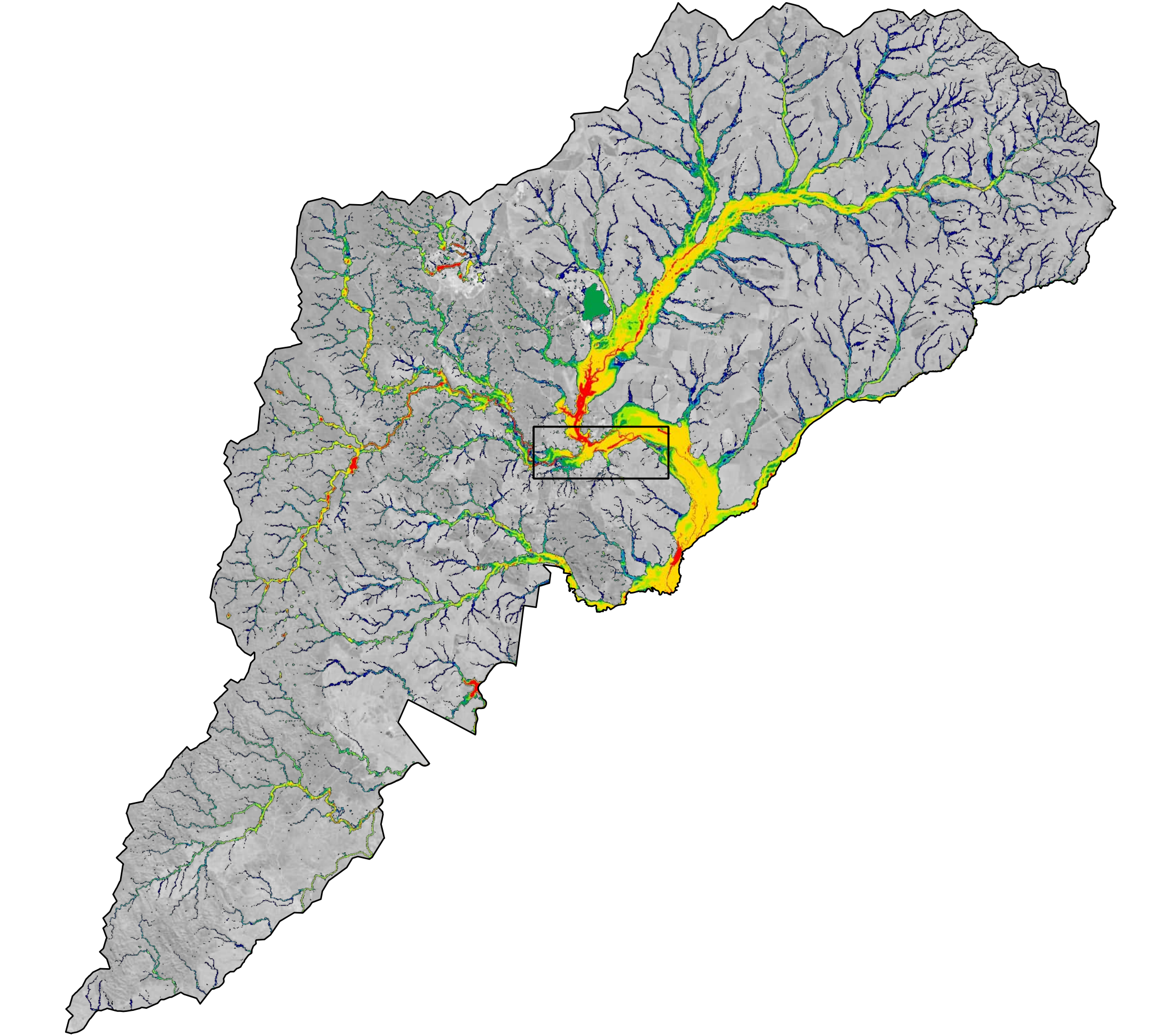
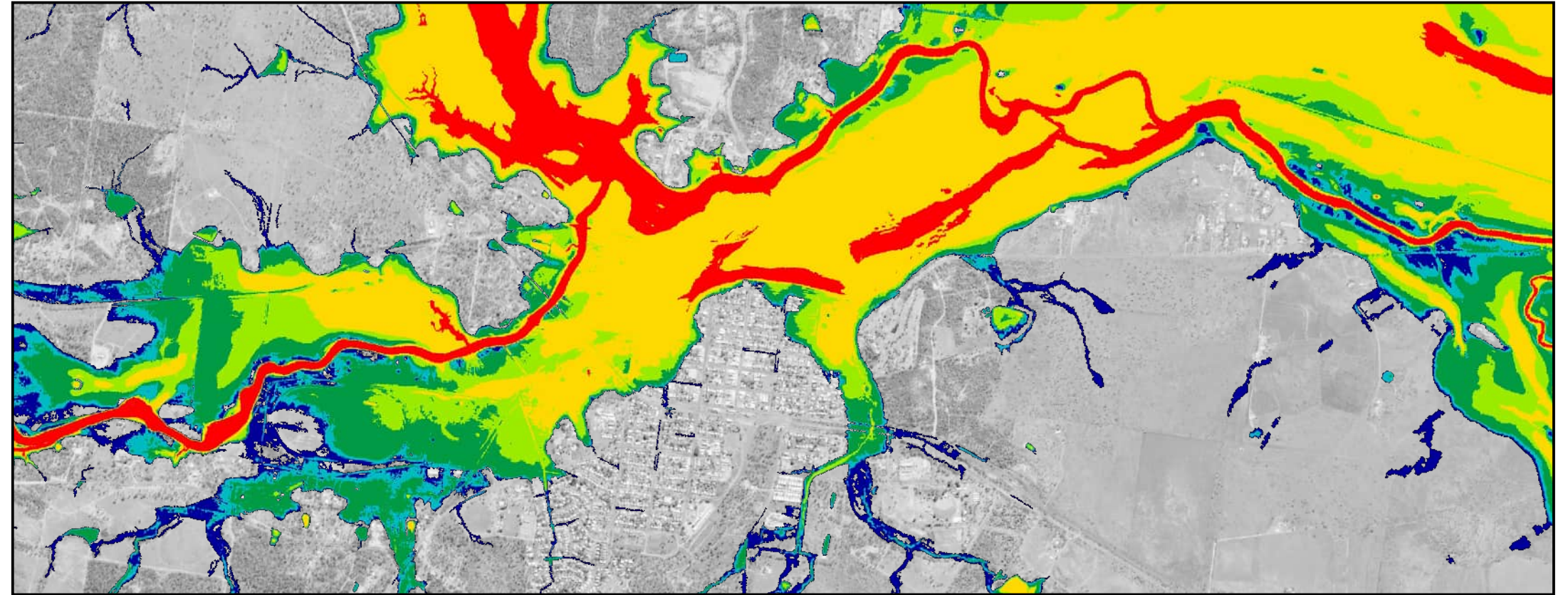
Title:

1% AEP (2030) Event Peak Flood Hazards (AIDR)

Upper Nogoa River (Clermont)

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LEGEND

Flood Hazards (AIDR)

H1	H4
H2	H5
H3	H6
Study Area	

Title:

0.5% AEP (2030) Event Peak Flood Hazards (AIDR)

Upper Nogoa River (Clermont)

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Scale:

0 2 4 6 8 10 km

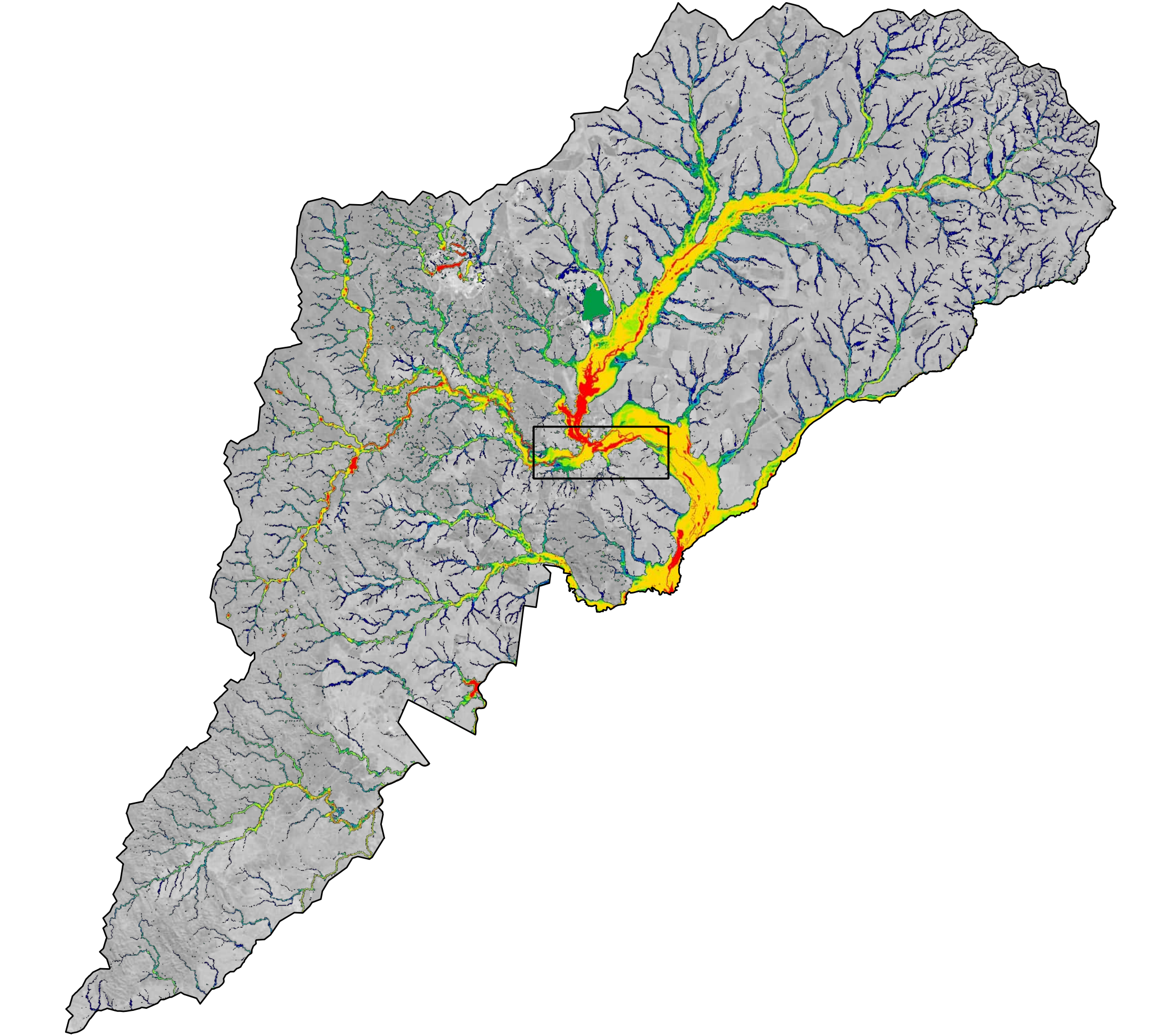
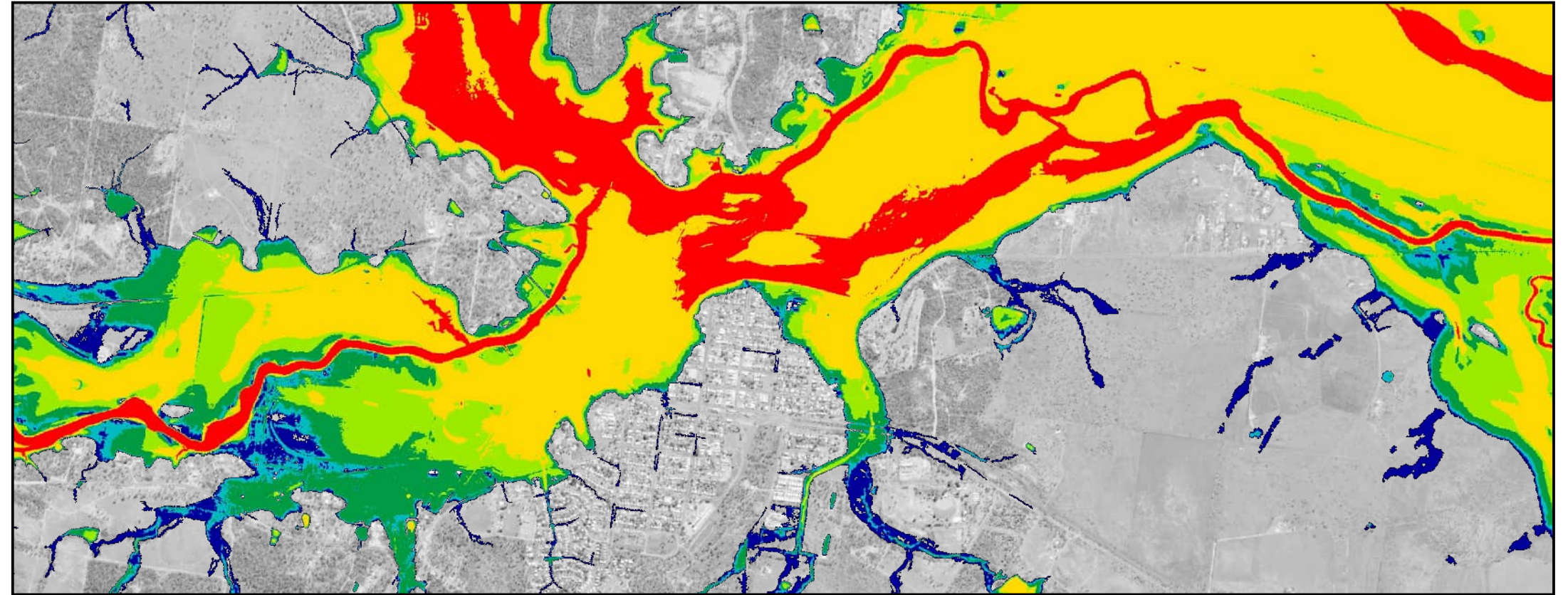
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Figure:

C-33

Rev:

0



LEGEND

Flood Hazards (AIDR)

H1	H4
H2	H5
H3	H6
Study Area	

Title:

0.2% AEP (2030) Event Peak Flood Hazards (AIDR)

Upper Nogoa River (Clermont)

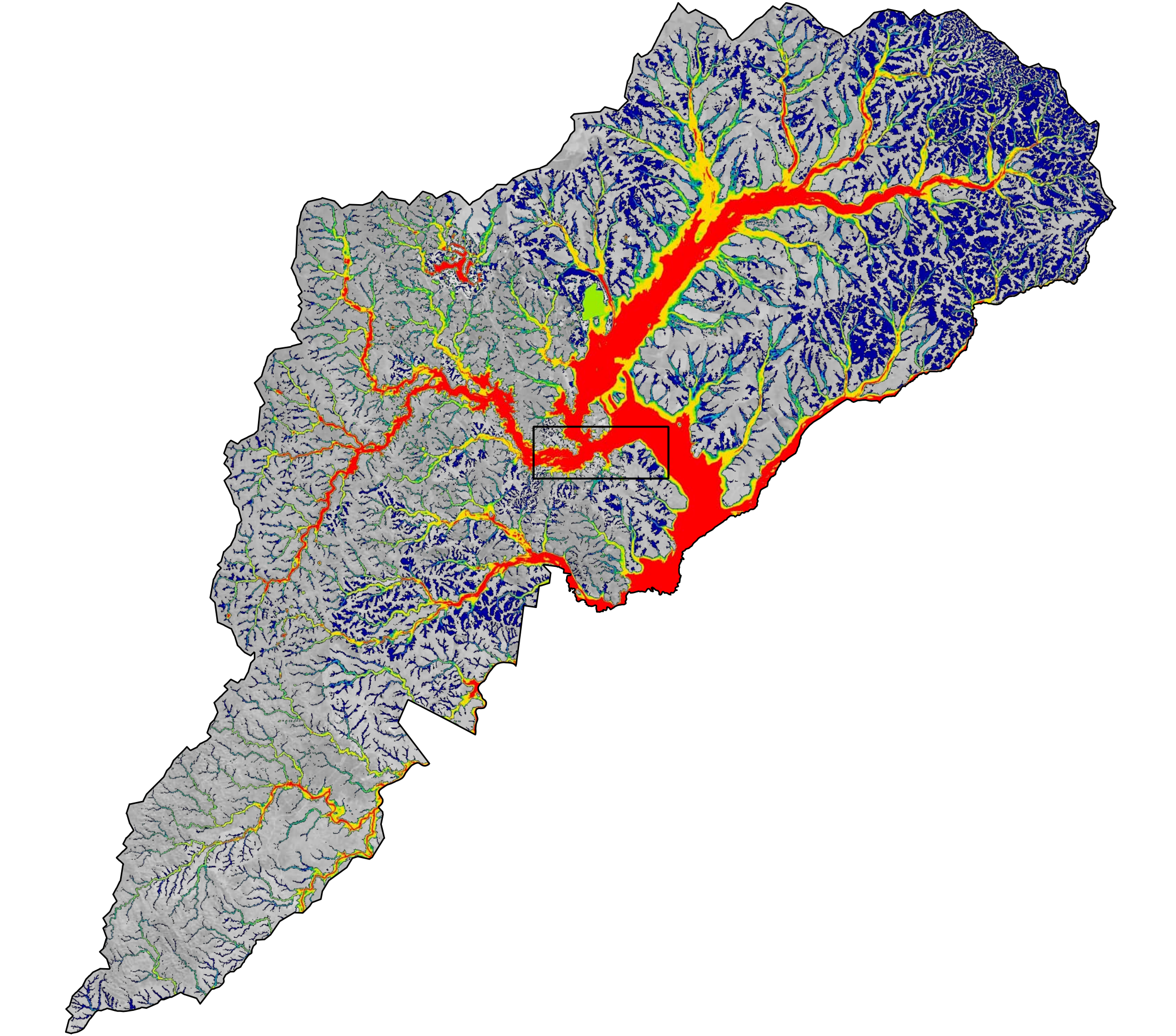
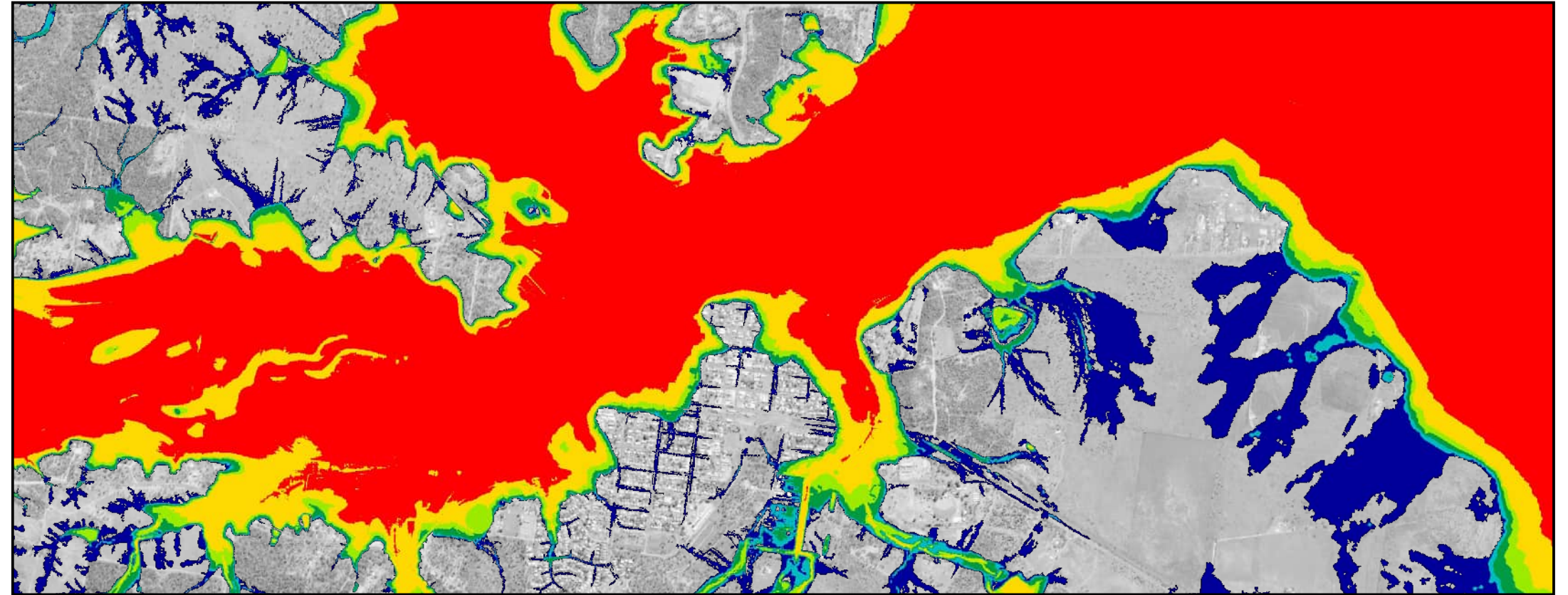
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Scale:

0 2 4 6 8 10 km

1:300,000

Figure:	Rev:
C-34	0



LEGEND

Flood Hazards (AIDR)

H1	H4
H2	H5
H3	H6
	Study Area

Title:

PMF Event (2030) Peak Flood Hazards (AIDR)

Upper Nogoa River (Clermont)

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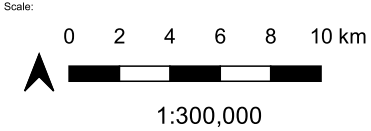
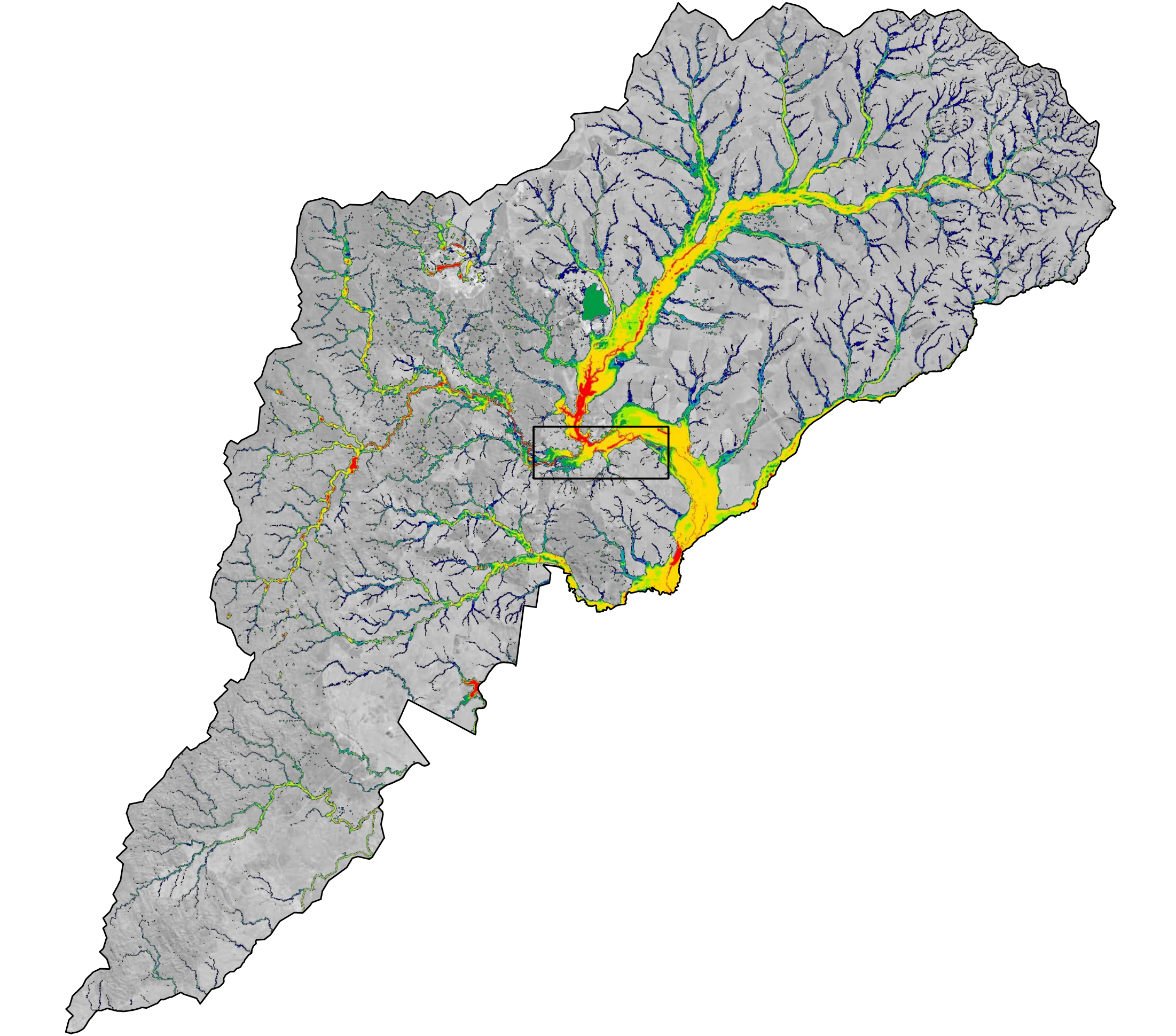
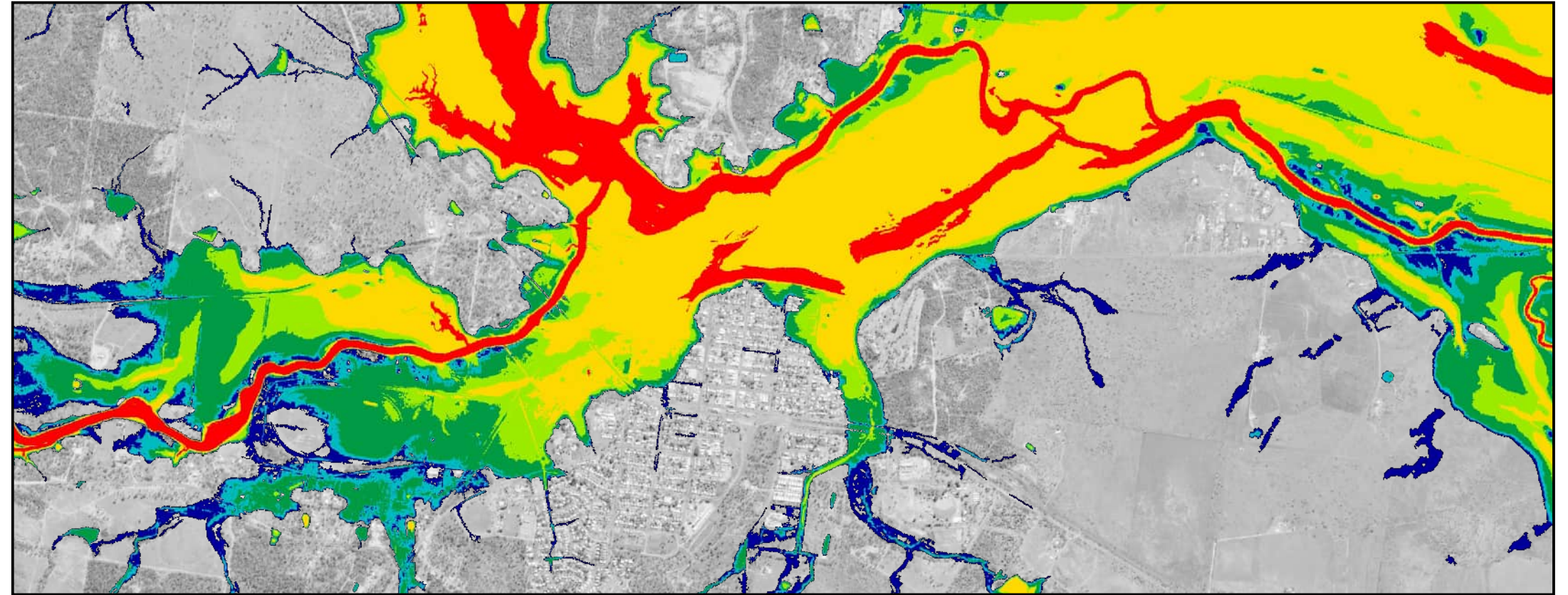


Figure:	Rev:
C-35	0



LEGEND

Flood Hazards (AIDR)

	H1		H4
	H2		H5
	H3		H6
	Study Area		

Title:

1% AEP (2100) Event Peak Flood Hazards (AIDR)

Upper Nogoa River (Clermont)

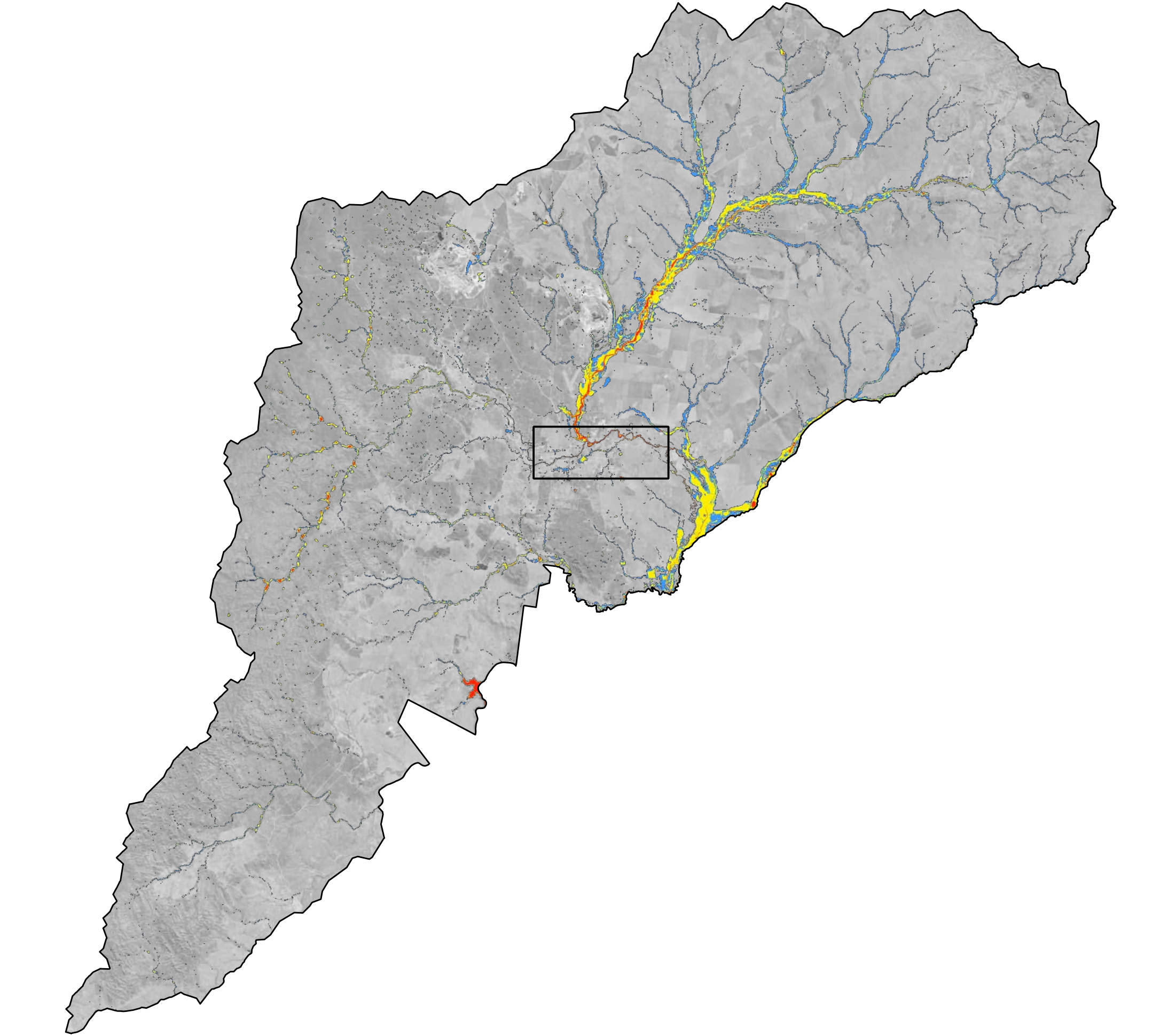
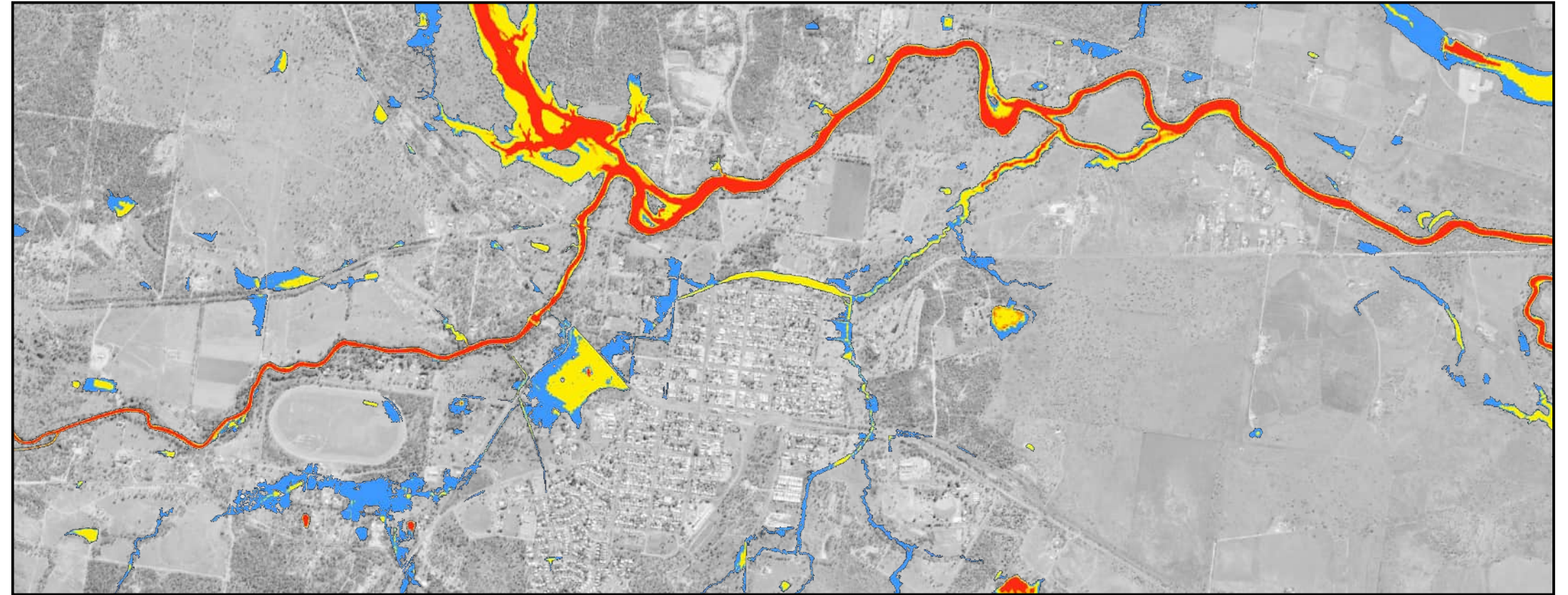
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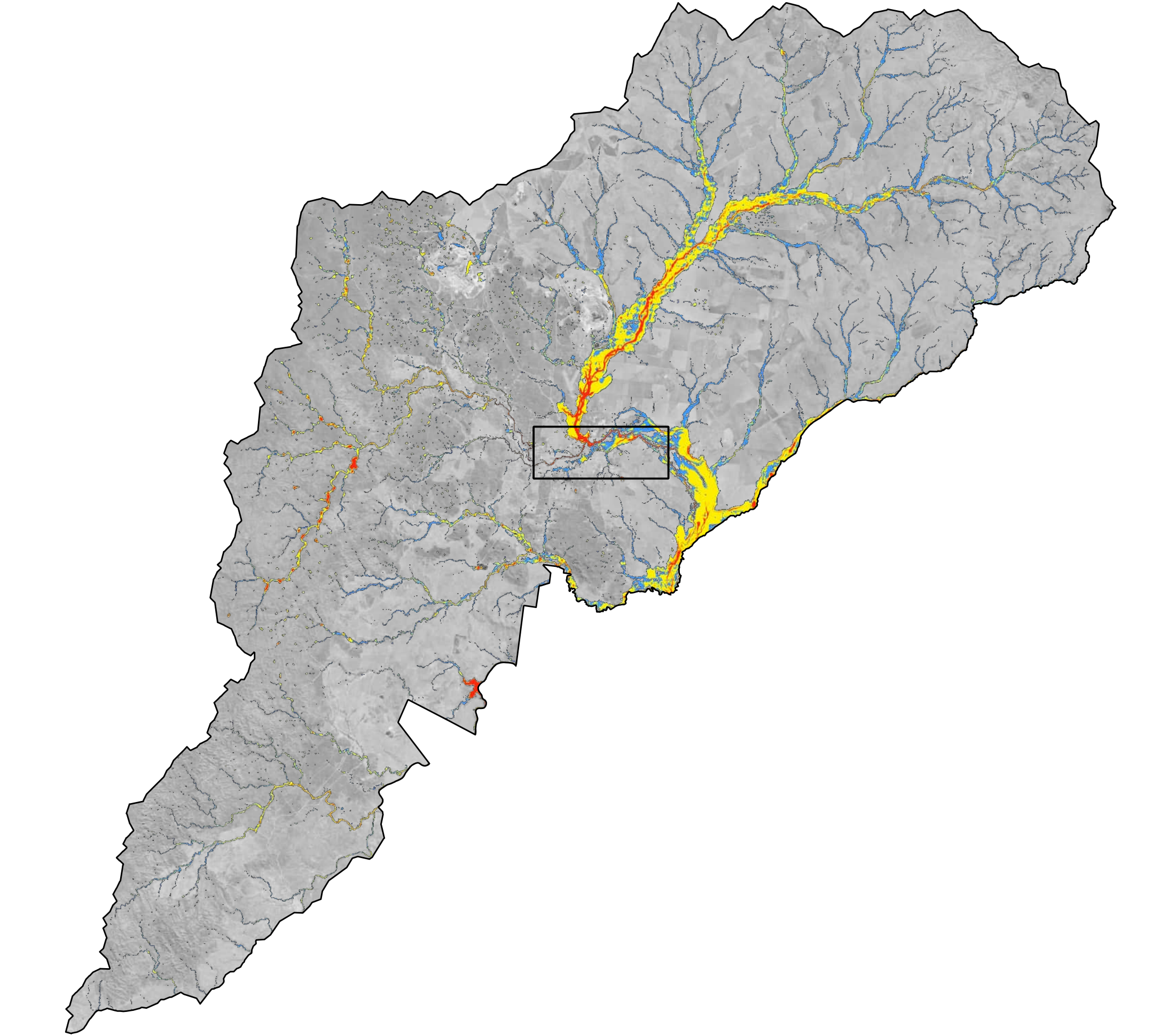
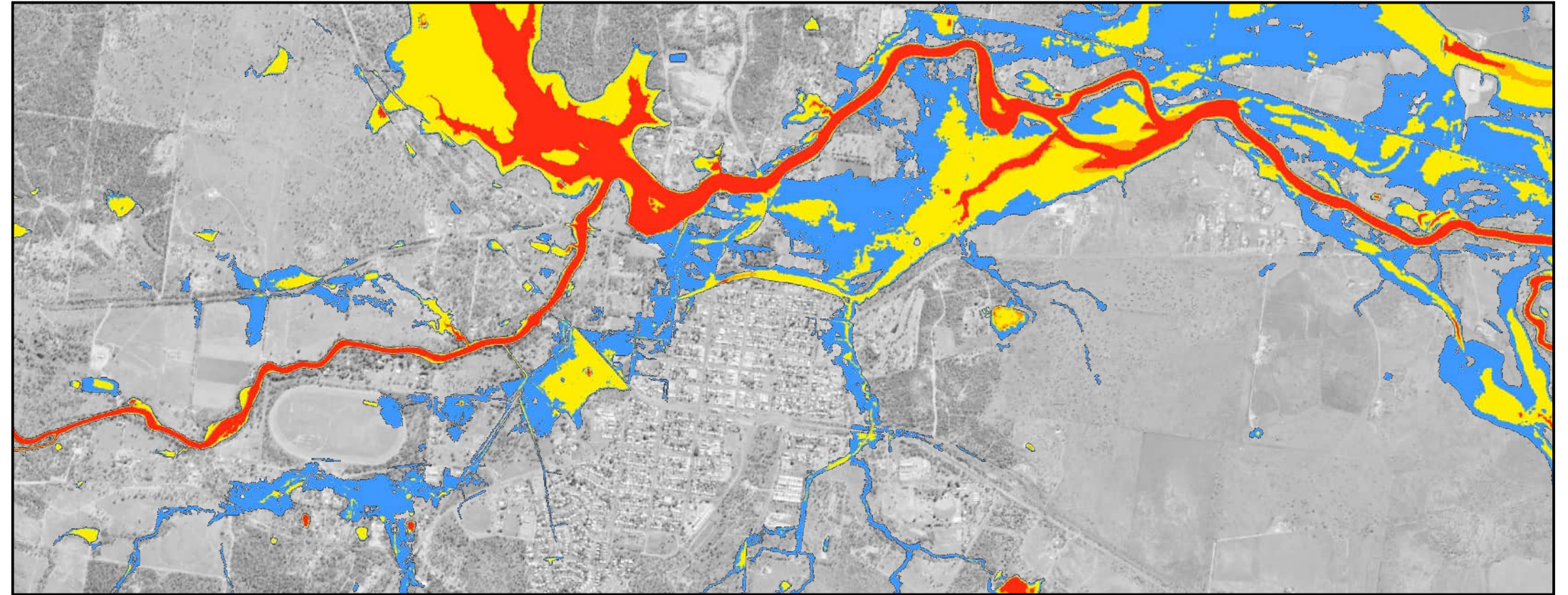
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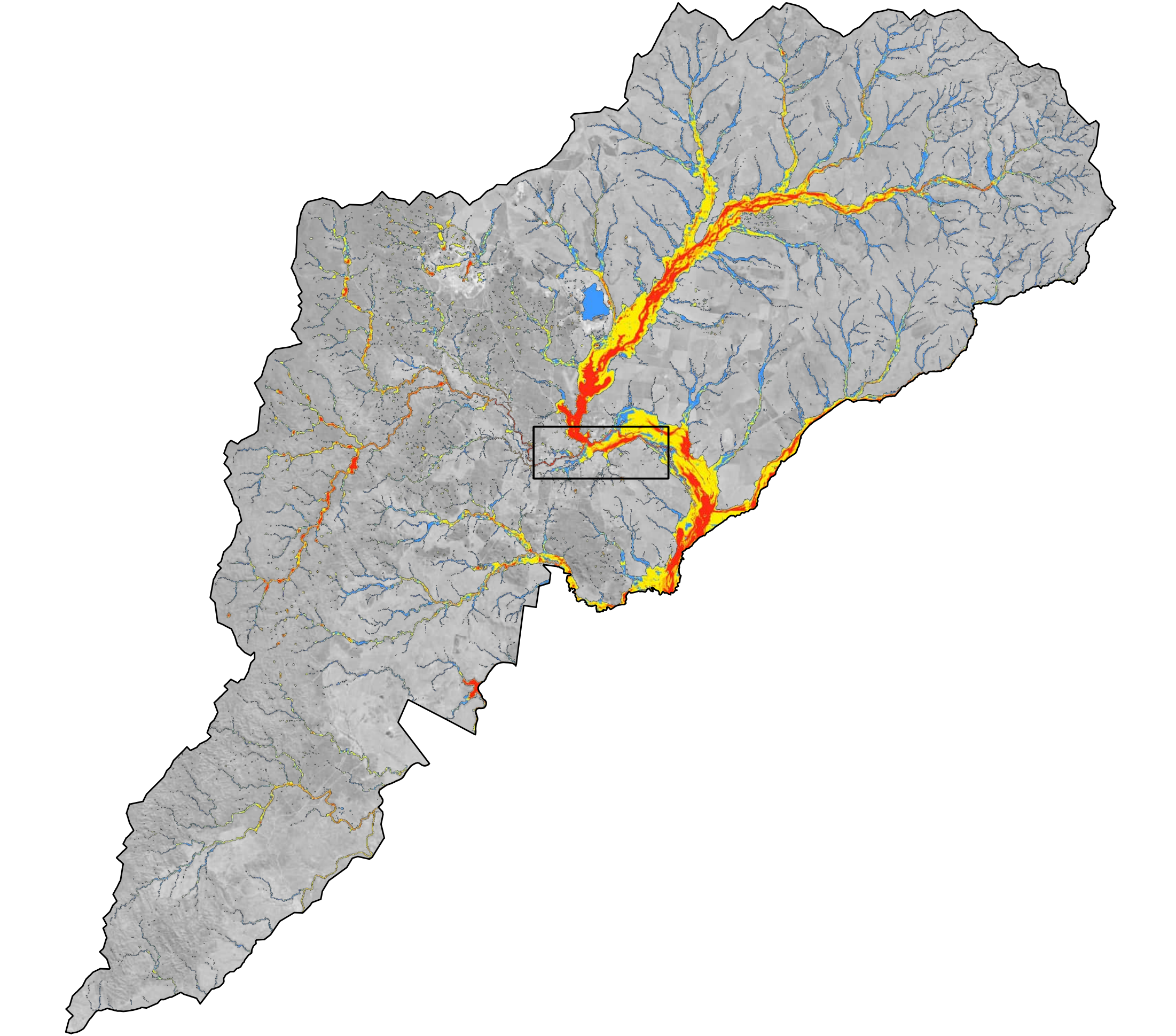
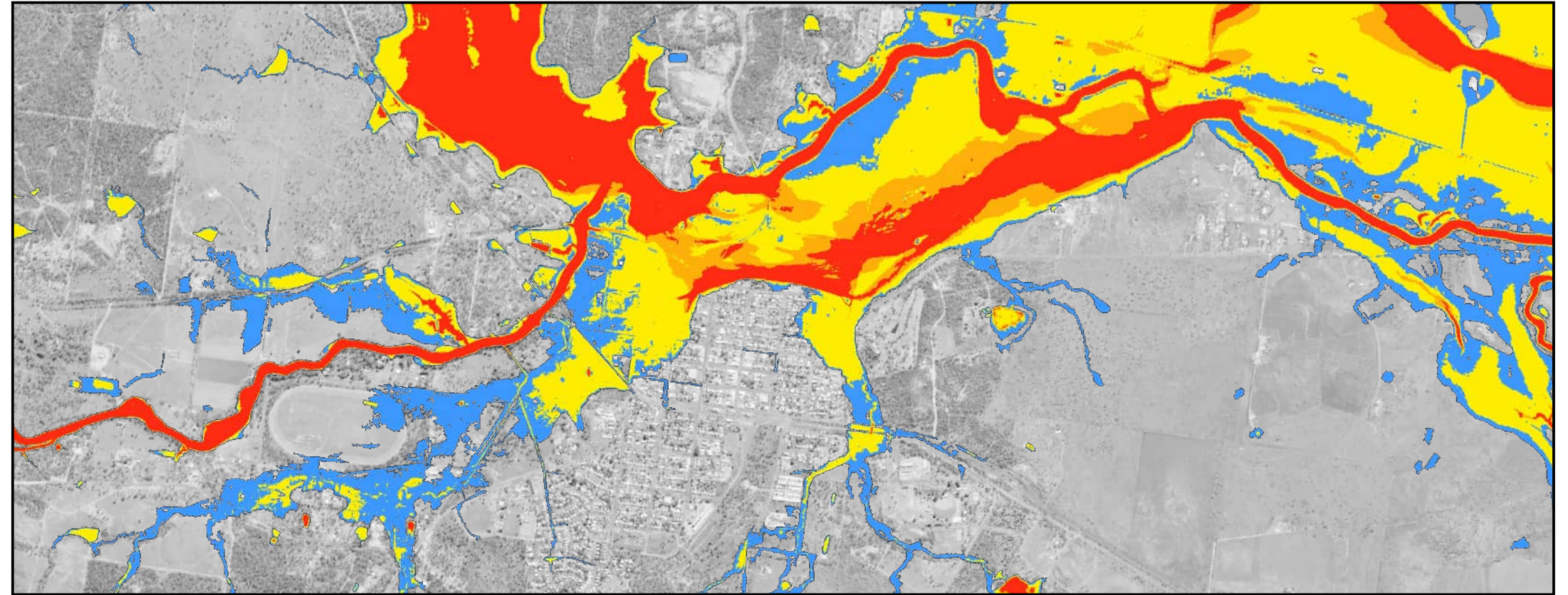
Figure:	C-36	Rev:	0
			



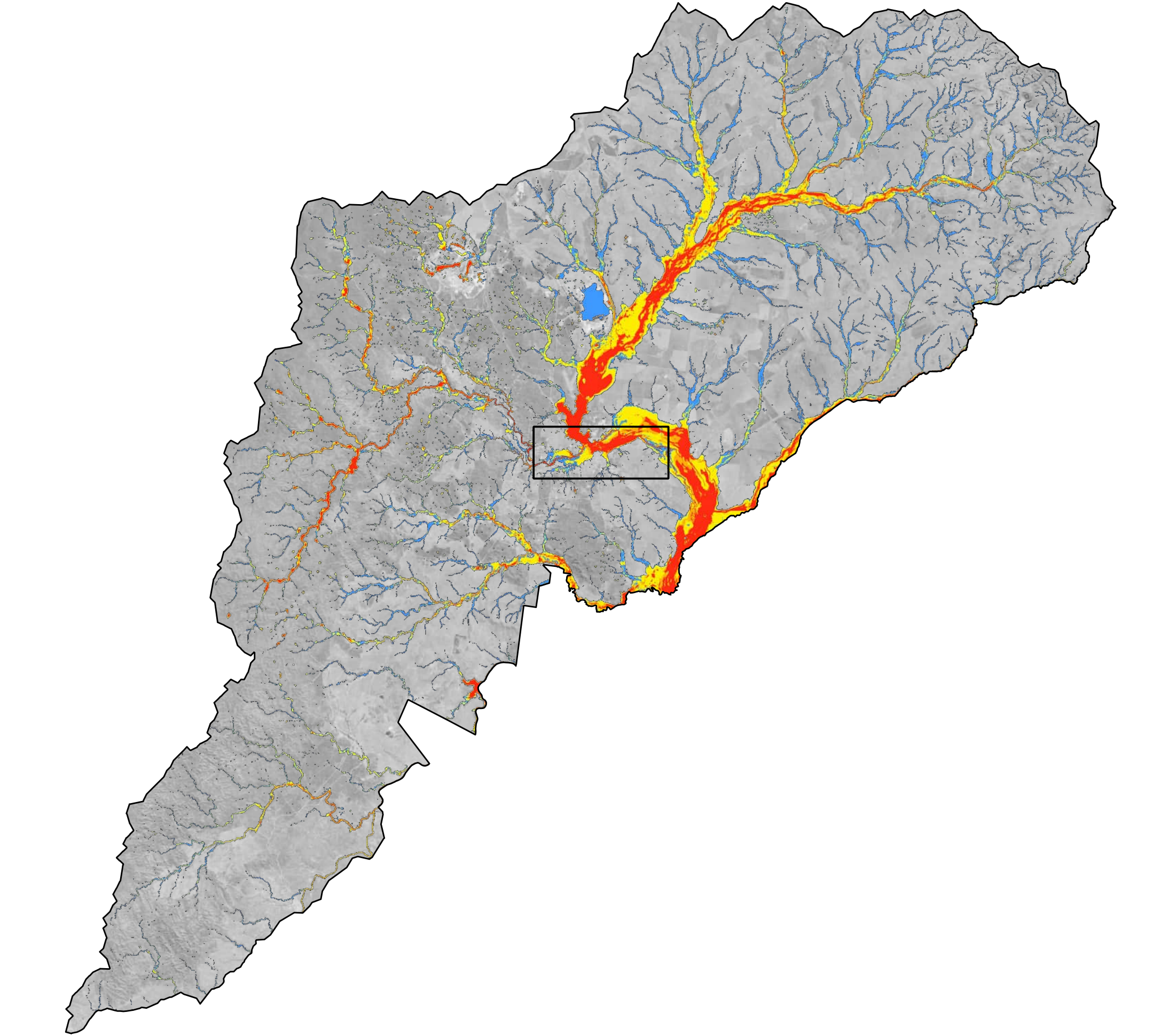
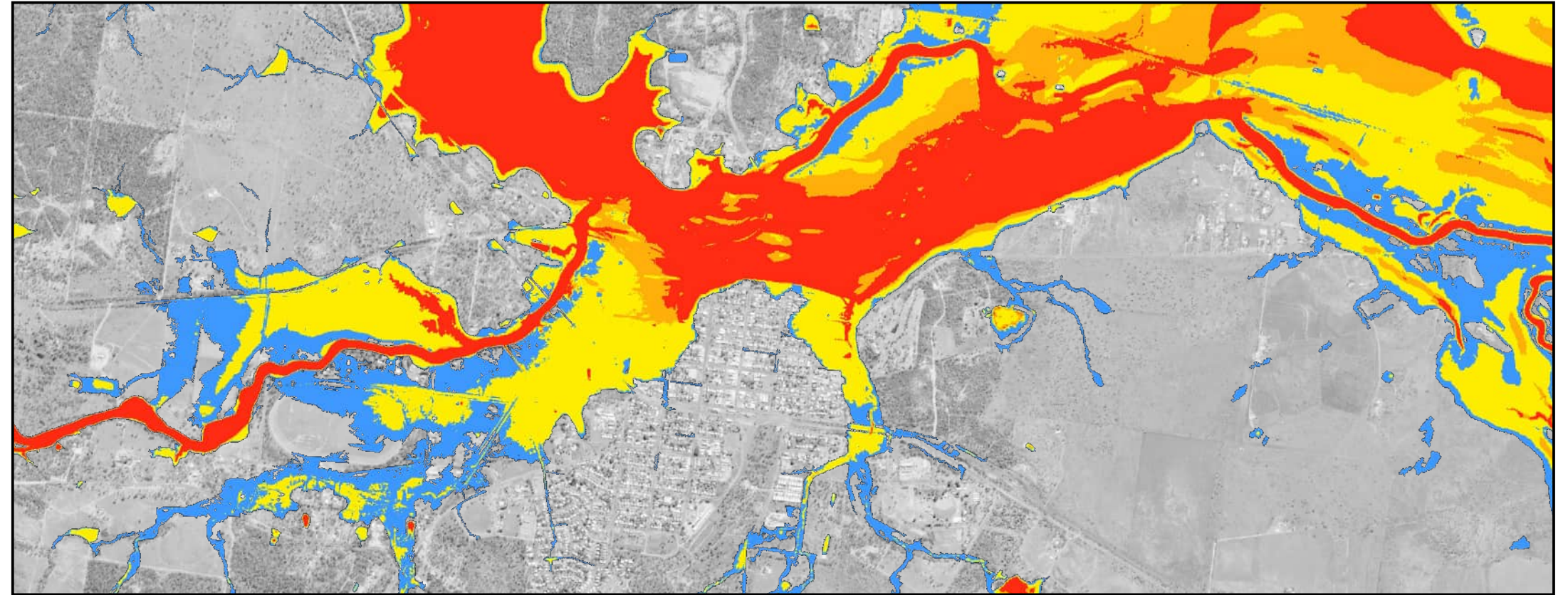
LEGEND Flood Hazards (QRA) Low Significant High Extreme Study Area	Title: 50% AEP (2030) Event Peak Flood Hazards (QRA) Upper Nogoa River (Clermont)		Figure: C-37	Rev: 0	
	Scale at A3 © Kellogg Brown & Root Pty Ltd, Produced 2026-07-29T14:59:11.081 by K138966 Data © Esri all accessed under a Creative Commons 3.0 Australia licence. Full terms at https://creativecommons.org/licenses/by/3.0/au/legalcode While effort has been made to ensure the accuracy and completeness of the information presented, no guarantee is given, nor responsibility taken by KBR for any errors or omission. File: \\perfile001\data\$\Water_Resources\Projects\BEW571 - Upper Nogoa and Mackenzie\G - GIS\Workspaces\260630_Mapping_Atlas.qgz		Scale: 0 2 4 6 8 10 km 1:300,000		



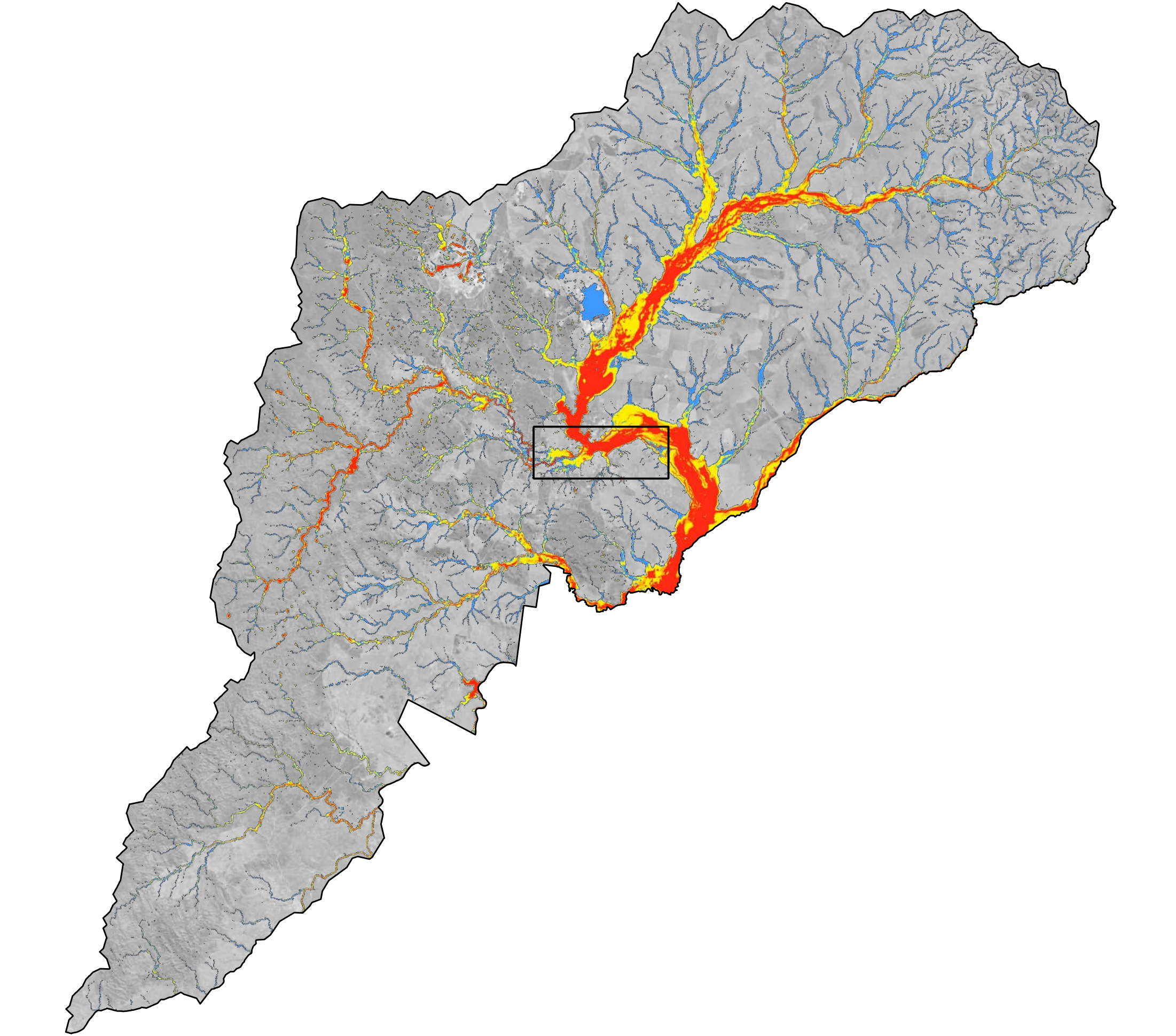
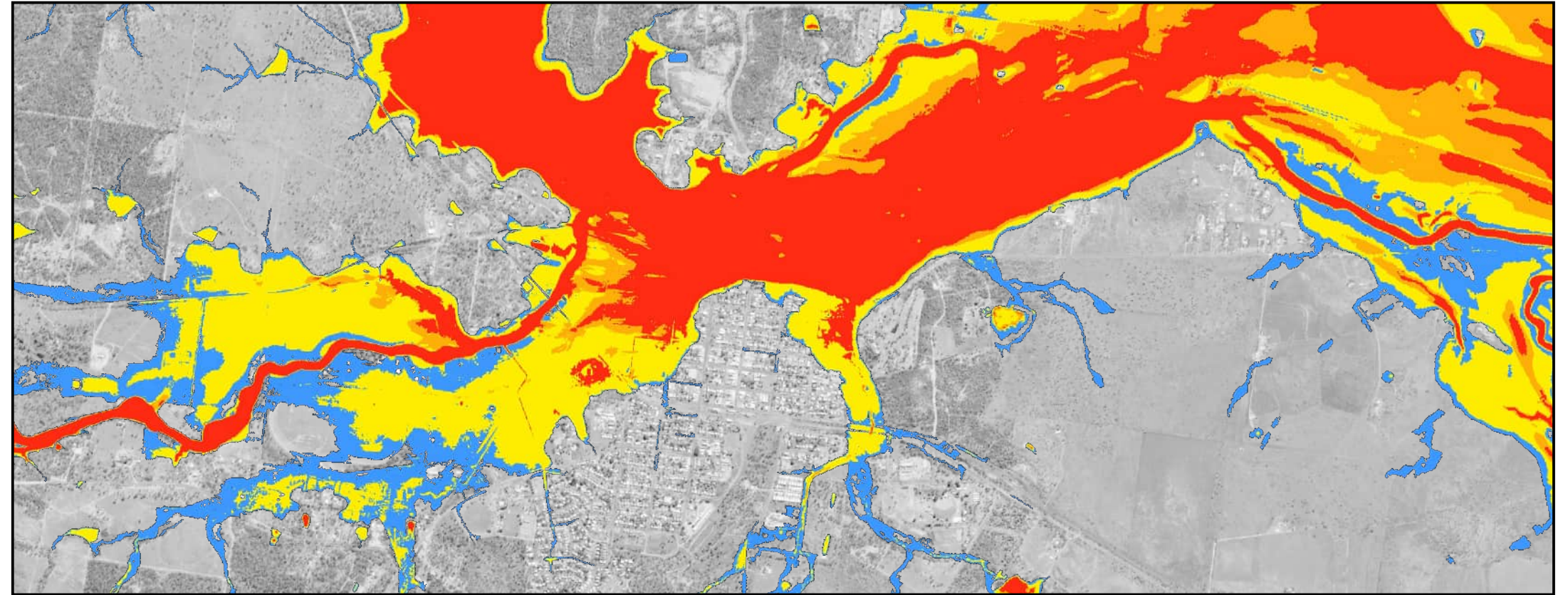
LEGEND Flood Hazards (QRA) Low Significant High Extreme Study Area	Title: 20% AEP (2030) Event Peak Flood Hazards (QRA) Upper Nogoa River (Clermont)	Figure: C-38	Rev: 0
	Scale at A3 © Kellogg Brown & Root Pty Ltd, Produced 2026-07-29T14:59:15.313 by K138966 Data © Esri all accessed under a Creative Commons 3.0 Australia licence. Full terms at https://creativecommons.org/licenses/by/3.0/au/legalcode While effort has been made to ensure the accuracy and completeness of the information presented, no guarantee is given, nor responsibility taken by KBR for any errors or omission. File: \\perfile001\data\$\Water_Resources\Projects\BEW571 - Upper Nogoa and Mackenzie\G - GIS\Workspaces\260630_Mapping_Atlas.qgz	Scale: 0246810 km 1:300,000	



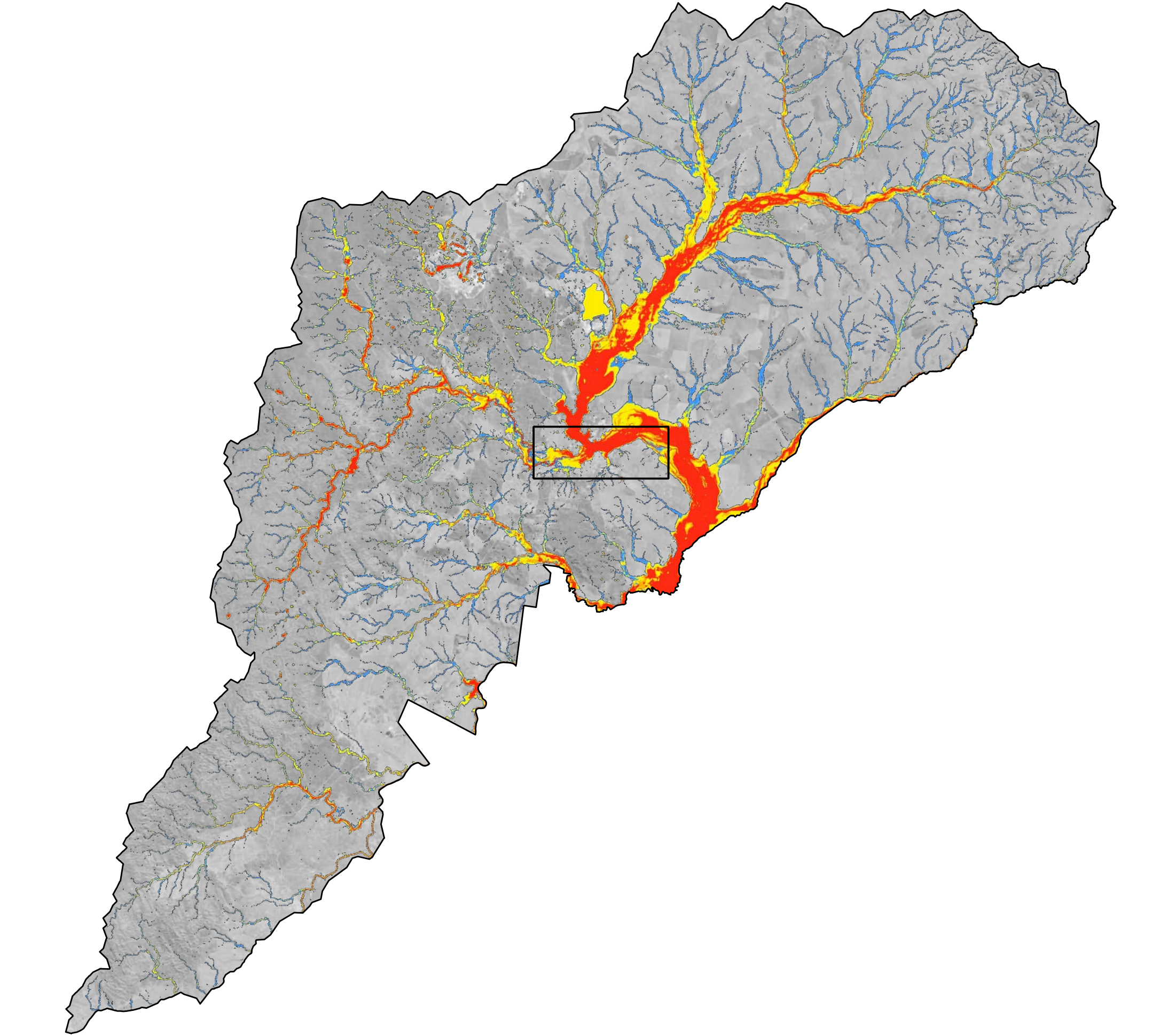
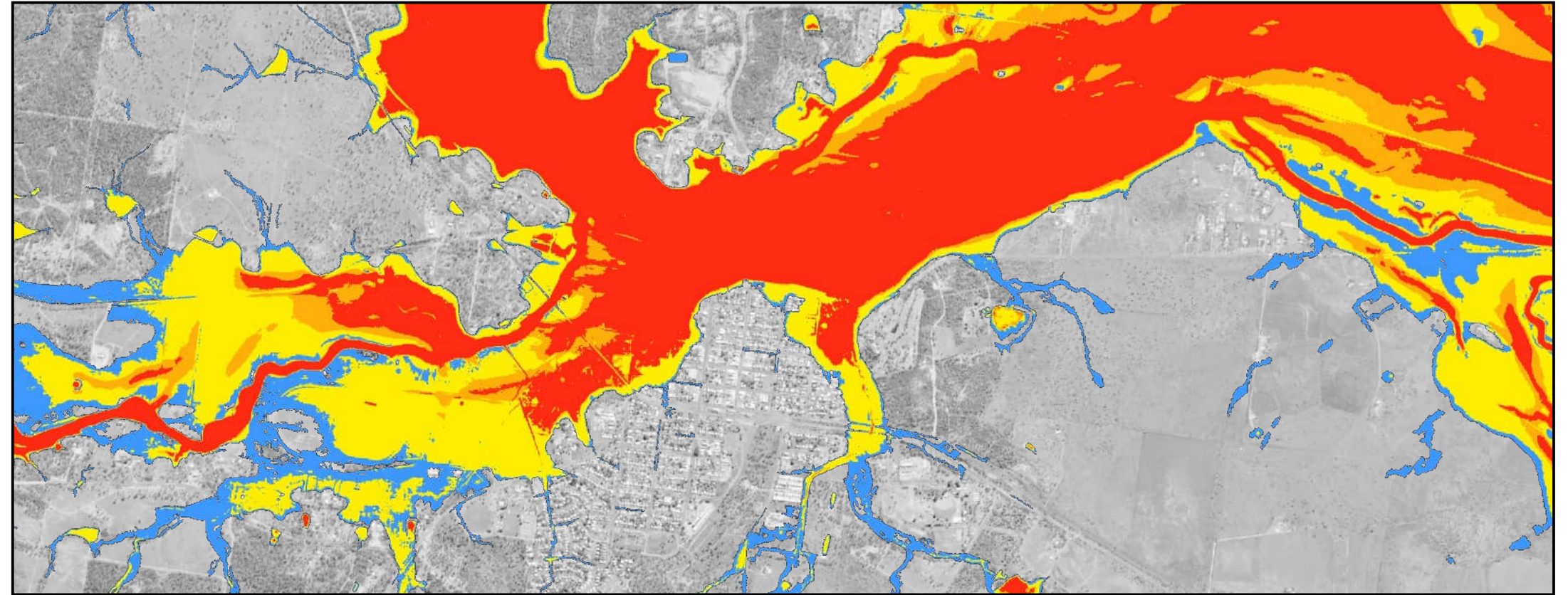
LEGEND Flood Hazards (QRA) Low Significant High Extreme Study Area	Title: 5% AEP (2030) Event Peak Flood Hazards (QRA) Upper Nogoa River (Clermont) Scale at A3 © Kellogg Brown & Root Pty Ltd, Produced 2026-07-29T14:59:19.550 by K138966 Data © Esri all accessed under a Creative Commons 3.0 Australia licence. Full terms at https://creativecommons.org/licenses/by/3.0/au/legalcode While effort has been made to ensure the accuracy and completeness of the information presented, no guarantee is given, nor responsibility taken by KBR for any errors or omission. File: \\profile001\data\$\Water_Resources\Projects\BEW571 - Upper Nogoa and Mackenzie\G - GIS\Workspaces\260630_Mapping_Atlas.qgz	Figure: C-39 Rev: 0
	Scale: 0 2 4 6 8 10 km 1:300,000	



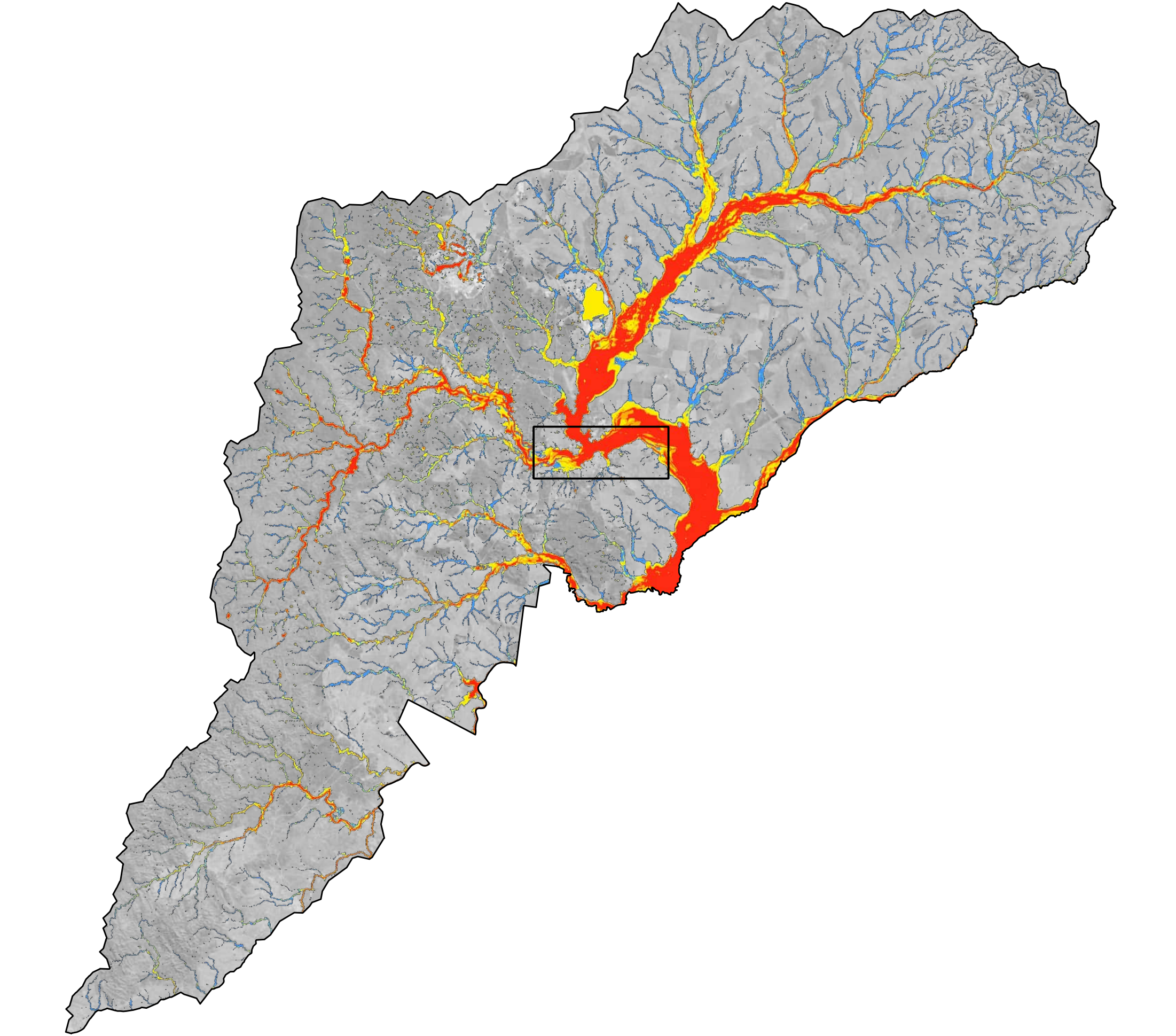
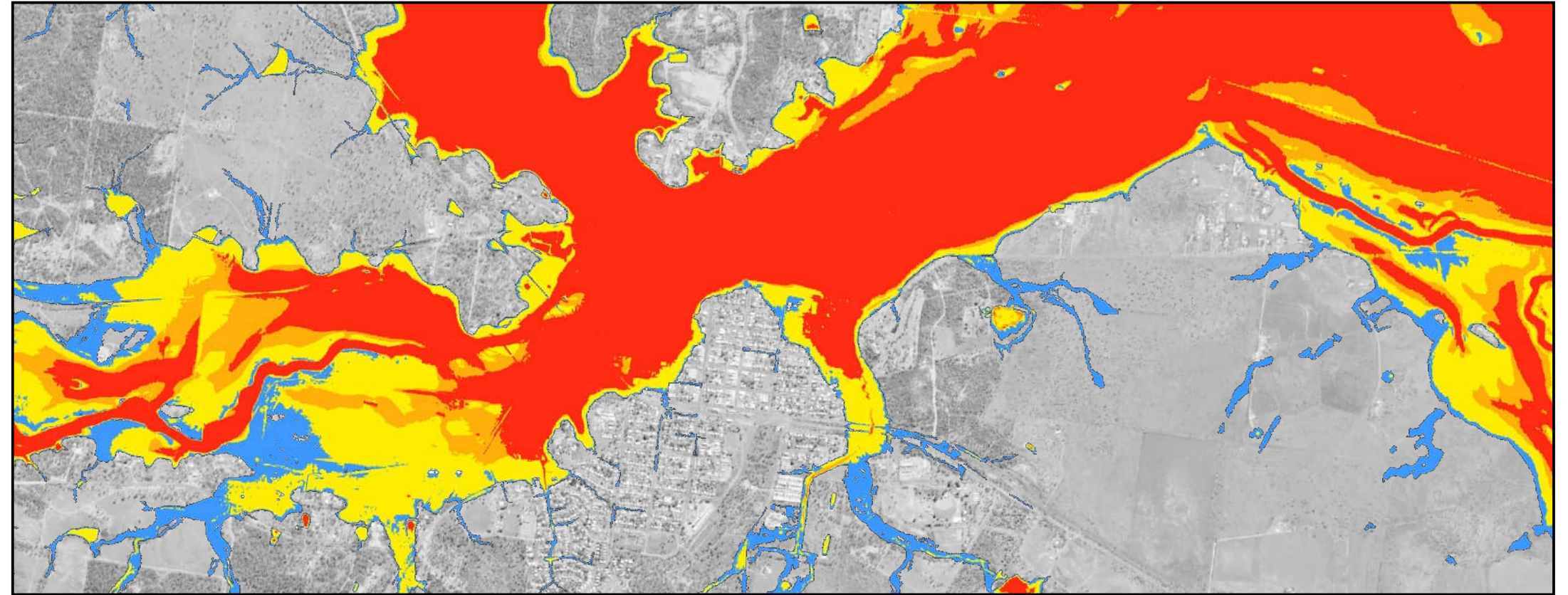
LEGEND Flood Hazards (QRA) Low Significant High Extreme Study Area	Title: 2% AEP (2030) Event Peak Flood Hazards (QRA) Upper Nogoa River (Clermont)		Figure: C-40	Rev: 0
	Scale at A3 © Kellogg Brown & Root Pty Ltd, Produced 2026-07-29T14:59:23.550 by K138966 Data © Esri all accessed under a Creative Commons 3.0 Australia licence. Full terms at https://creativecommons.org/licenses/by/3.0/au/legalcode While effort has been made to ensure the accuracy and completeness of the information presented, no guarantee is given, nor responsibility taken by KBR for any errors or omission. File: \\profile001\data\$\Water_Resources\Projects\BEW571 - Upper Nogoa and Mackenzie\G - GIS\Workspaces\260630_Mapping_Atlas.ggz		Scale: 0 2 4 6 8 10 km 1:300,000	



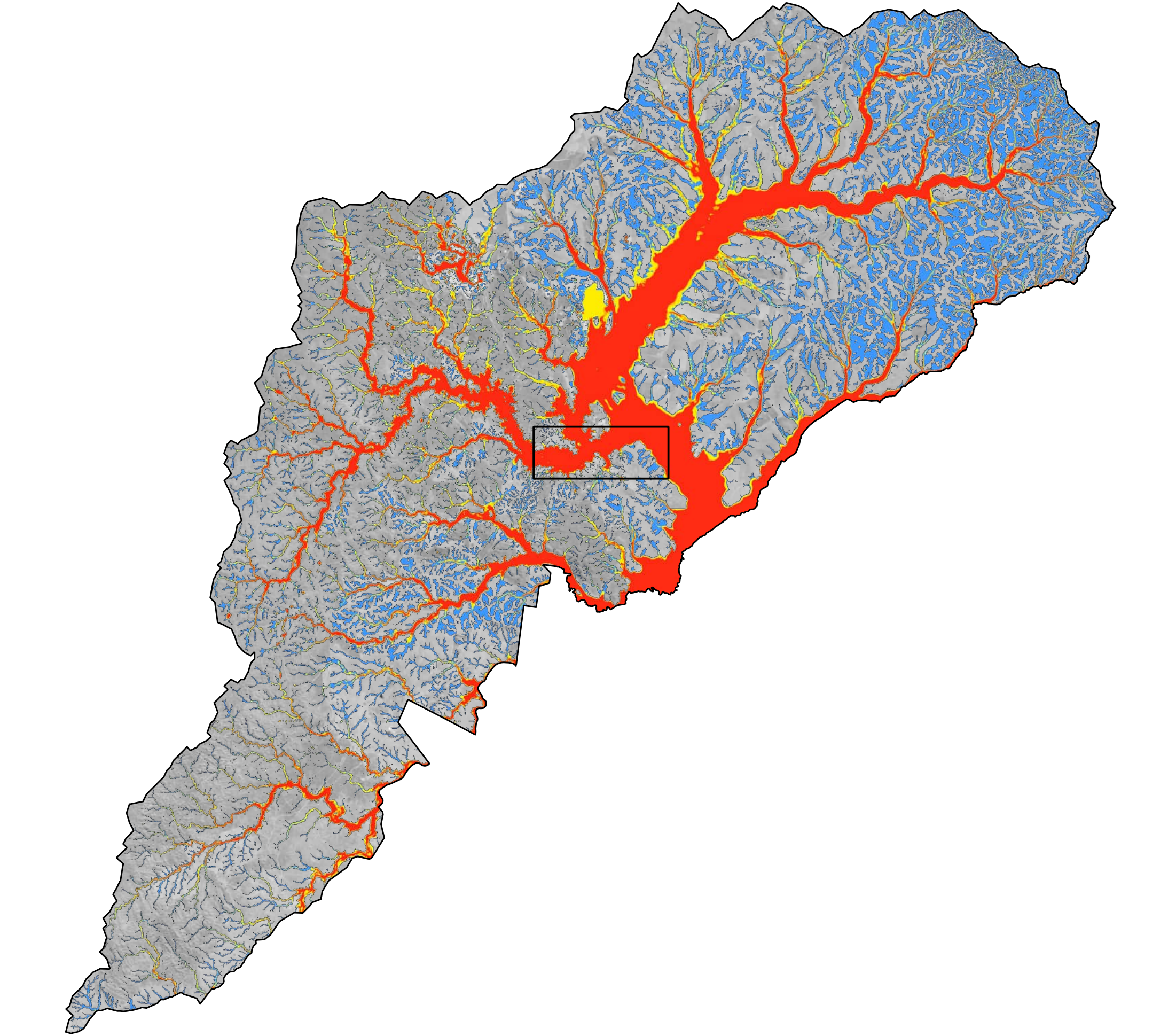
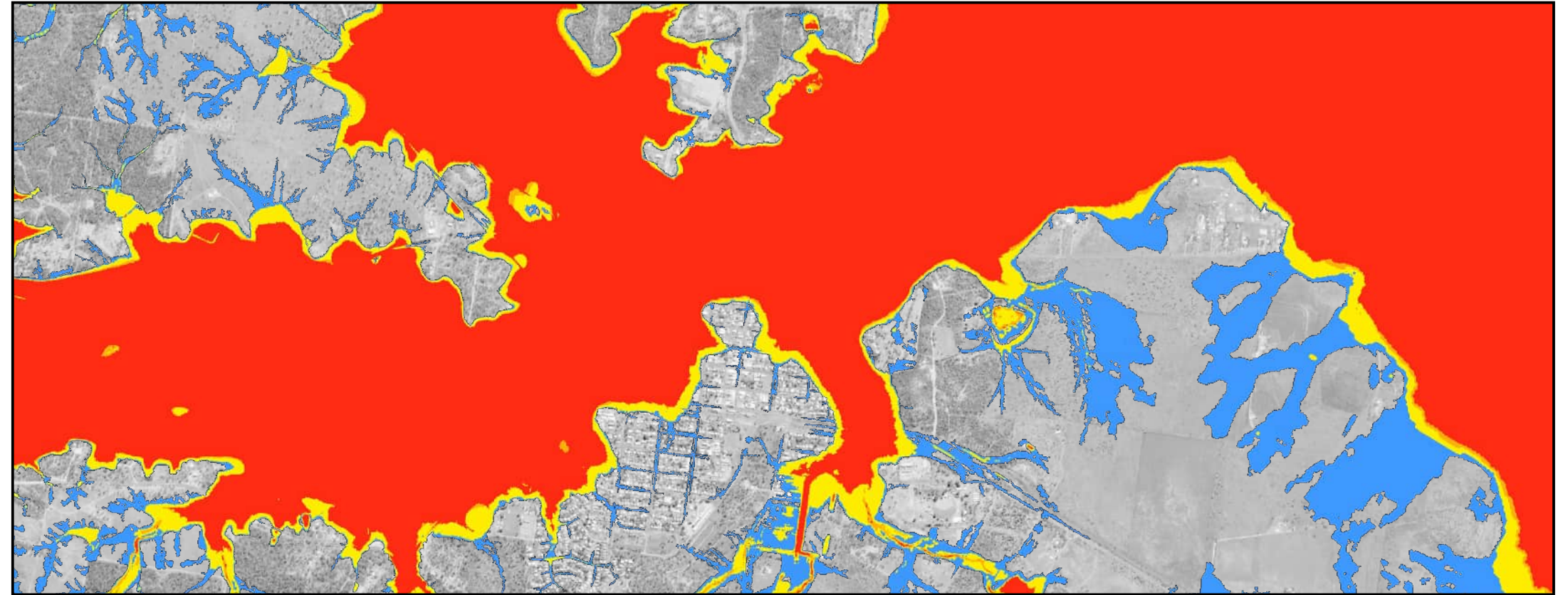
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	Scale at A3 © Kellogg Brown & Root Pty Ltd, Produced 2026-07-29T14:59:29.644 by K138966 Data © Esri all accessed under a Creative Commons 3.0 Australia licence. Full terms at https://creativecommons.org/licenses/by/3.0/au/legalcode While effort has been made to ensure the accuracy and completeness of the information presented, no guarantee is given, nor responsibility taken by KBR for any errors or omission. File: \\perfile001\data\$\Water_Resources\Projects\BEW571 - Upper Nogoa and Mackenzie\G - GIS\Workspaces\260630_Mapping_Atlas.qgz		Scale: 0 2 4 6 8 10 km 1:300,000		



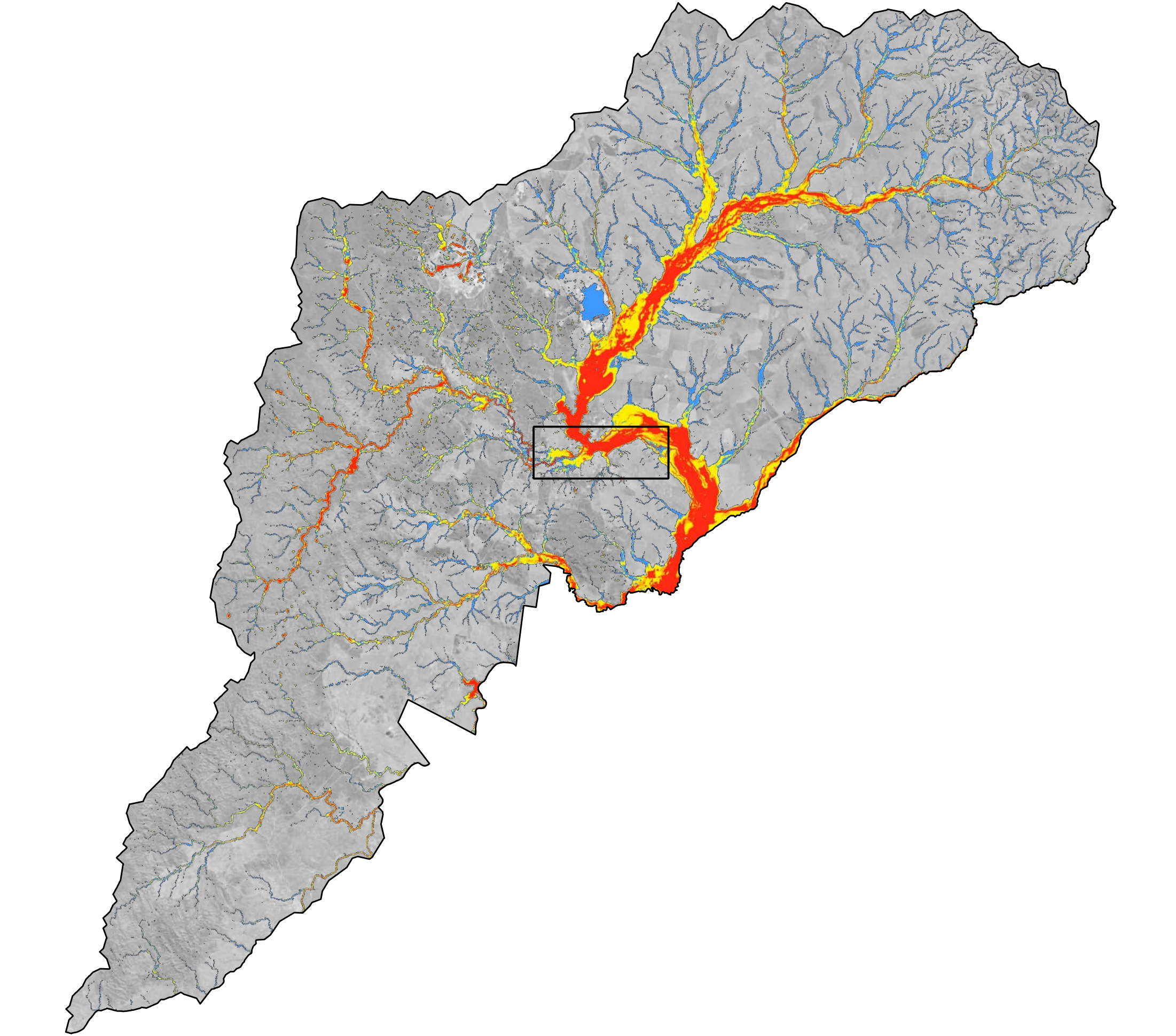
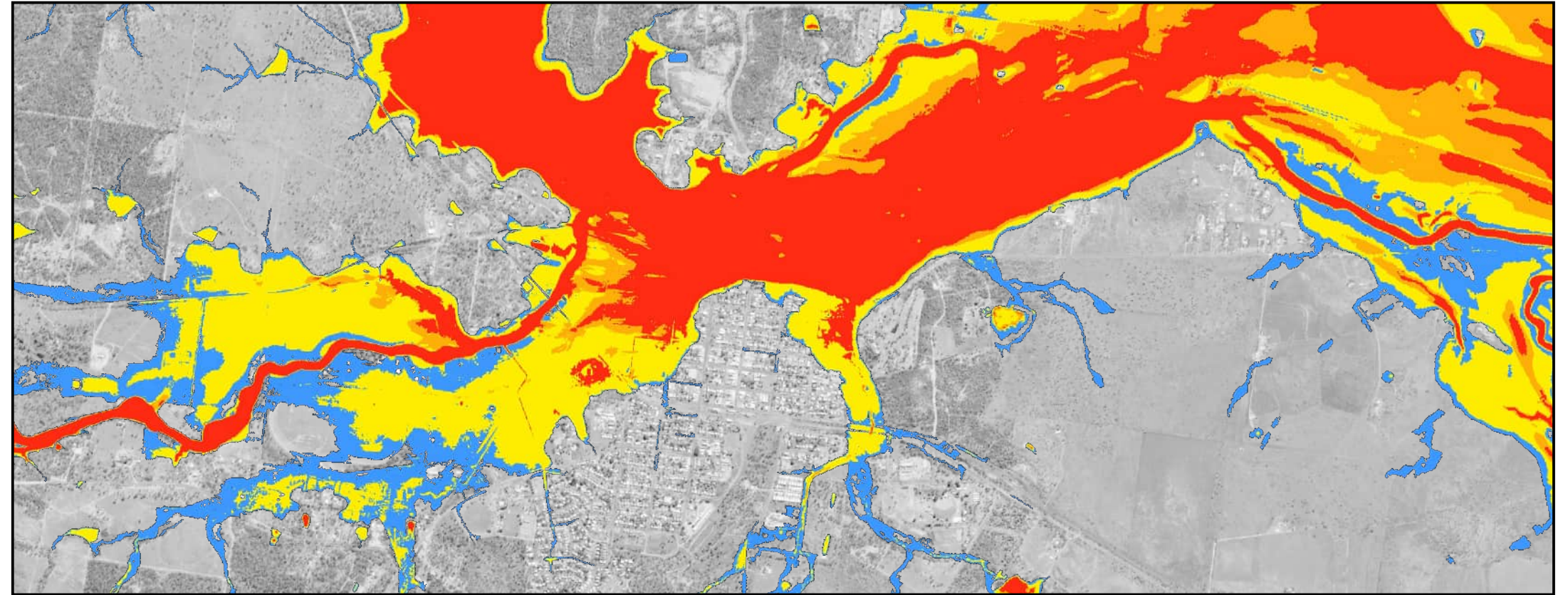
LEGEND Flood Hazards (QRA) Low Significant High Extreme Study Area	Title: 0.5% AEP (2030) Event Peak Flood Hazards (QRA) Upper Nogoa River (Clermont)		Figure: C-42	Rev: 0	
	Scale at A3 © Kellogg Brown & Root Pty Ltd, Produced 2026-07-29T14:59:33.628 by K138966 Data © Esri all accessed under a Creative Commons 3.0 Australia licence. Full terms at https://creativecommons.org/licenses/by/3.0/au/legalcode While effort has been made to ensure the accuracy and completeness of the information presented, no guarantee is given, nor responsibility taken by KBR for any errors or omission. File: \\perfile001\data\$\Water_Resources\Projects\BEW571 - Upper Nogoa and Mackenzie\G - GIS\Workspaces\260630_Mapping_Atlas.qgz		Scale: 0246810 km 1:300,000		



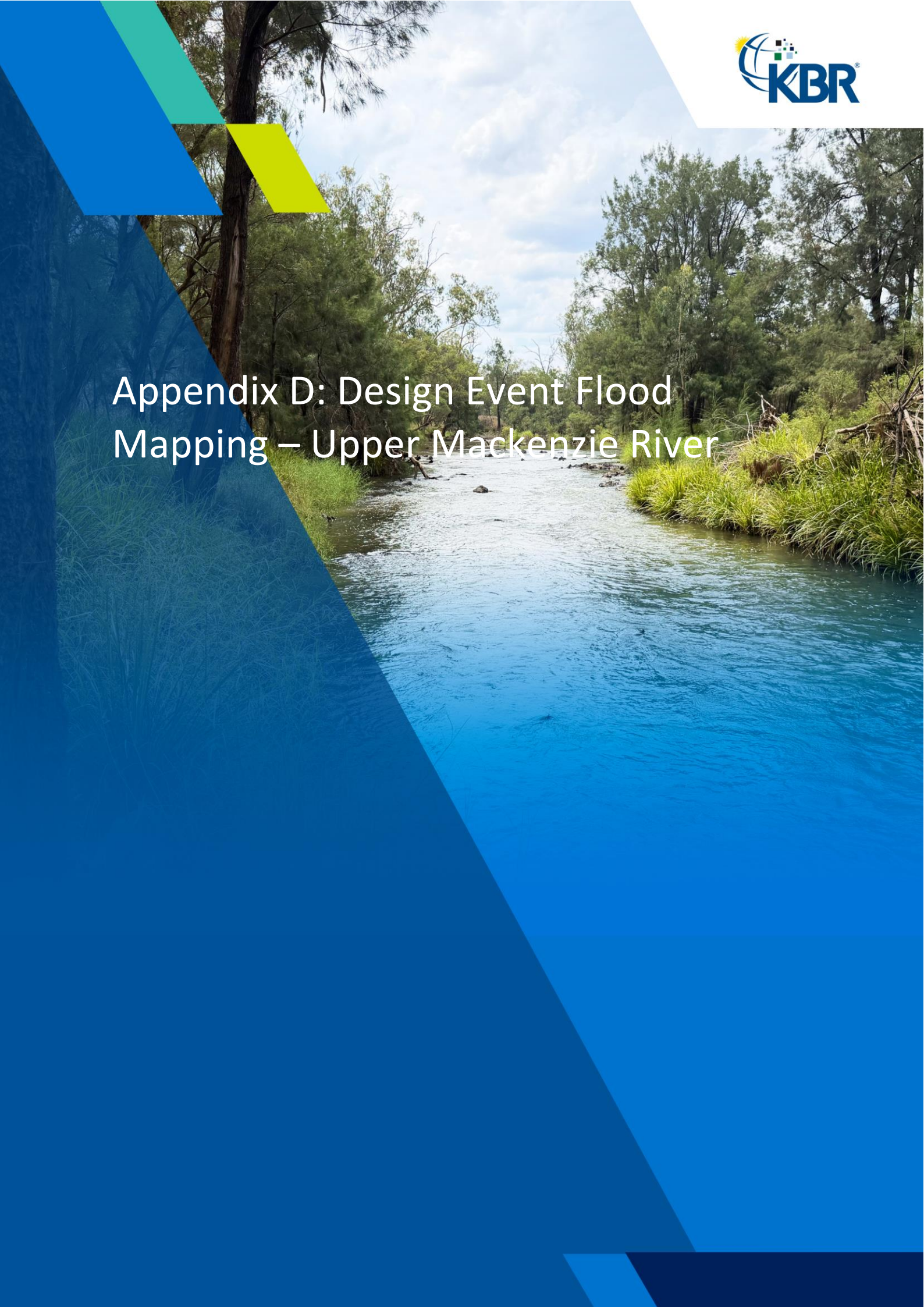
LEGEND Flood Hazards (QRA) Low Significant High Extreme Study Area	0.2% AEP (2030) Event Peak Flood Hazards (QRA) Upper Nogoa River (Clermont)		Figure: C-43	Rev: 0
	Scale at A3 © Kellogg Brown & Root Pty Ltd, Produced 2026-07-29T14:59:37.535 by K138966 Data © Esri all accessed under a Creative Commons 3.0 Australia licence. Full terms at https://creativecommons.org/licenses/by/3.0/au/legalcode While effort has been made to ensure the accuracy and completeness of the information presented, no guarantee is given, nor responsibility taken by KBR for any errors or omission. File: \\perfile001\data\$\Water_Resources\Projects\BEW571 - Upper Nogoa and Mackenzie\G - GIS\Workspaces\260630_Mapping_Atlas.qgz			
	Scale: 0 2 4 6 8 10 km 1:300,000			



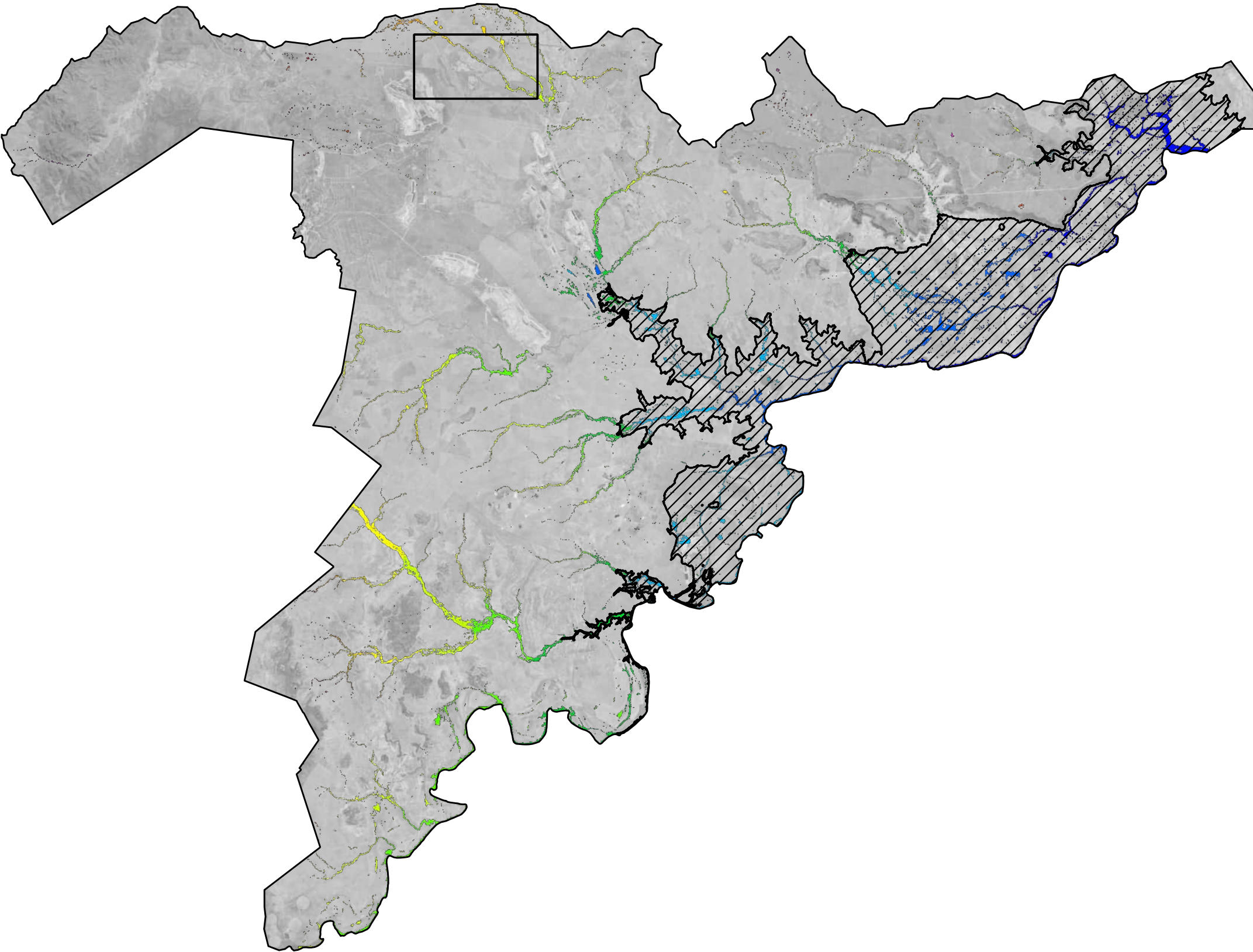
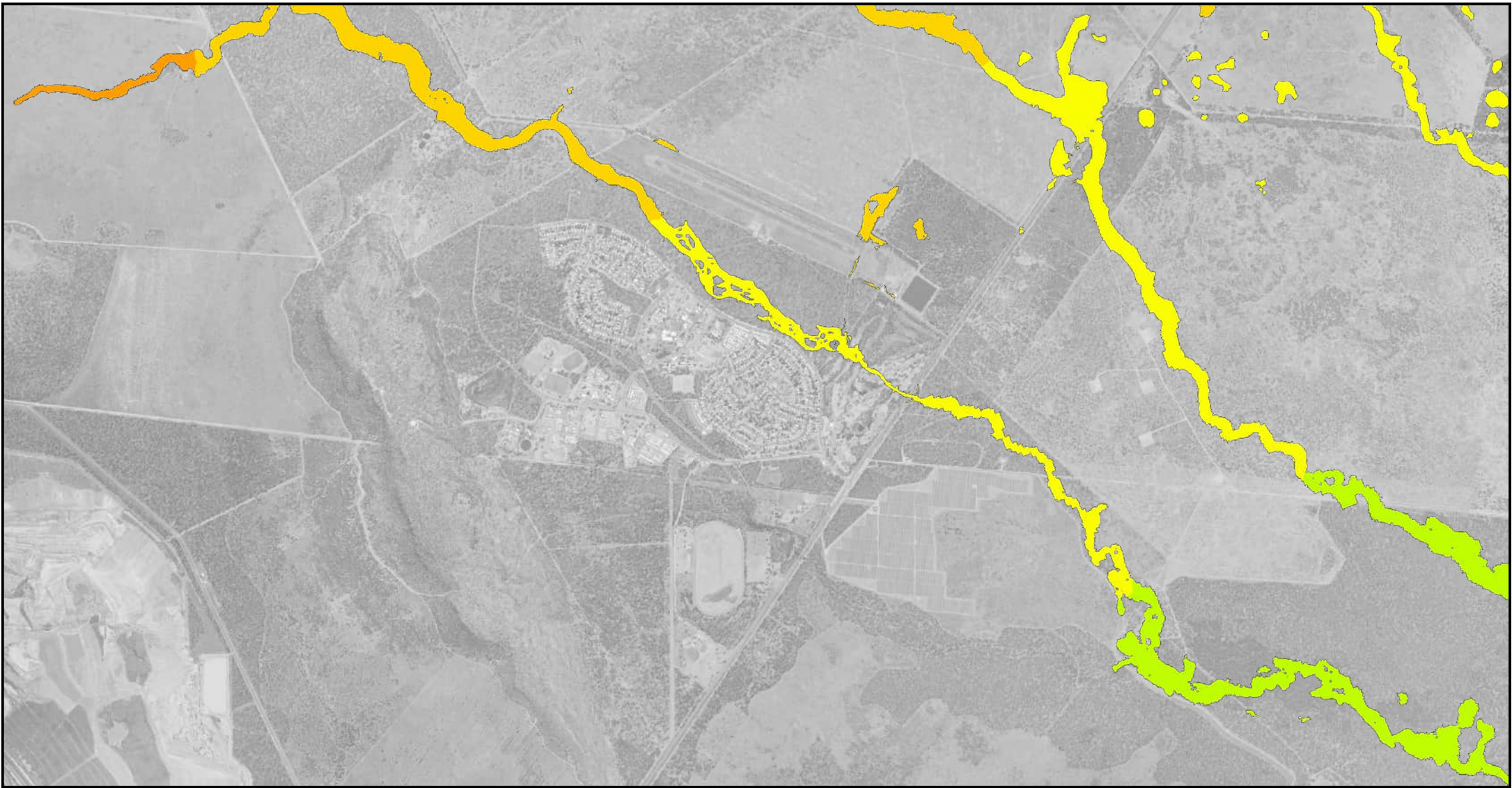
LEGEND Flood Hazards (QRA) Low Significant High Extreme Study Area	Title: PMF Event (2030) Peak Flood Hazards (QRA) Upper Nogoa River (Clermont)	Figure: C-44	Rev: 0
	Scale at A3 © Kellogg Brown & Root Pty Ltd, Produced 2026-07-29T14:59:41.504 by K138966 Data © Esri all accessed under a Creative Commons 3.0 Australia licence. Full terms at https://creativecommons.org/licenses/by/3.0/au/legalcode While effort has been made to ensure the accuracy and completeness of the information presented, no guarantee is given, nor responsibility taken by KBR for any errors or omission. File: \\perfile001\data\Water_Resources\Projects\BEW571 - Upper Nogoa and Mackenzie\G - GIS\Workspaces\260630_Mapping_Atlas.qgz	Scale: 0246810 km 1:300,000	



LEGEND Flood Hazards (QRA) Low Significant High Extreme Study Area	Title: 1% AEP (2100) Event Peak Flood Hazards (QRA) Upper Nogoa River (Clermont)		Figure: C-45	Rev: 0	
	Scale at A3 © Kellogg Brown & Root Pty Ltd, Produced 2026-07-29T14:59:45.467 by K138966 Data © Esri all accessed under a Creative Commons 3.0 Australia licence. Full terms at https://creativecommons.org/licenses/by/3.0/au/legalcode While effort has been made to ensure the accuracy and completeness of the information presented, no guarantee is given, nor responsibility taken by KBR for any errors or omission. File: \\perfile001\data\$\Water_Resources\Projects\BEW571 - Upper Nogoa and Mackenzie\G - GIS\Workspaces\260630_Mapping_Atlas.ggz		Scale: 0 2 4 6 8 10 km 1:300,000		

The background of the slide is a photograph of a river flowing through a forested area. The river is in the center, with water that appears slightly rippled. The banks are lined with tall, green trees and dense vegetation. The sky is visible in the background, showing some clouds. Overlaid on the left side of the image is a large, semi-transparent blue geometric shape that tapers towards the bottom. The title text is positioned within this blue area.

Appendix D: Design Event Flood Mapping – Upper Mackenzie River



LEGEND			
Peak Flood Levels (mAHD)			
	<= 100		130 - 140
	100 - 110		140 - 150
	110 - 120		150 - 160
	120 - 130		160 - 170
	180 - 190		190 - 200
	>200		Study Area
			Uncertainty Extent

Title:

20% AEP (2030) Event Peak Flood Levels Upper Mackenzie River (Middlemount)

Scale at A3
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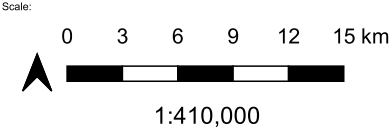
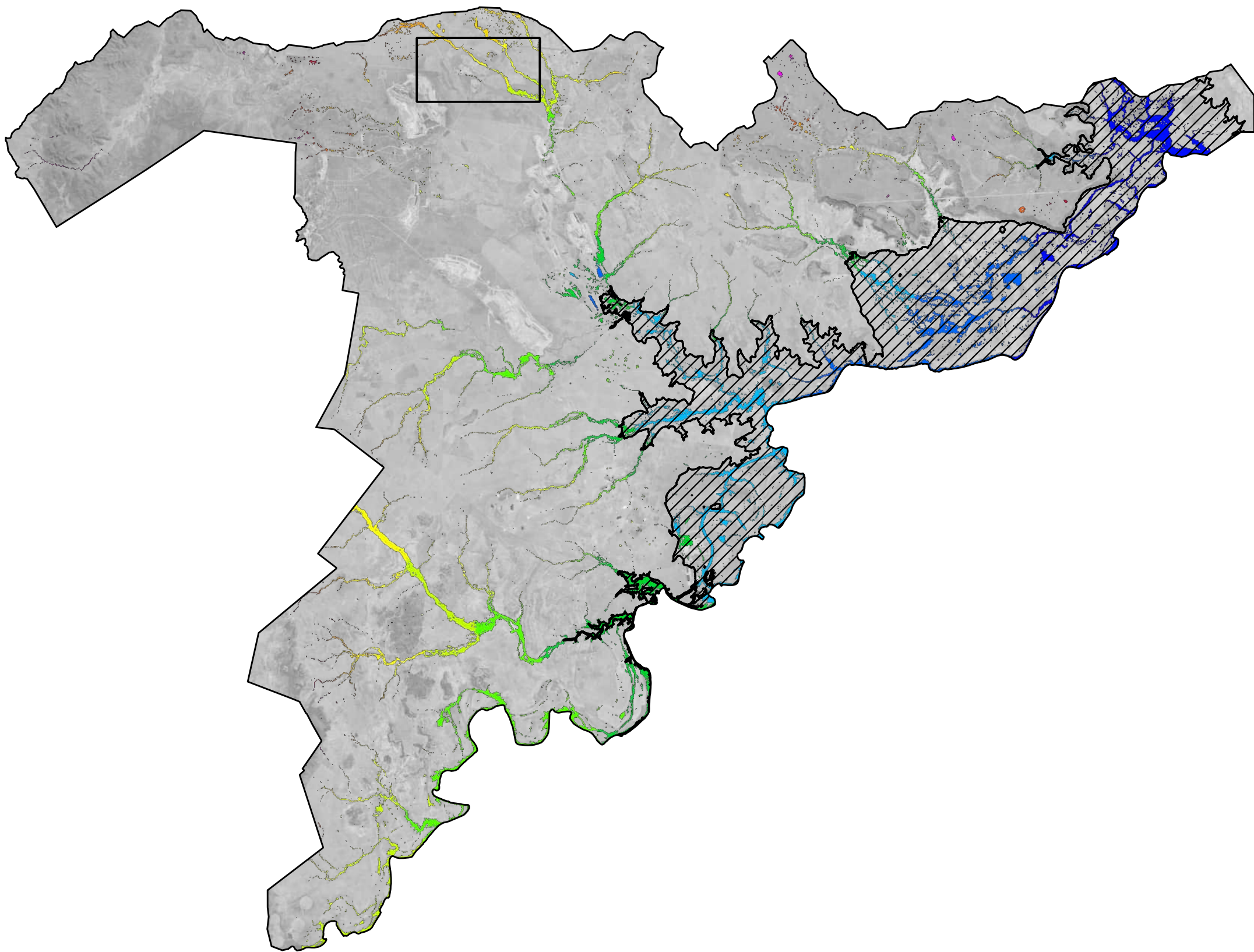
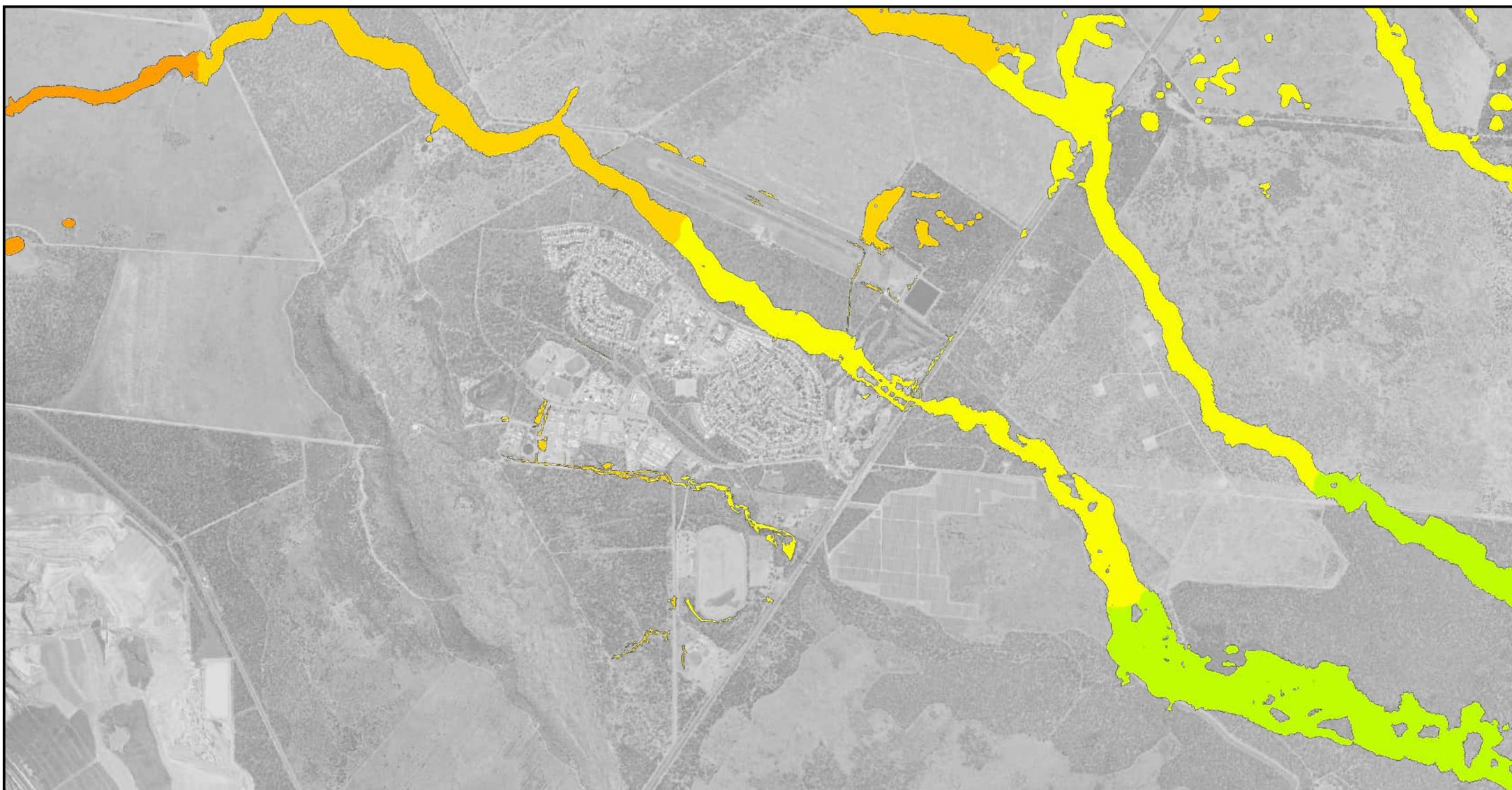


Figure:	D-2	Rev:	0



LEGEND

Peak Flood Levels
(mAHD)



Title

5% AEP (2030) Event Peak Flood Levels Upper Mackenzie River (Middlemount)

Scale at A3

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File: \\perfile001\data\$\Water_Resources\Projects\BEW571 - Upper Nogoia and Mackenzie\G - GIS\Workspaces\260630_Mapping_Atlas.qgz

Scale:



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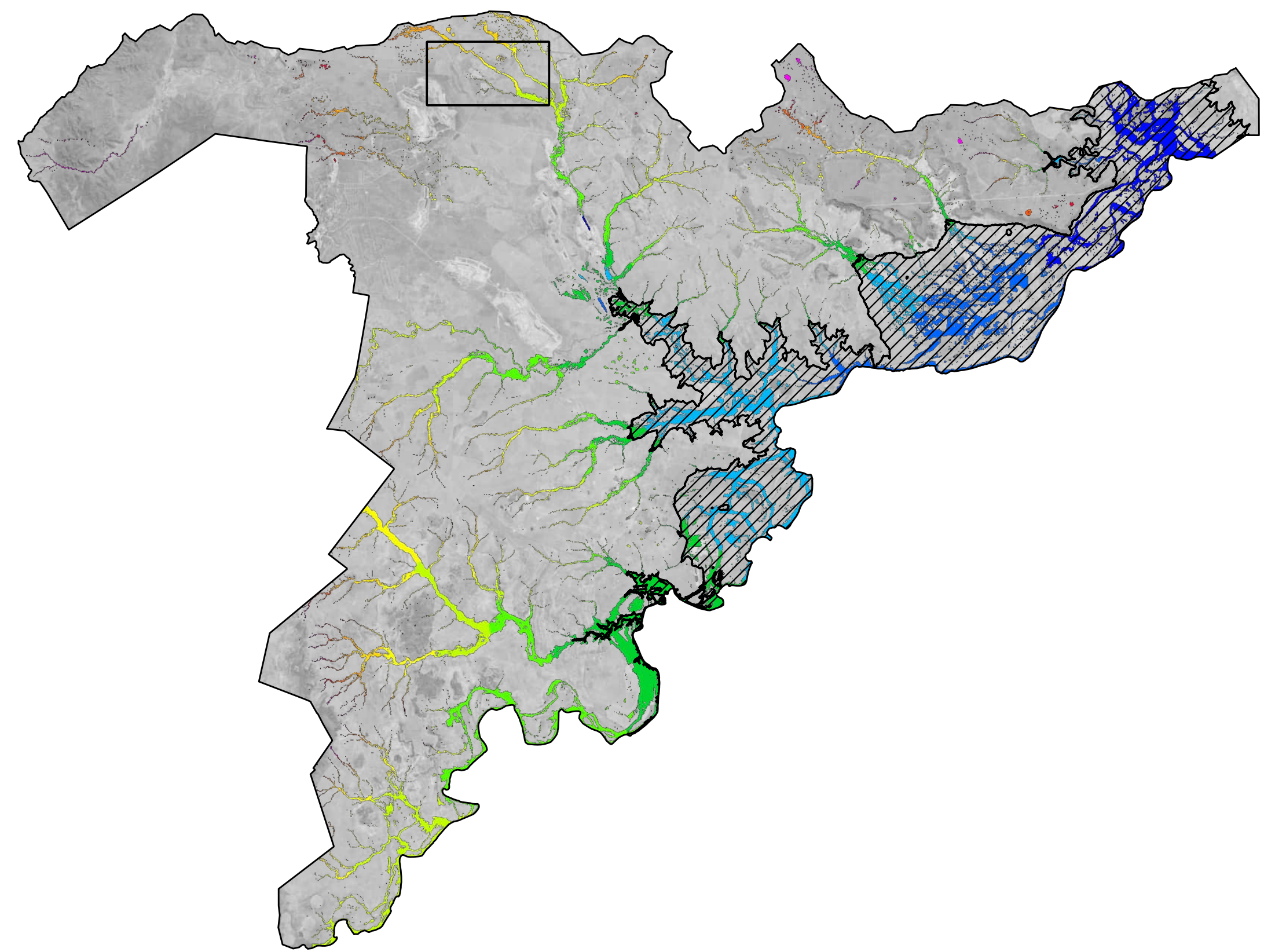
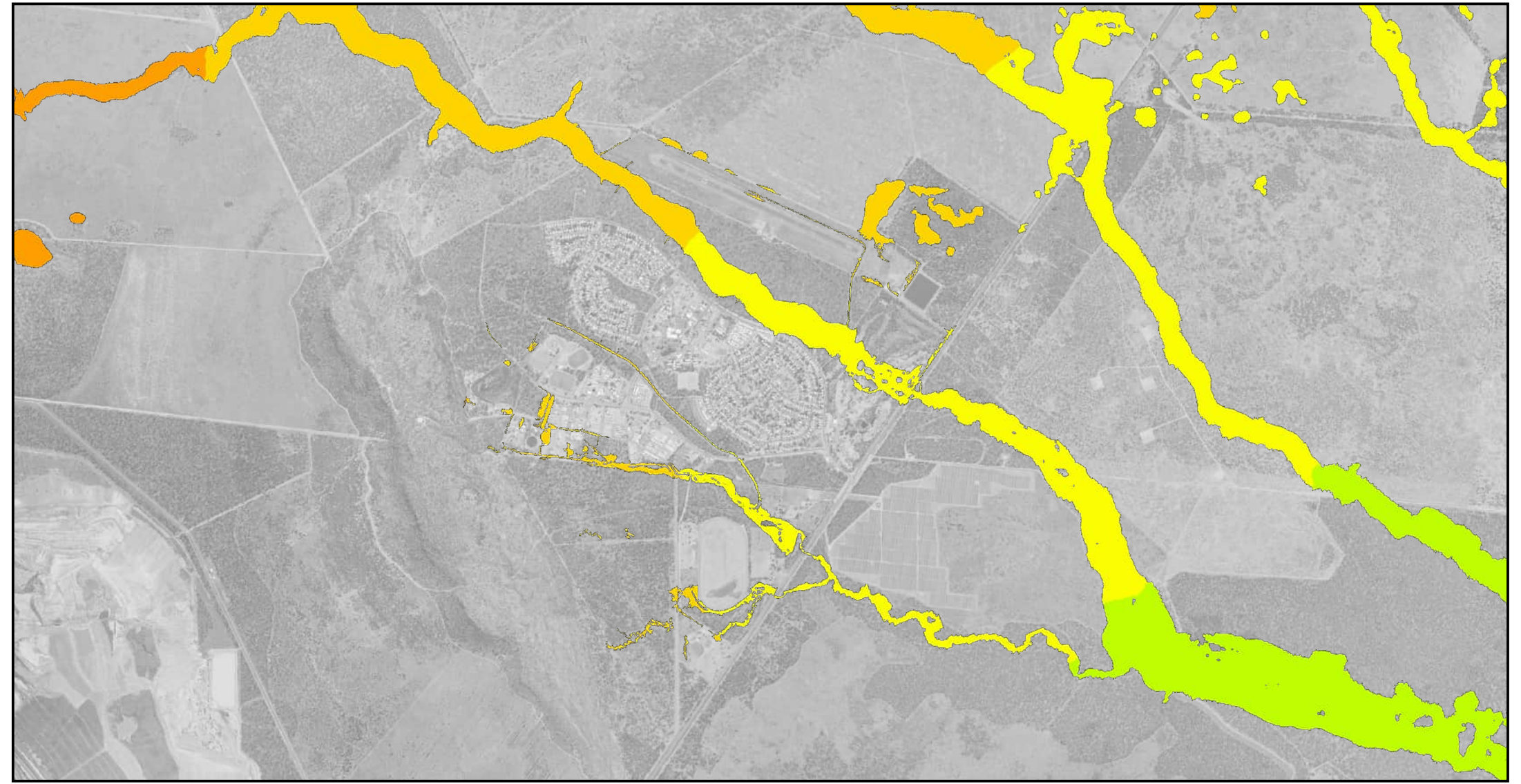
Figure:

D-3

Rev

0





LEGEND

Peak Flood Levels (mAHD)

≤ 100	130 - 140	190 - 200
100 - 110	140 - 150	>200
110 - 120	150 - 160	Study Area
120 - 130	160 - 170	Uncertainty Extent
	170 - 180	
	180 - 190	

Title:

2% AEP (2030) Event Peak Flood Levels Upper Mackenzie River (Middlemount)

Scale at A3
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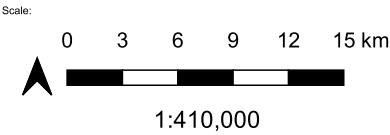
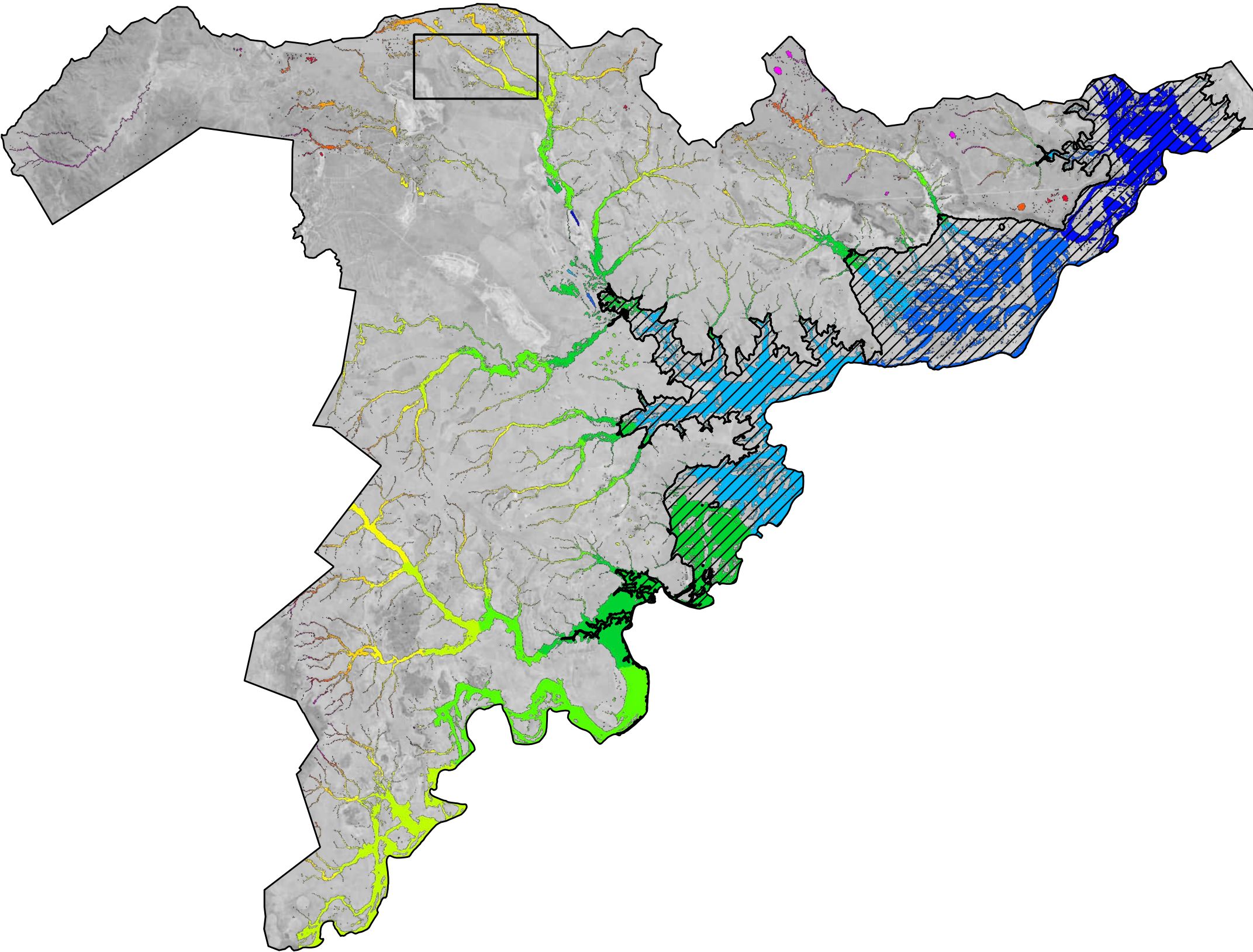
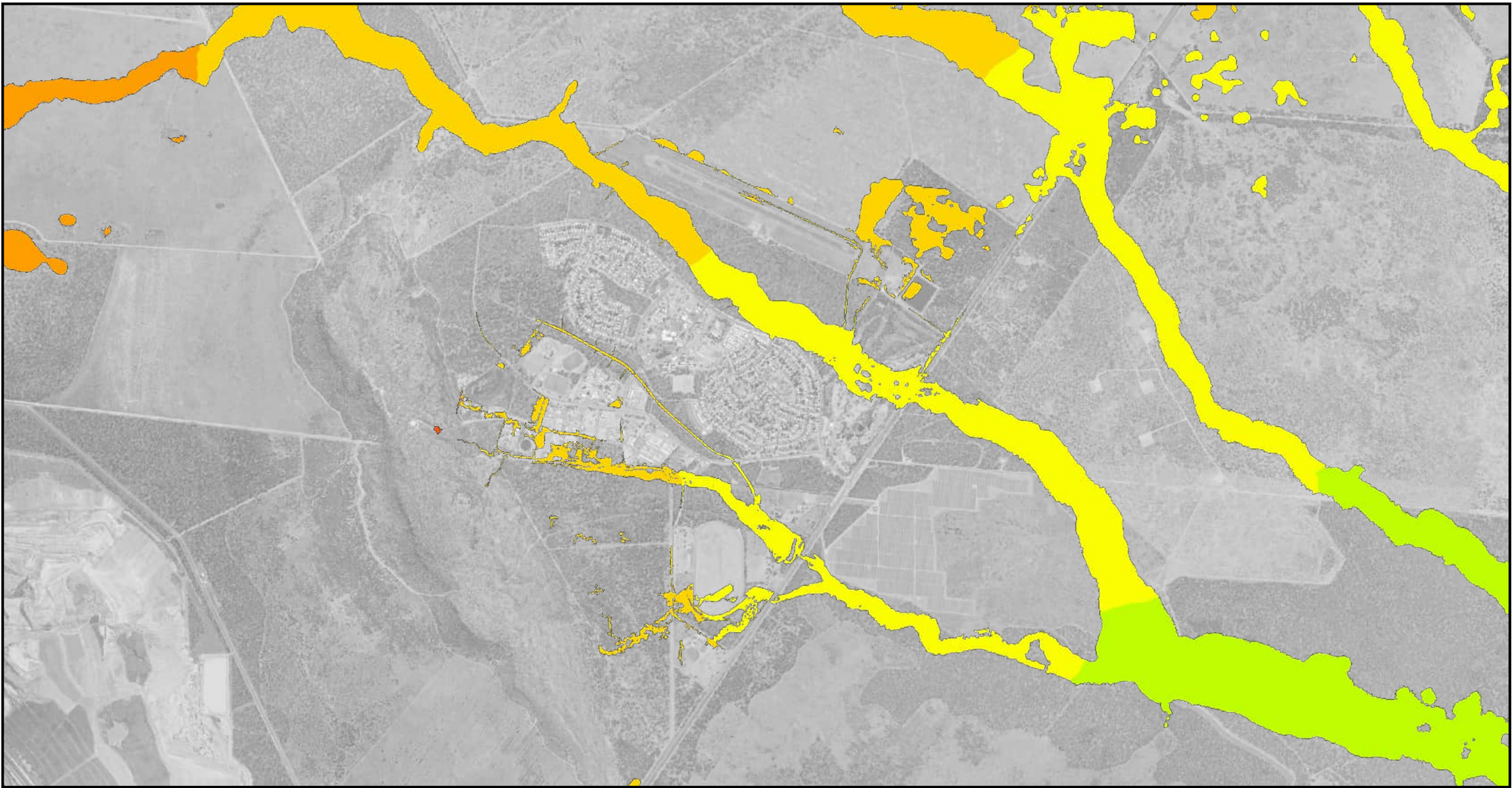


Figure:	D-4	Rev:	0

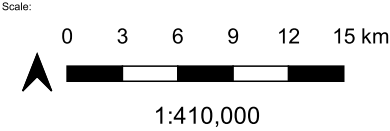


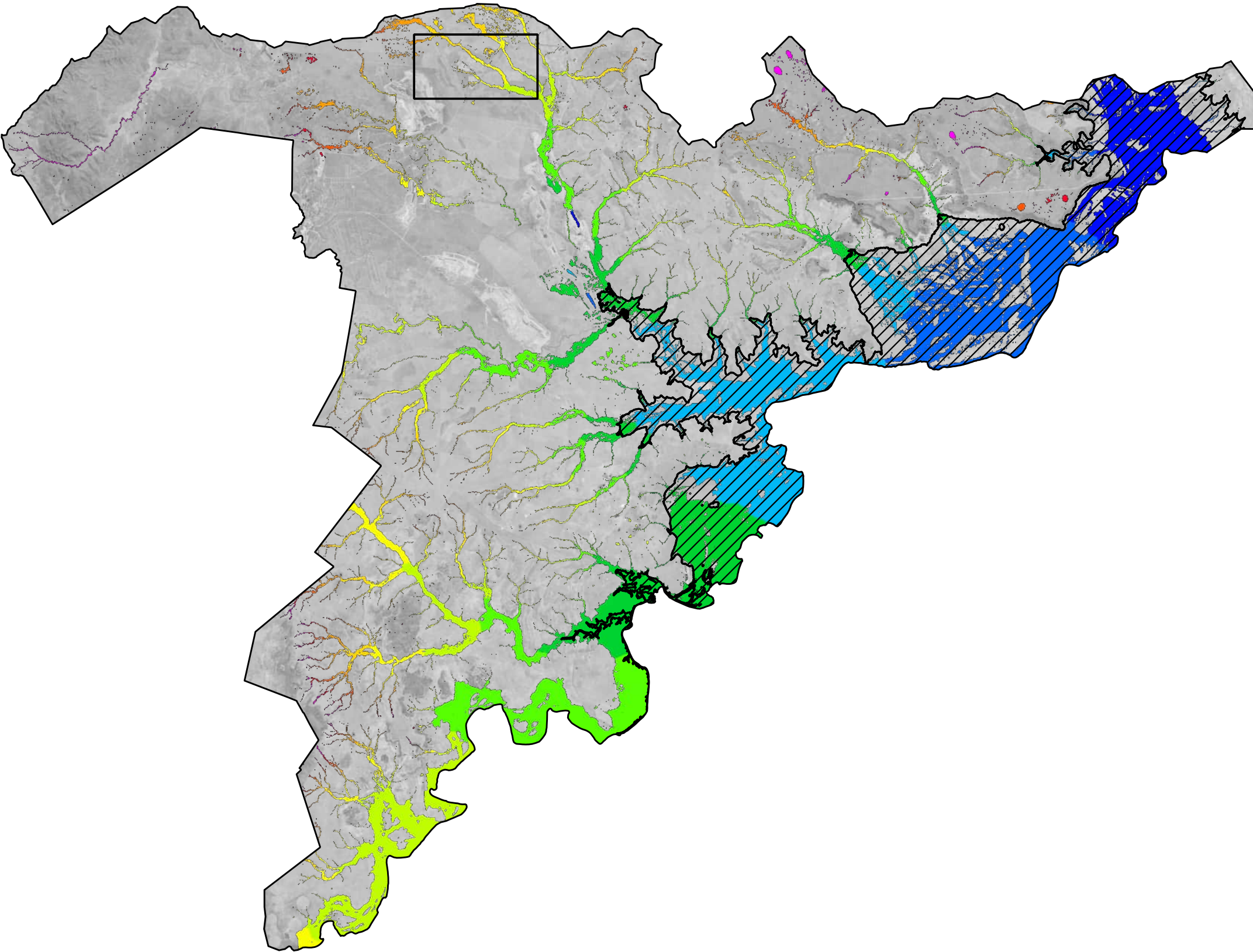
LEGEND			
Peak Flood Levels (mAHD)			
<= 100	130 - 140	190 - 200	
100 - 110	140 - 150	>200	
110 - 120	150 - 160	Study Area	
120 - 130	160 - 170	Uncertainty Extent	
	170 - 180		
	180 - 190		

Title:

0.5% AEP (2030) Event Peak Flood Levels Upper Mackenzie River (Middlemount)

Scale at A3
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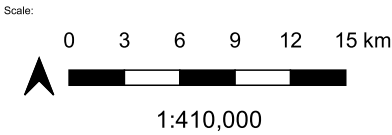


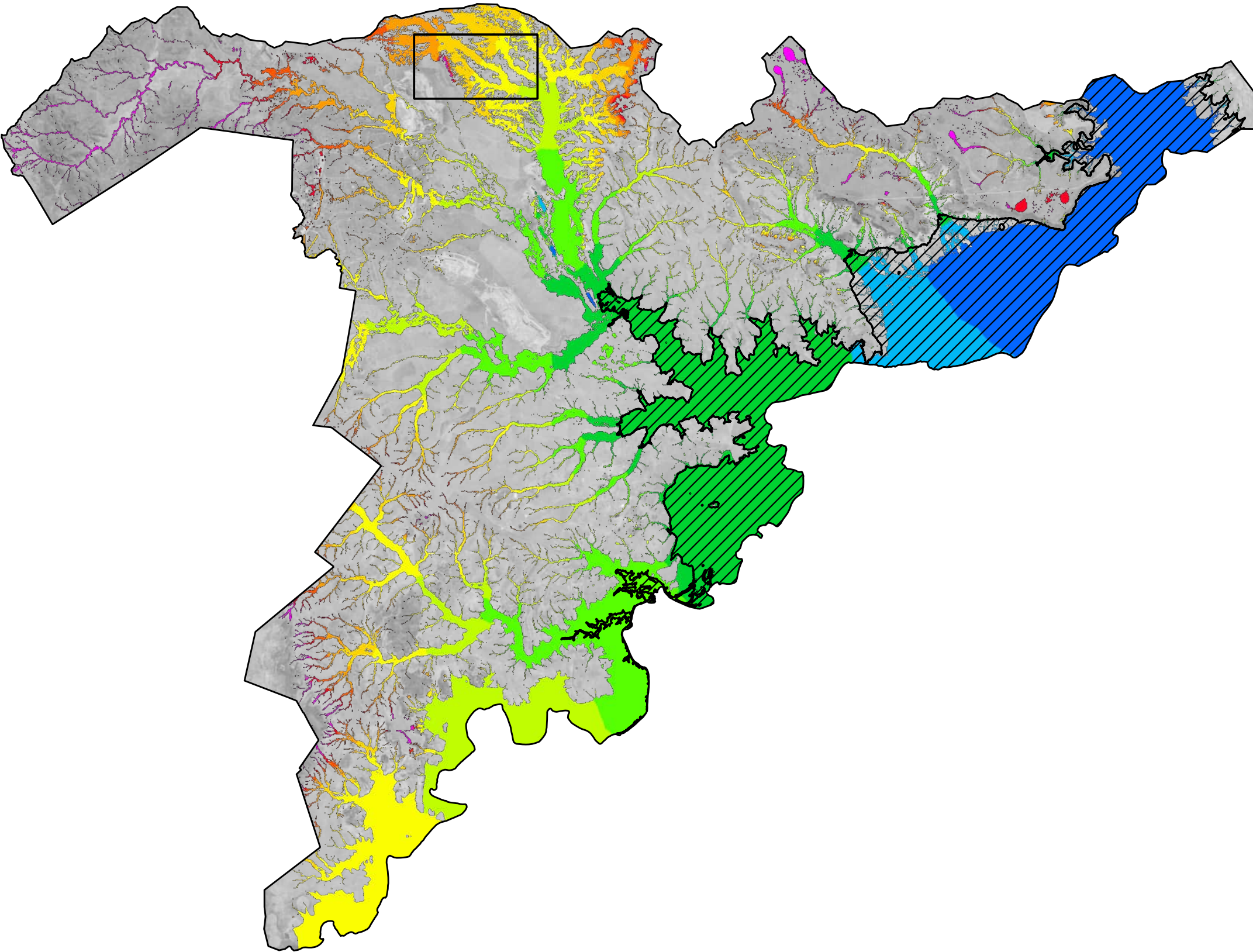
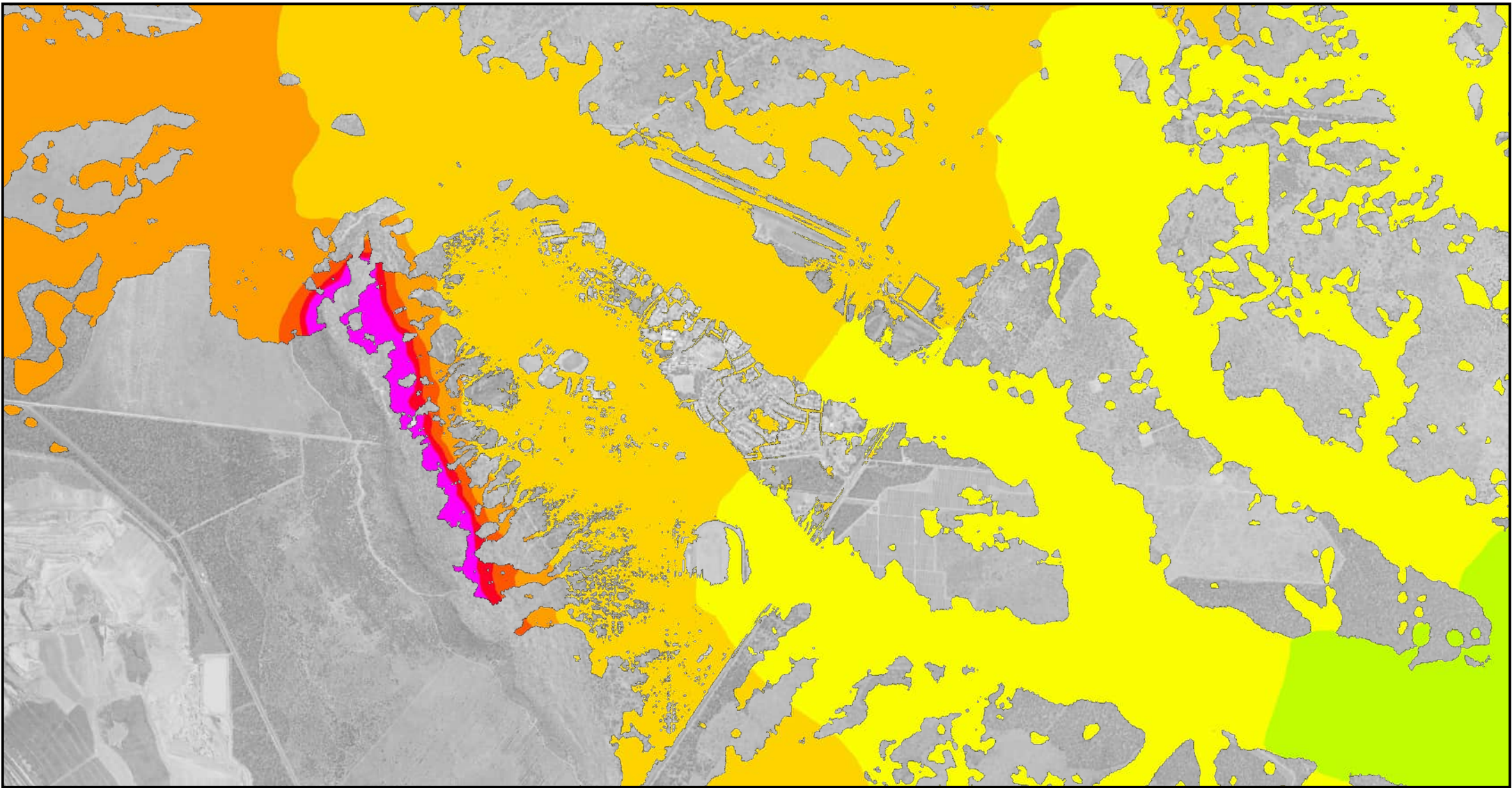
LEGEND		
Peak Flood Levels (mAHd)		
■ <= 100	■ 130 - 140	■ 190 - 200
■ 100 - 110	■ 140 - 150	■ >200
■ 110 - 120	■ 150 - 160	 Study Area
■ 120 - 130	■ 160 - 170	 Uncertainty Extent
■ 180 - 190		

Title:

0.2% AEP (2030) Event Peak Flood Levels Upper Mackenzie River (Middlemount)

Scale at A3
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LEGEND			
Peak Flood Levels (mAHD)			
	<= 100		130 - 140
	100 - 110		140 - 150
	110 - 120		150 - 160
	120 - 130		160 - 170
			170 - 180
			180 - 190
			190 - 200
			>200
			Study Area
			Uncertainty Extent

Title:

PMF Event (2030) Peak Flood Levels Upper Mackenzie River (Middlemount)

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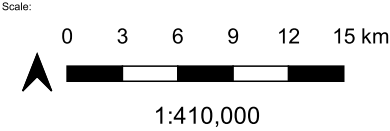
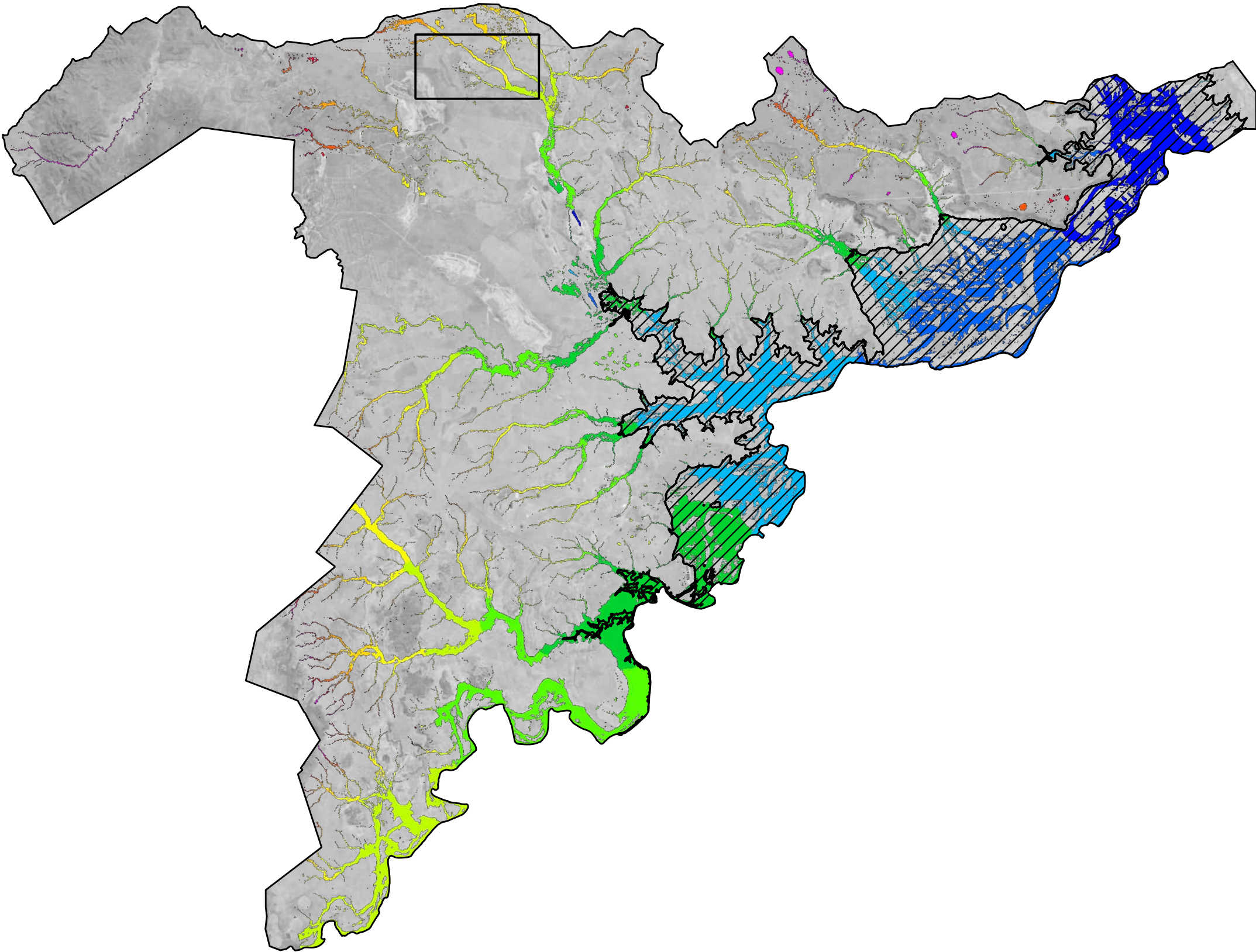
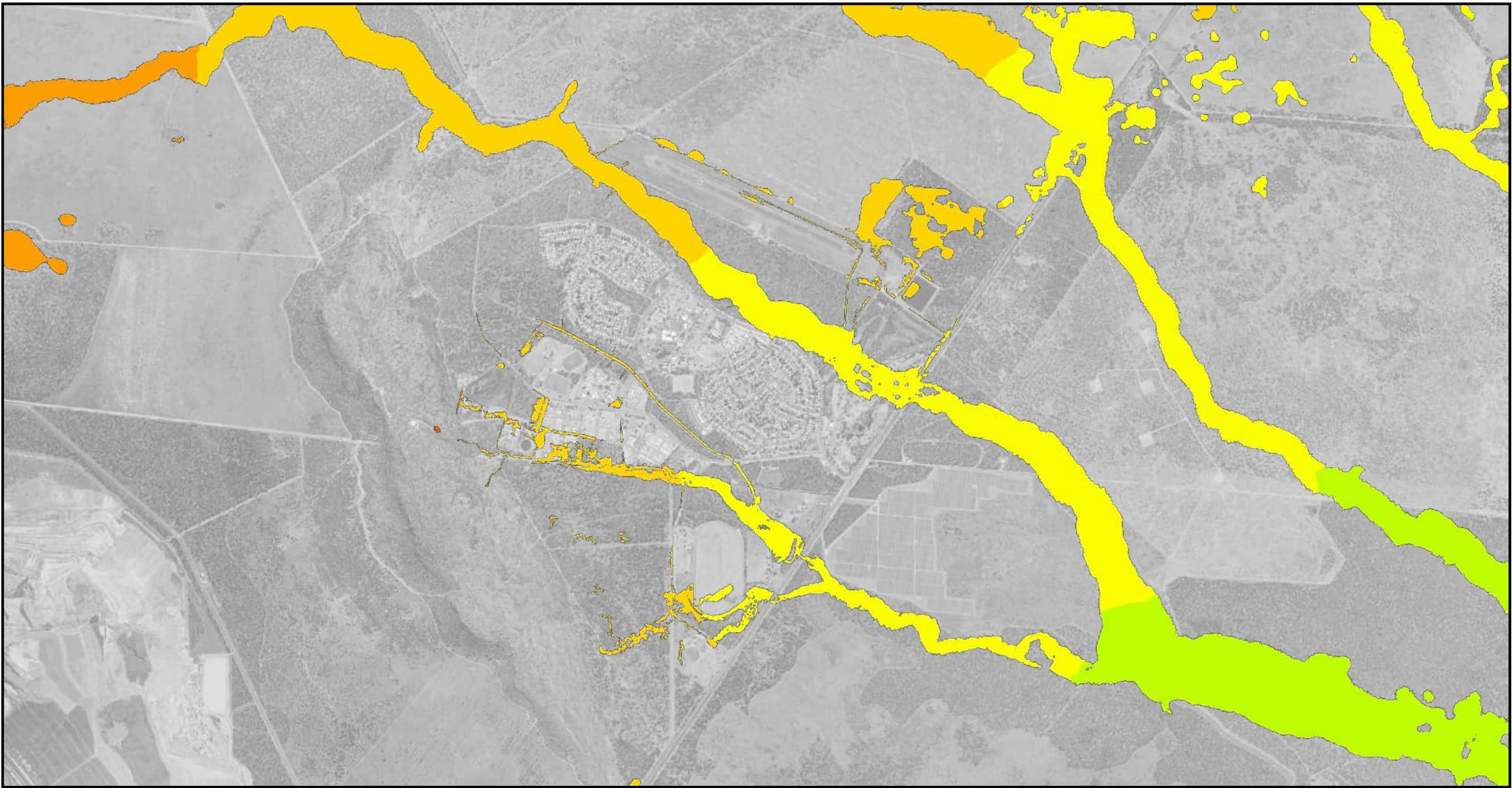


Figure:	D-8	Rev:	0



LEGEND			
Peak Flood Levels (mAHD)			
 <= 100	 130 - 140	 190 - 200	
 100 - 110	 140 - 150	 >200	
 110 - 120	 150 - 160	 Study Area	
 120 - 130	 160 - 170	 Uncertainty Extent	
	 170 - 180		
	 180 - 190		

Title:

1% AEP (2100) Event Peak Flood Levels Upper Mackenzie River (Middlemount)

Scale at A3
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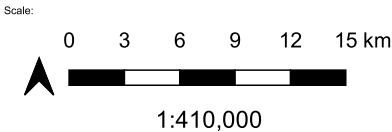
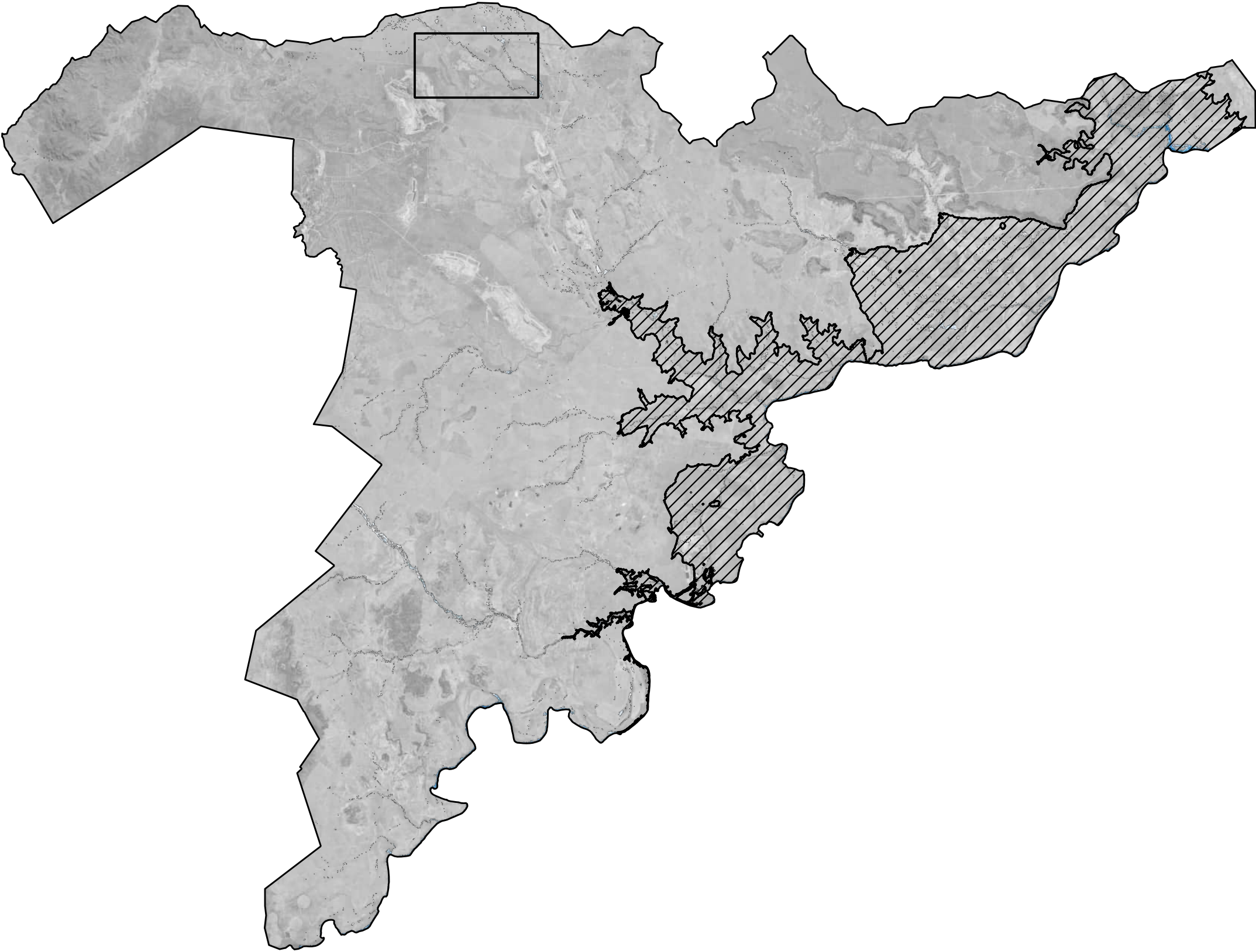
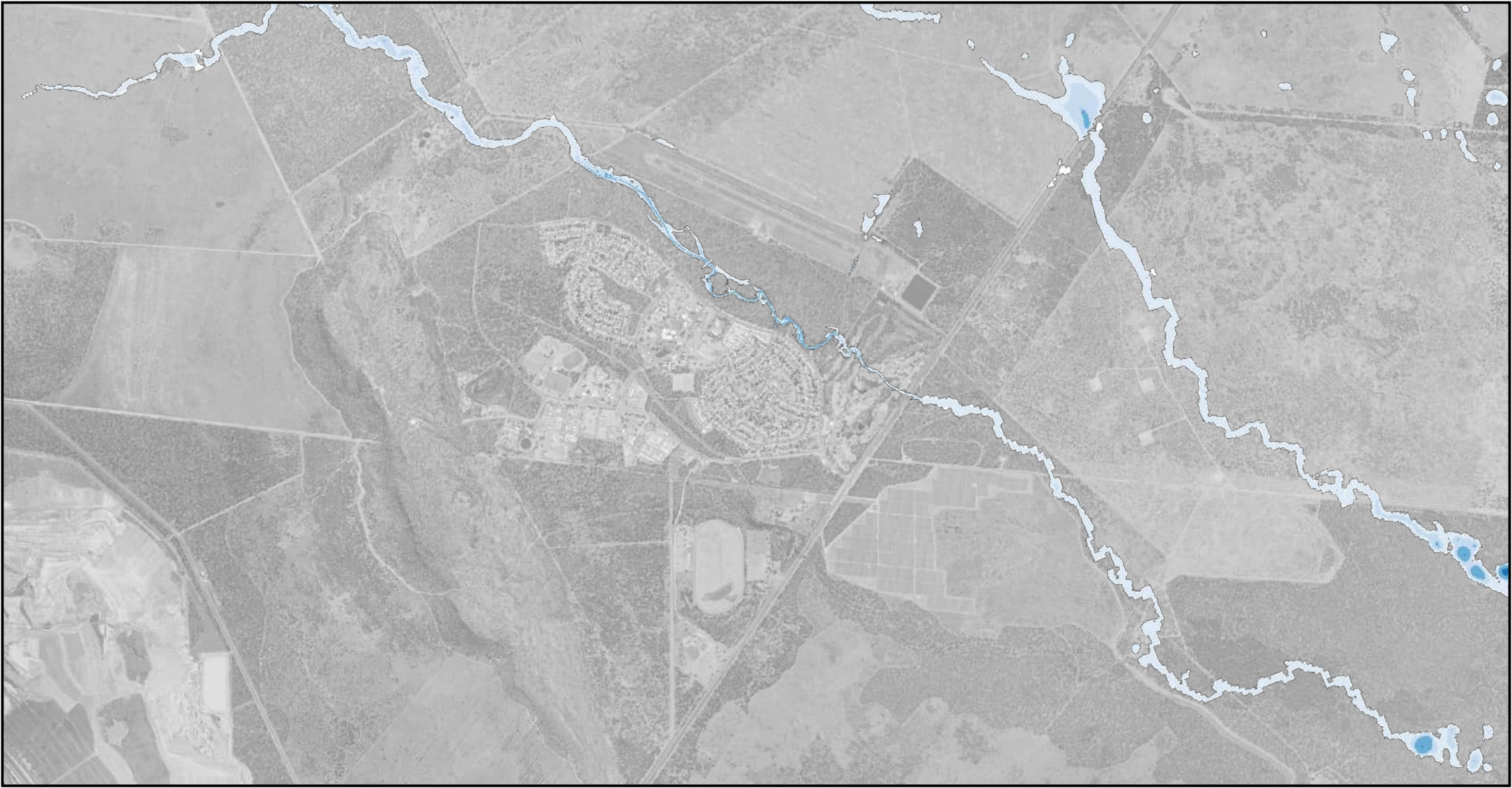


Figure:	Rev:
D-9	0





LEGEND

Peak Flood Depths (m)

<= 0.1

0.1 - 0.5

0.5 - 1.0

1.0 - 2.5

2.5 - 5.0

5.0 - 10.0

> 10.0

Study Area

Uncertainty Extent

Title:

**50% AEP (2030) Event Peak Flood Depths
Upper Mackenzie River (Middlemount)**

Scale at A3
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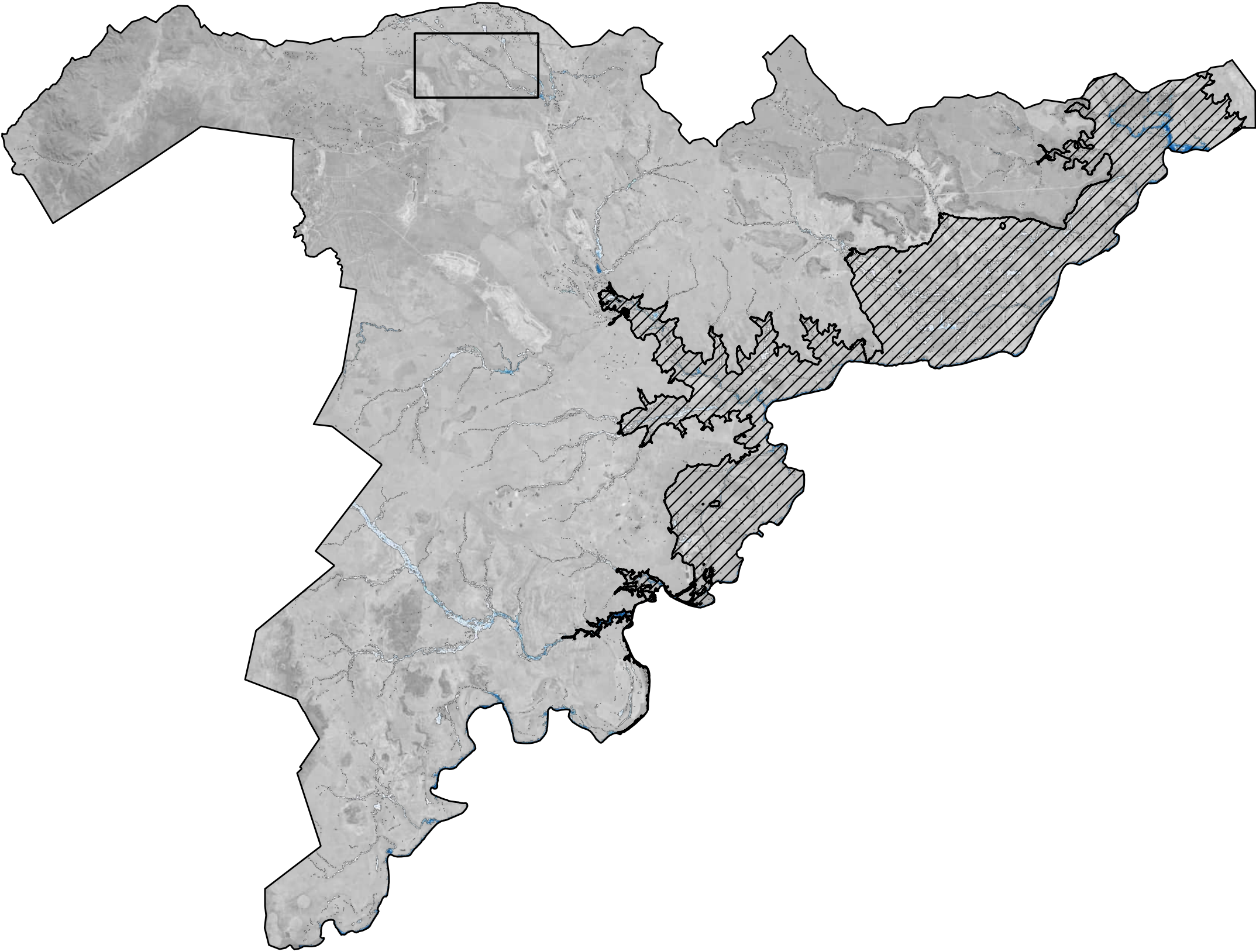
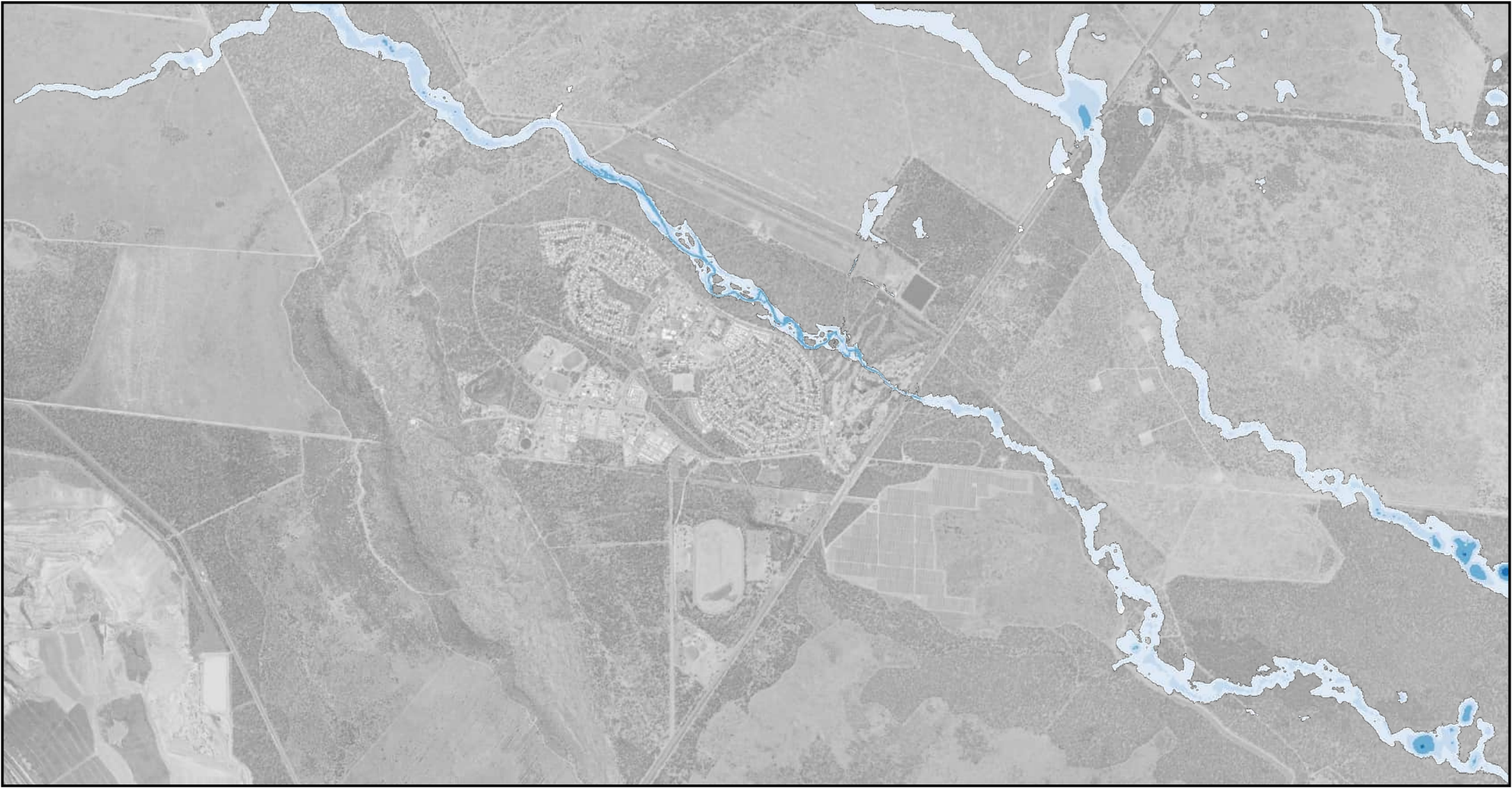
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Figure:

D-10

Rev:

0



LEGEND

Peak Flood Depths (m)

<= 0.1

0.1 - 0.5

0.5 - 1.0

1.0 - 2.5

2.5 - 5.0

5.0 - 10.0

> 10.0

Study Area

Uncertainty Extent

Title:

**20% AEP (2030) Event Peak Flood Depths
Upper Mackenzie River (Middlemount)**

Scale at A3
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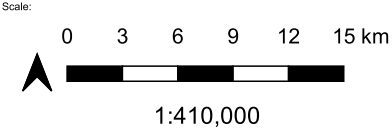
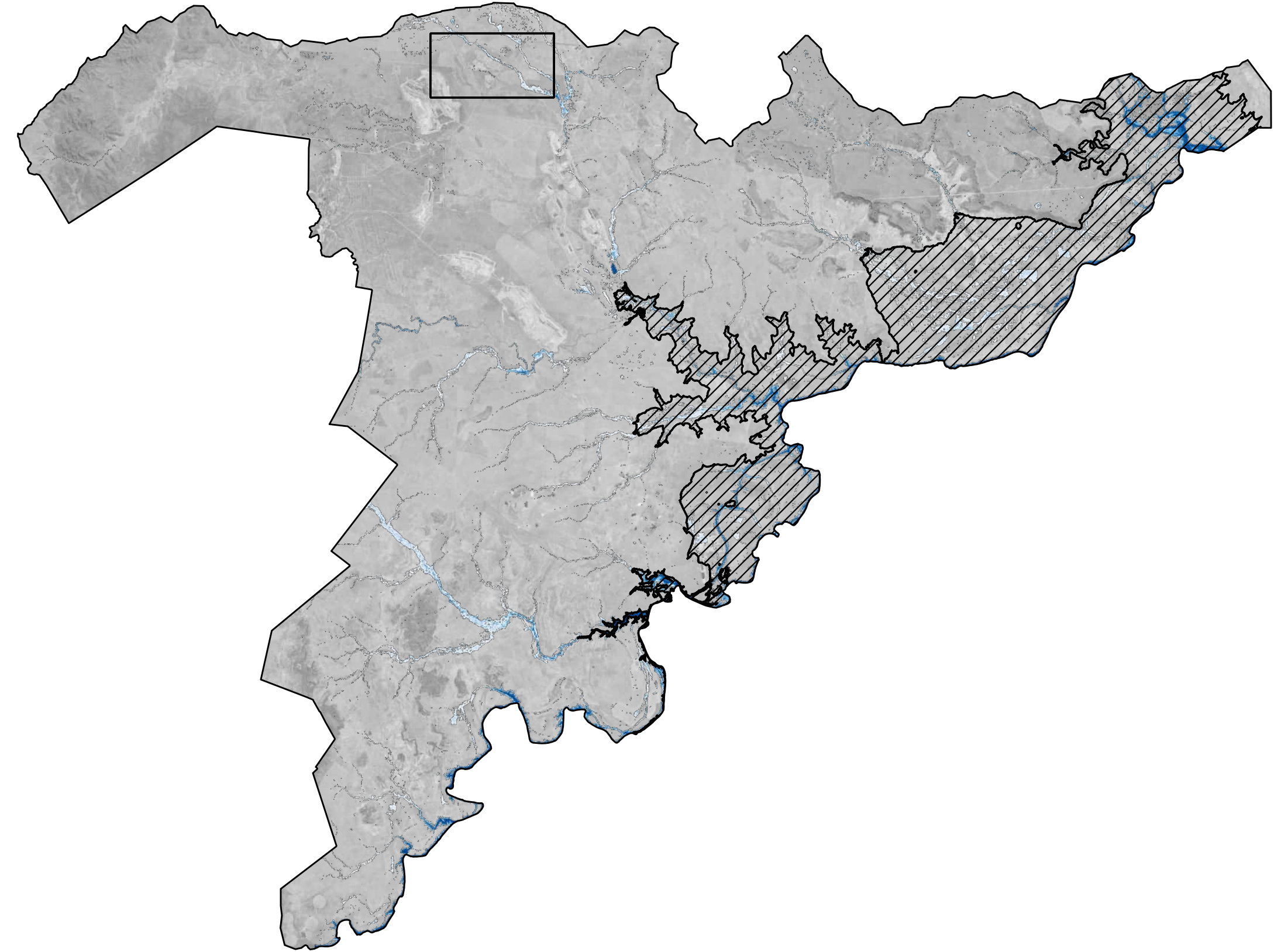
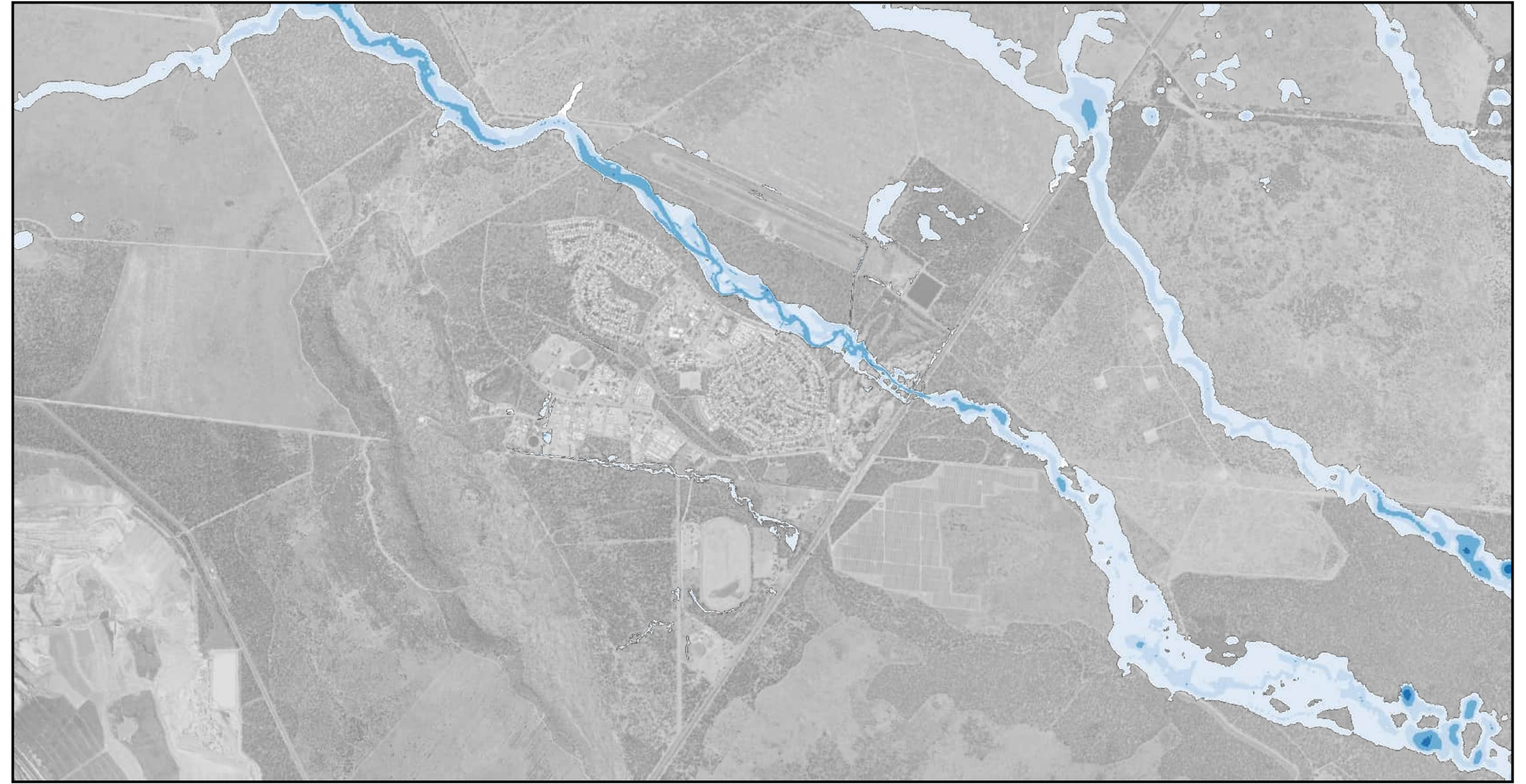


Figure:

D-11

Rev:

0



LEGEND

Peak Flood Depths (m)

	<= 0.1		2.5 - 5.0
	0.1 - 0.5		5.0 - 10.0
	0.5 - 1.0		> 10.0
	1.0 - 2.5		Study Area
			Uncertainty Extent

Title:

5% AEP (2030) Event Peak Flood Depths Upper Mackenzie River (Middlemount)

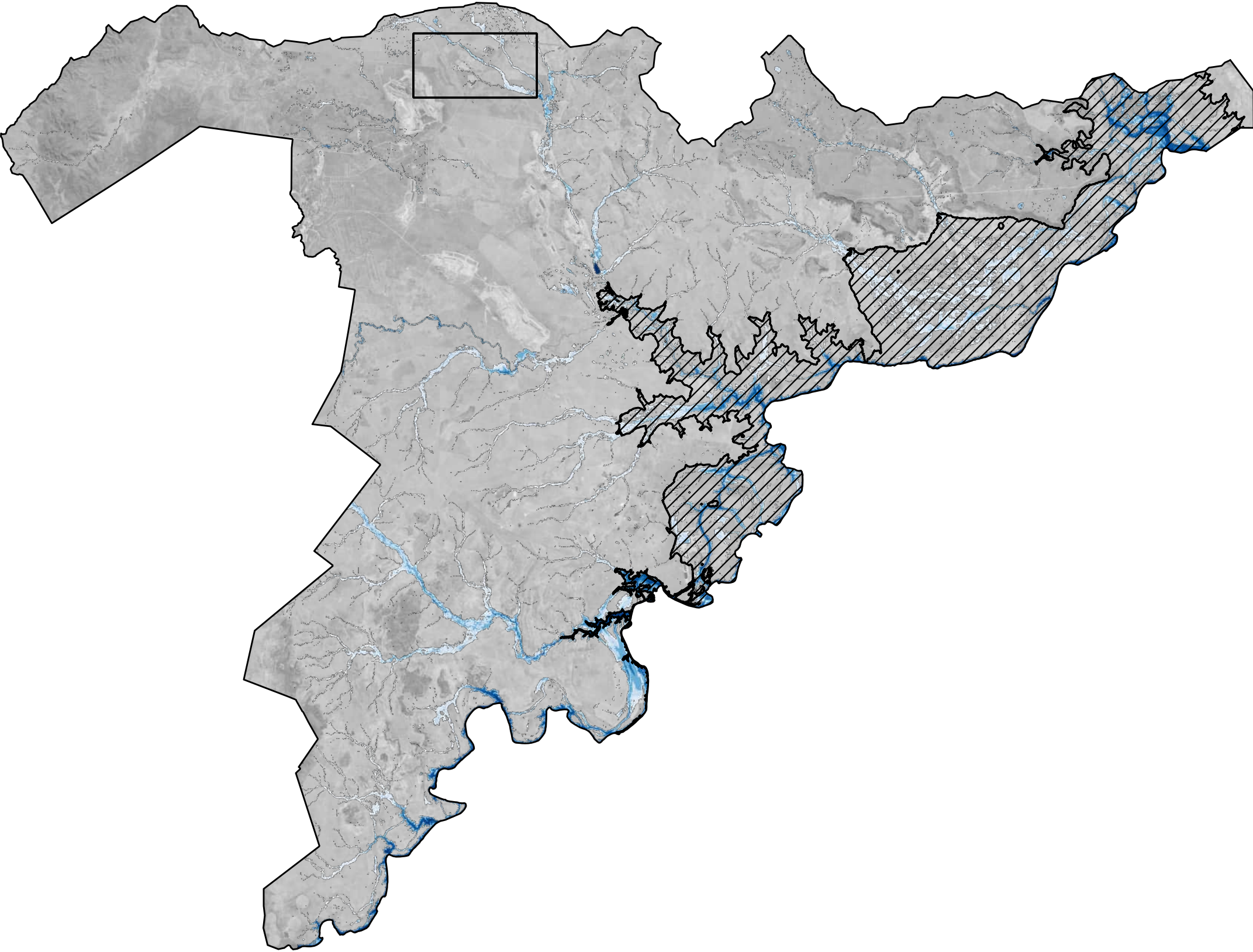
Scale at A3
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File: \\perfile001\data\$\Water_Resources\Projects\BEW571 - Upper Nogoa and Mackenzie\G - GIS\Workspaces\260630_Mapping_Atlas.qgz

Scale:

0 3 6 9 12 15 km

1:410,000

Figure: **D-12** Rev: **0**



LEGEND

Peak Flood Depths (m)

<= 0.1

0.1 - 0.5

0.5 - 1.0

1.0 - 2.5

2.5 - 5.0

5.0 - 10.0

> 10.0

Study Area

Uncertainty Extent

Title:

**2% AEP (2030) Event Peak Flood Depths
Upper Mackenzie River (Middlemount)**

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File: \\profile001\data\$\Water_Resources\Projects\BEW571 - Upper Nogoa and Mackenzie\G - GIS\Workspaces\260630_Mapping_Atlas.qgz

Scale:

03691215 km

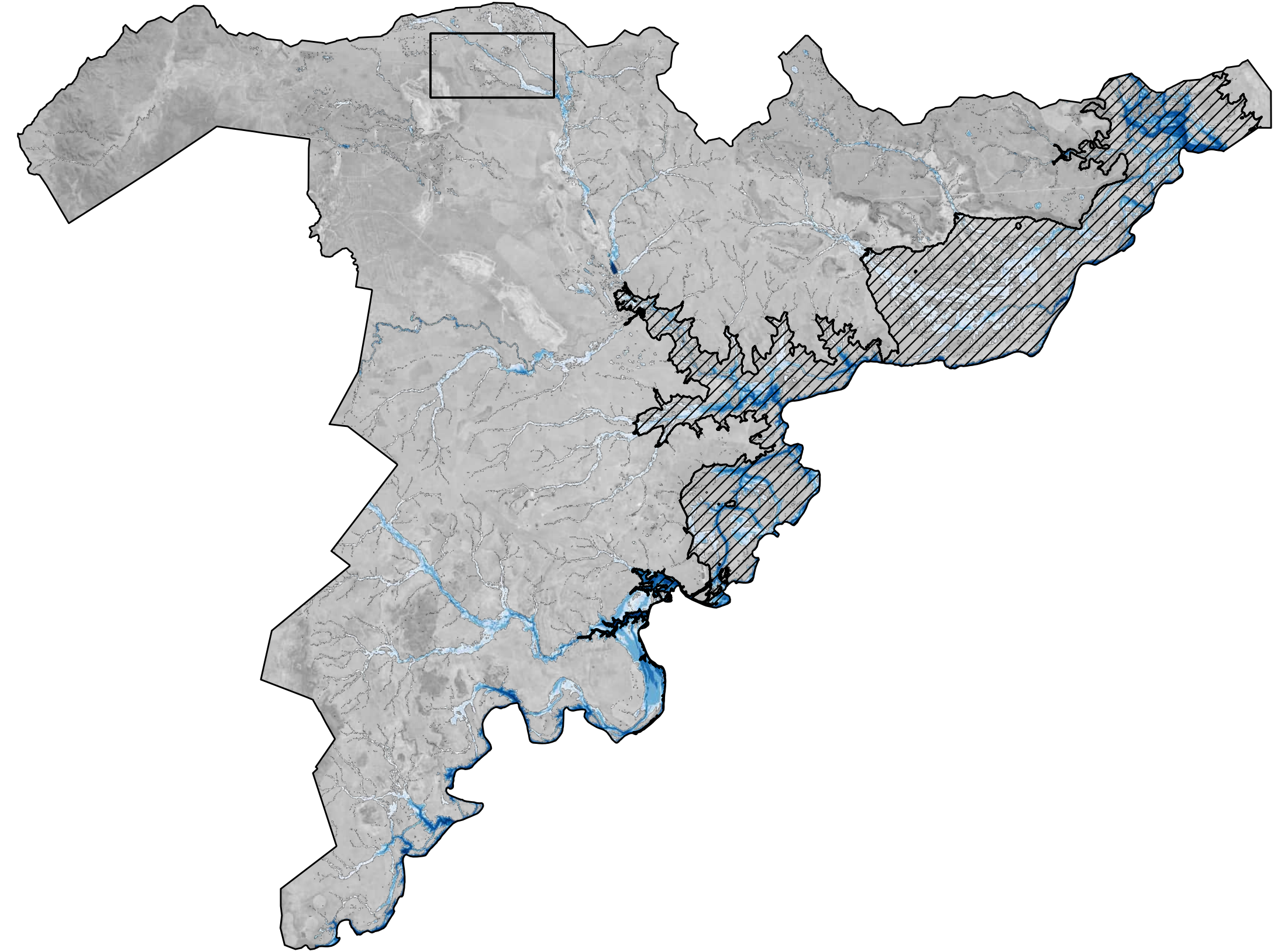
1:410,000

Figure:

D-13

Rev:

0



LEGEND

Peak Flood Depths (m)

	<= 0.1		2.5 - 5.0
	0.1 - 0.5		5.0 - 10.0
	0.5 - 1.0		Study Area
	1.0 - 2.5		Uncertainty Extent

Title:

1% AEP (2030) Event Peak Flood Depths Upper Mackenzie River (Middlemount)

Scale at A3
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File: \\perfile001\data\$\Water_Resources\Projects\BEW571 - Upper Nogoa and Mackenzie\G - GIS\Workspaces\260630_Mapping_Atlas.qgz

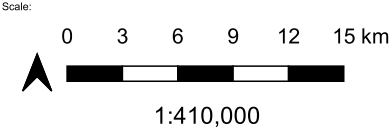
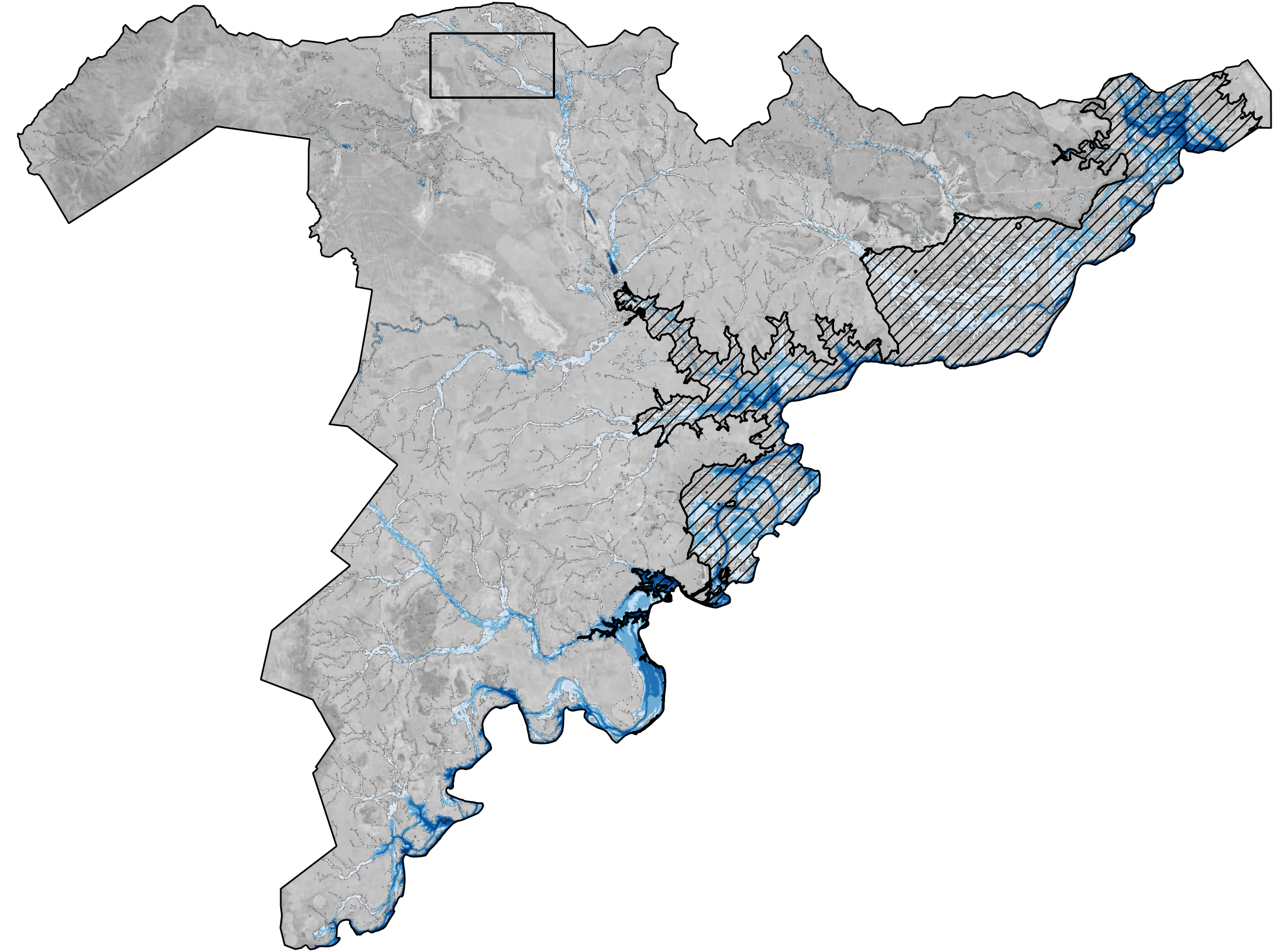


Figure:	D-14	Rev:	0



LEGEND

Peak Flood Depths (m)

<= 0.1

0.1 - 0.5

0.5 - 1.0

1.0 - 2.5

2.5 - 5.0

5.0 - 10.0

> 10.0

Study Area

Uncertainty Extent

Title:

**0.5% AEP (2030) Event Peak Flood Depths
Upper Mackenzie River (Middlemount)**

Scale at A3
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File: \\perfile001\data\$\Water_Resources\Projects\BEW571 - Upper Nogoa and Mackenzie\G - GIS\Workspaces\260630_Mapping_Atlas.qgz

Scale:

03691215 km

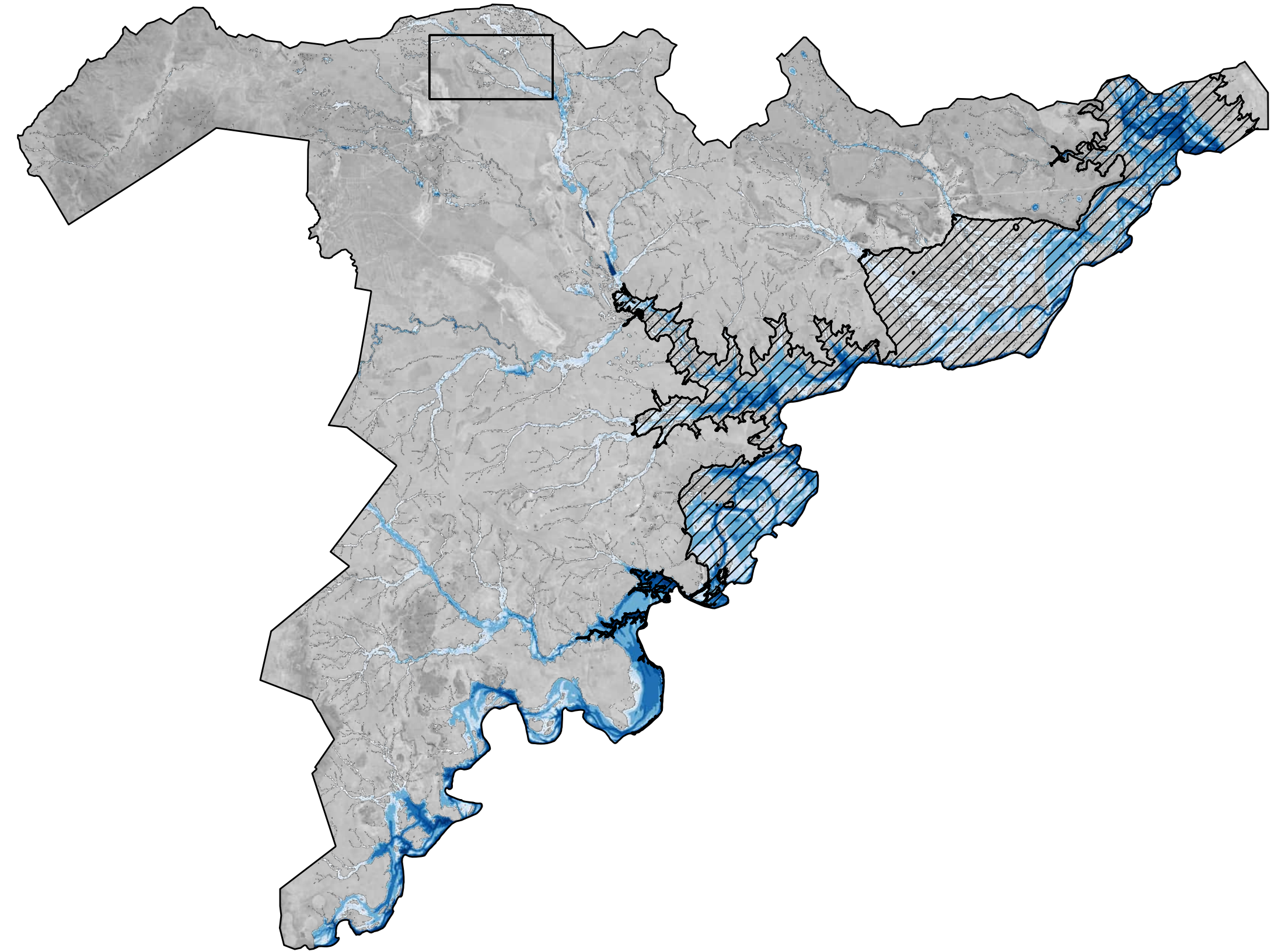
1:410,000

Figure:

D-15

Rev:

0



LEGEND

Peak Flood Depths (m)

	<= 0.1		2.5 - 5.0
	0.1 - 0.5		5.0 - 10.0
	0.5 - 1.0		> 10.0
	1.0 - 2.5		Study Area
			Uncertainty Extent

Title:

0.2% AEP (2030) Event Peak Flood Depths Upper Mackenzie River (Middlemount)

Scale at A3
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File: \\perfile001\data\$\Water_Resources\Projects\BEW571 - Upper Nogoa and Mackenzie\G - GIS\Workspaces\260630_Mapping_Atlas.qgz

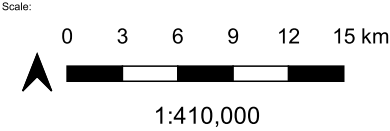
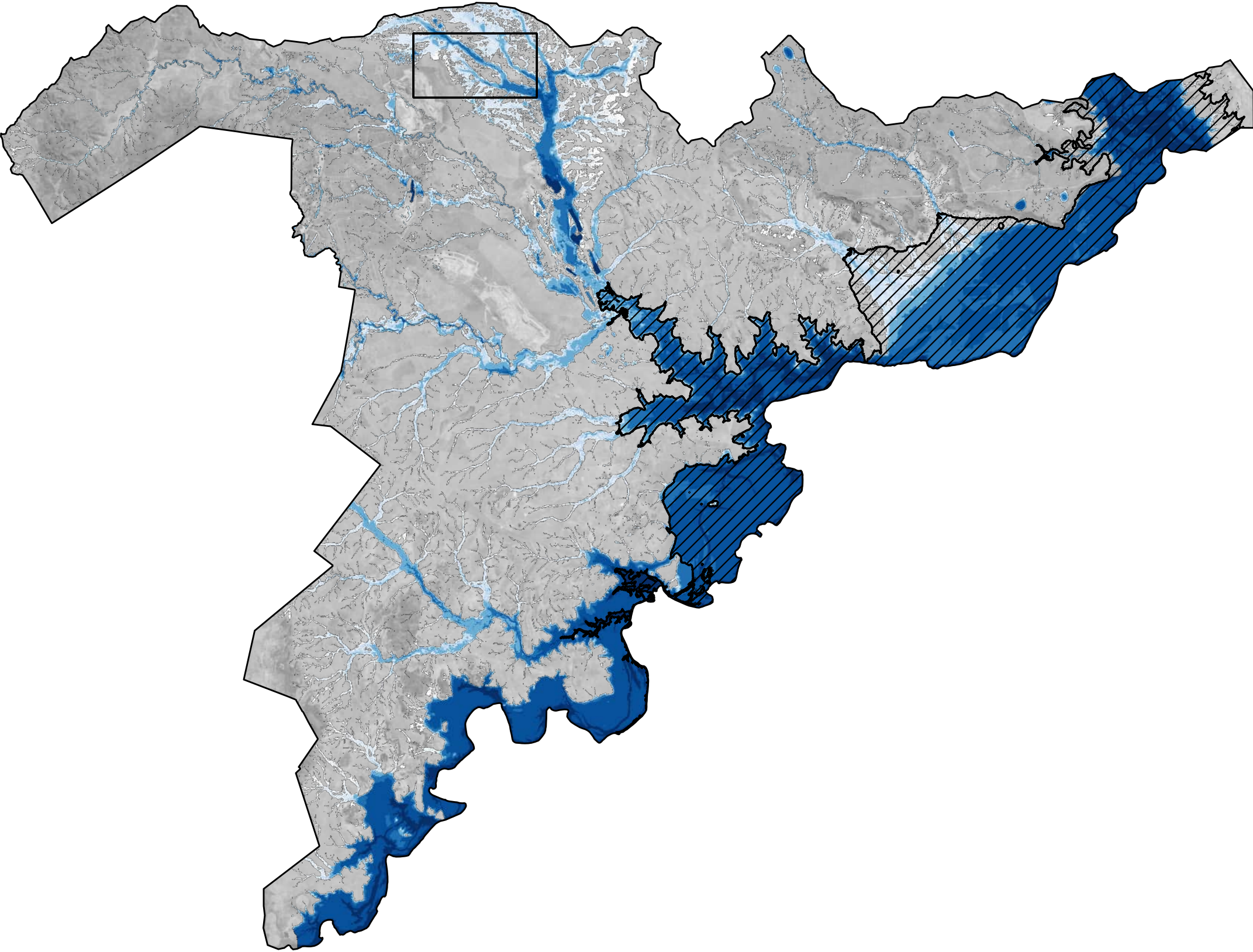
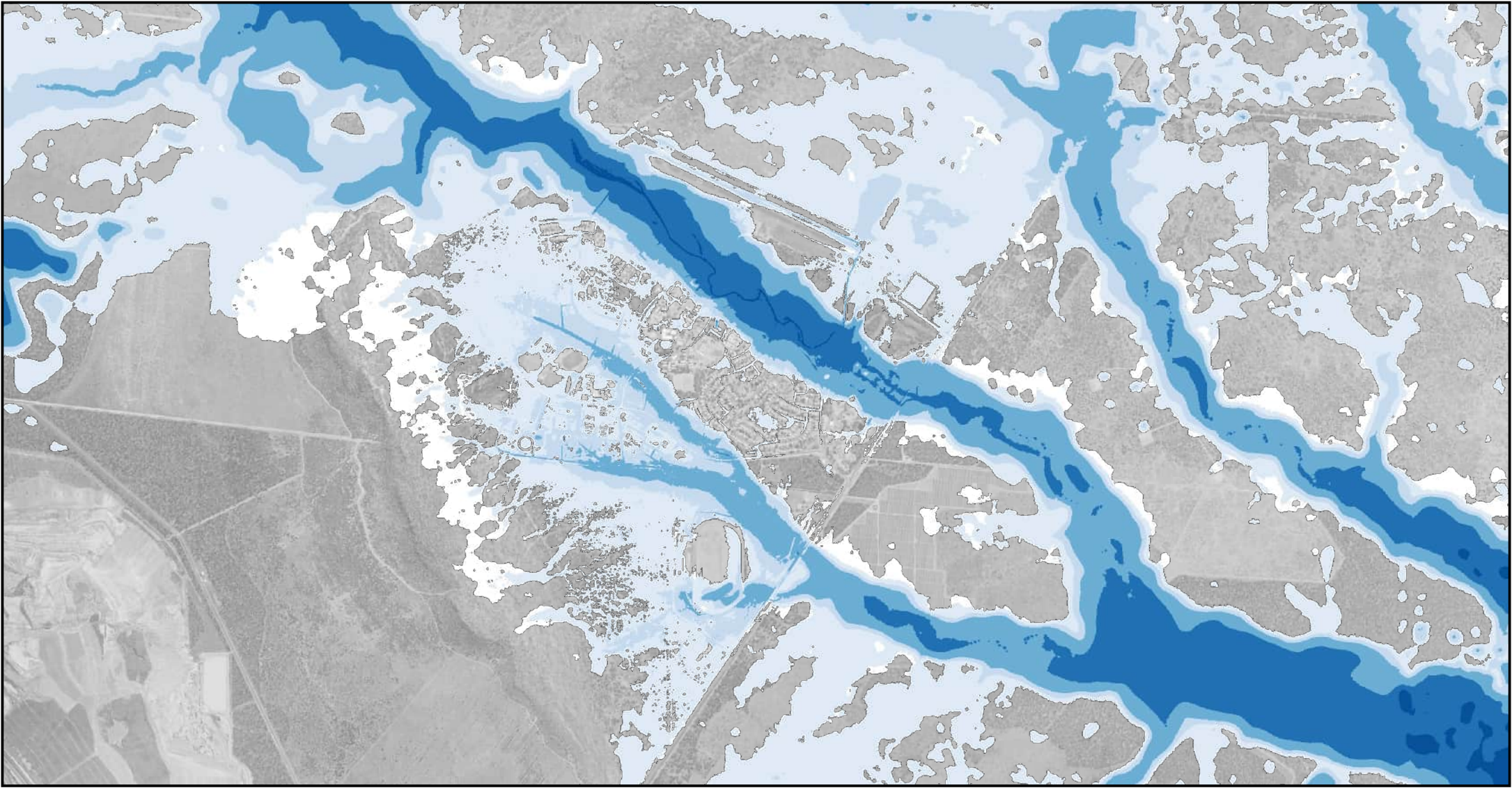


Figure:	D-16	Rev:	0



LEGEND

Peak Flood Depths (m)

<= 0.1

0.1 - 0.5

0.5 - 1.0

1.0 - 2.5

2.5 - 5.0

5.0 - 10.0

> 10.0

Study Area

Uncertainty Extent

Title:

**PMF Event (2030) Peak Flood Depths
Upper Mackenzie River (Middlemount)**

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File: \\perfile001\data\$\Water_Resources\Projects\BEW571 - Upper Nogoa and Mackenzie\G - GIS\Workspaces\260630_Mapping_Atlas.qgz

Scale:

03691215 km

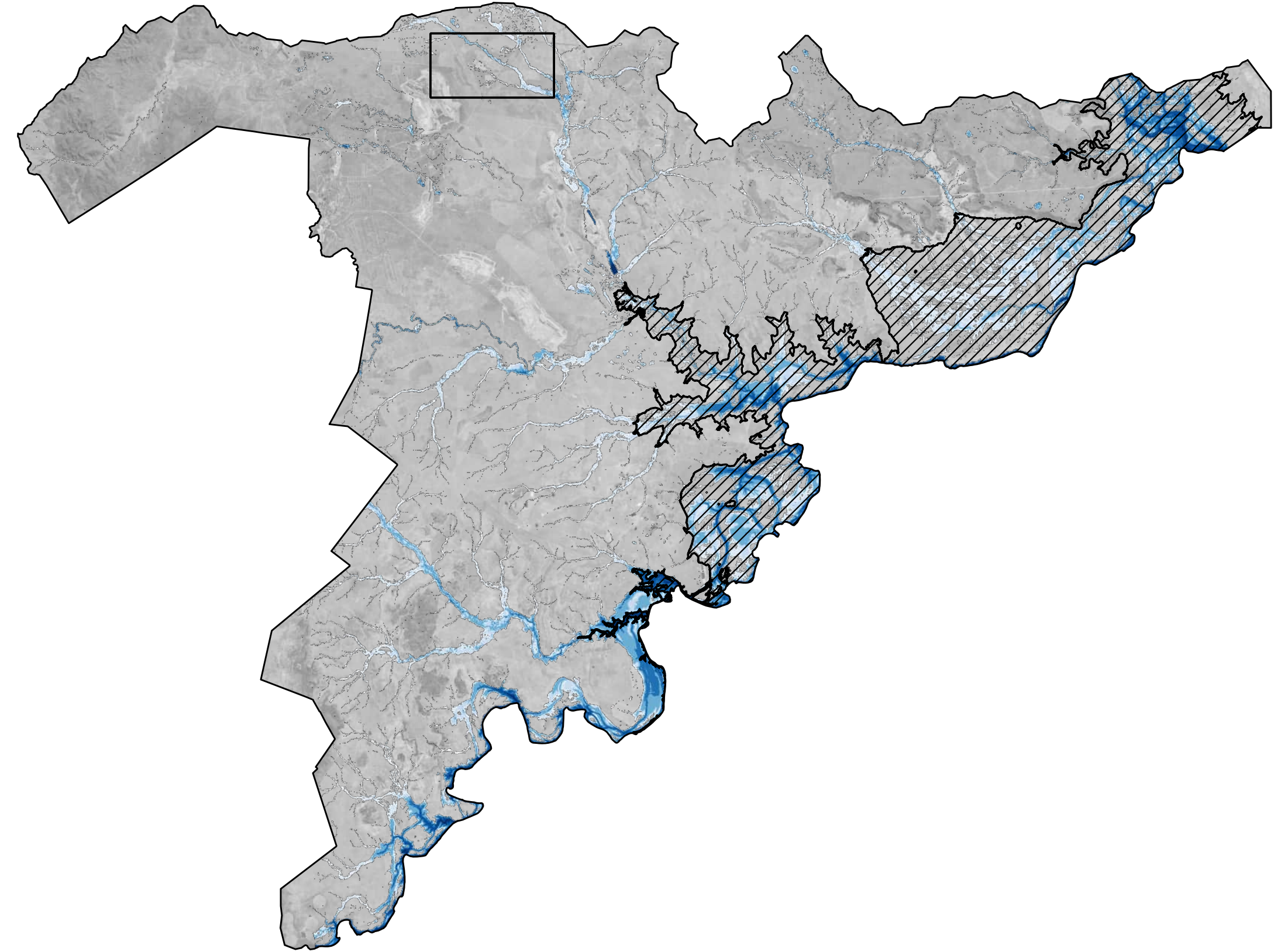
1:410,000

Figure:

D-17

Rev:

0



LEGEND

Peak Flood Depths (m)

<= 0.1

0.1 - 0.5

0.5 - 1.0

1.0 - 2.5

2.5 - 5.0

5.0 - 10.0

> 10.0

Study Area

Uncertainty Extent

Title:

**1% AEP (2100) Event Peak Flood Depths
Upper Mackenzie River (Middlemount)**

Scale at A3
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File: \\perfile001\data\$\Water_Resources\Projects\BEW571 - Upper Nogoa and Mackenzie\G - GIS\Workspaces\260630_Mapping_Atlas.qgz

Scale:

03691215 km

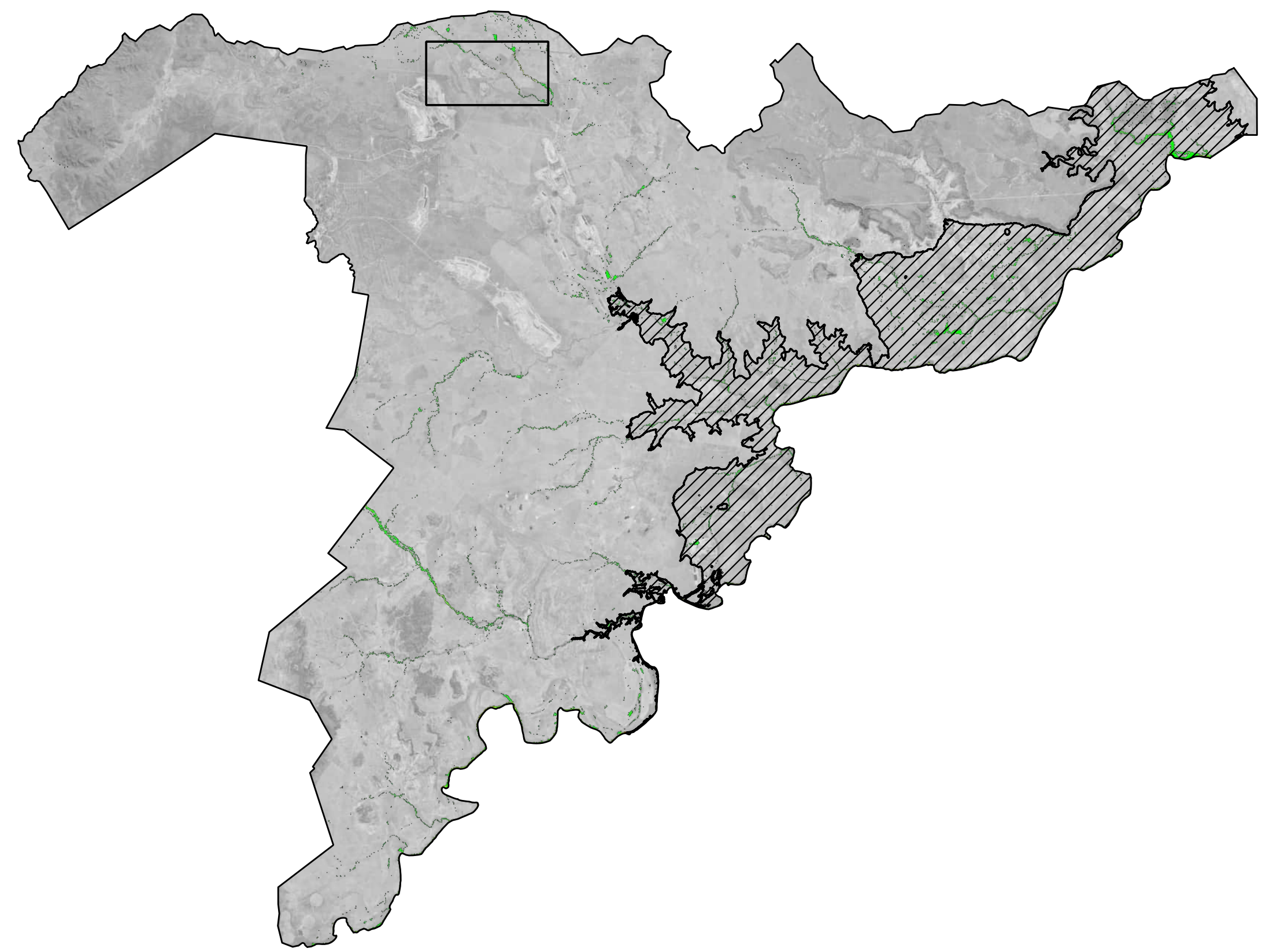
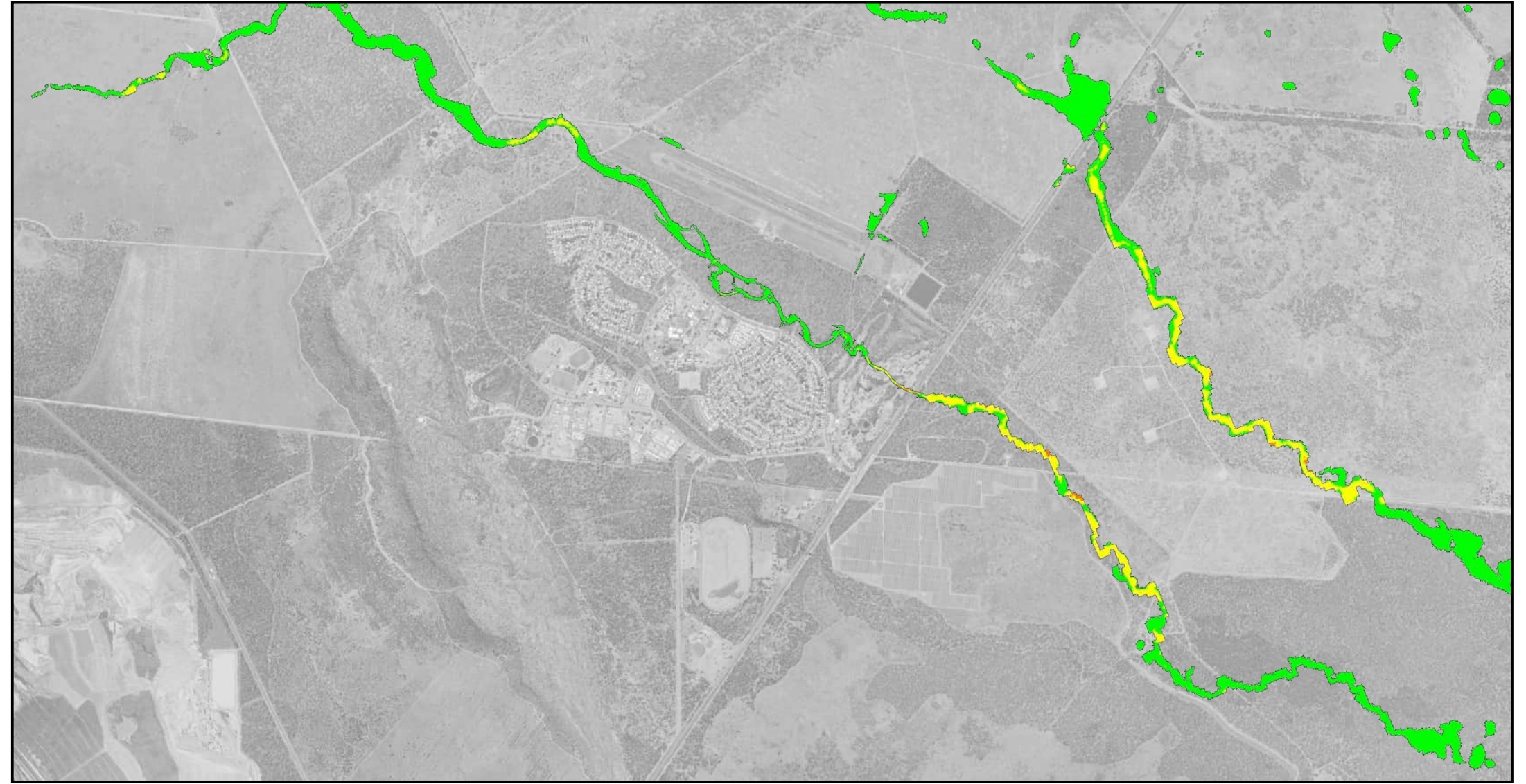
1:410,000

Figure:

D-18

Rev:

0



LEGEND

Peak Flood Velocities (m/s)

<= 0.5

0.5 - 1.0

1.0 - 2.0

2.0 - 4.0

> 4.0

Study Area

Uncertainty Extent

Title:

**50% AEP (2030) Event Peak Flood Velocities
Upper Mackenzie River (Middlemount)**

Scale at A3
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File: \\profile001\data\$\Water_Resources\Projects\BEW571 - Upper Nogoa and Mackenzie\G - GIS\Workspaces\260630_Mapping_Atlas.qgz

Scale:

03691215 km

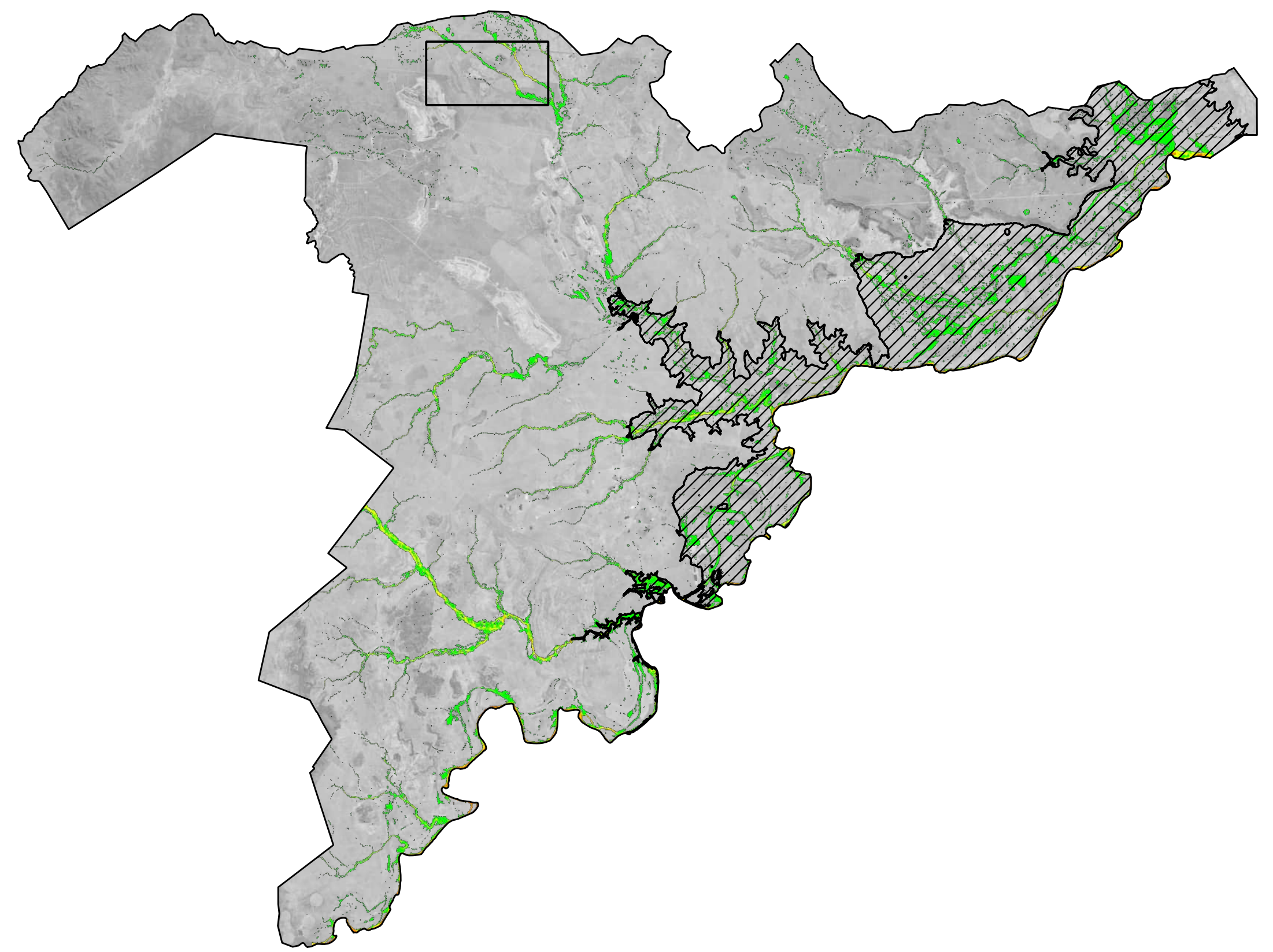
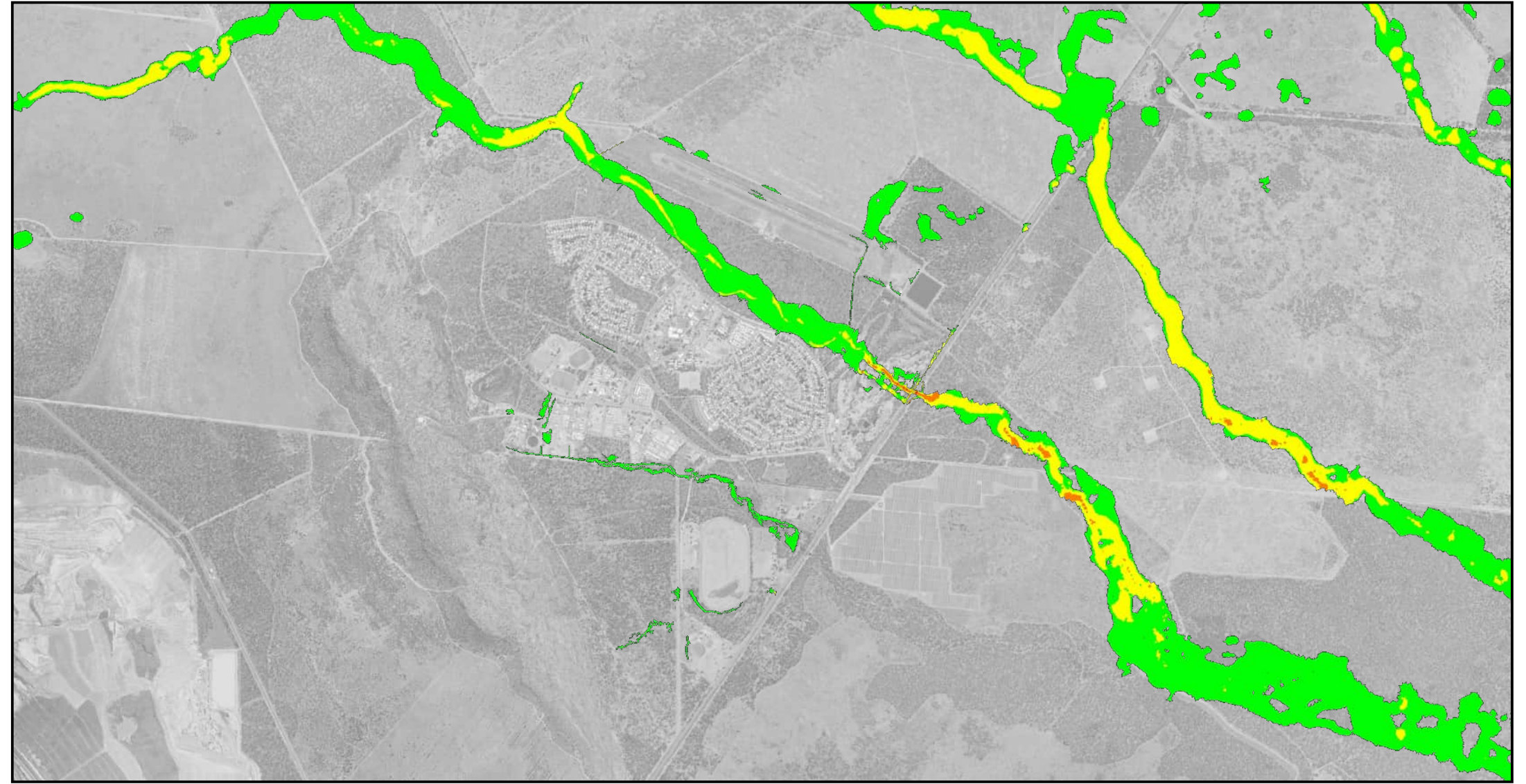
1:410,000

Figure:

D-19

Rev:

0



LEGEND

Peak Flood Velocities (m/s)

	2.0 - 4.0
	<= 0.5
	0.5 - 1.0
	1.0 - 2.0
	> 4.0
	Study Area
	Uncertainty Extent

Title:

5% AEP (2030) Event Peak Flood Velocities Upper Mackenzie River (Middlemount)

Scale at A3
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File: \\perfile001\data\$\Water_Resources\Projects\BEW571 - Upper Nogoa and Mackenzie\G - GIS\Workspaces\260630_Mapping_Atlas.qgz

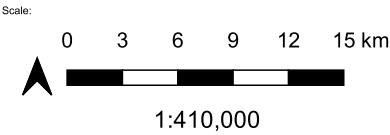
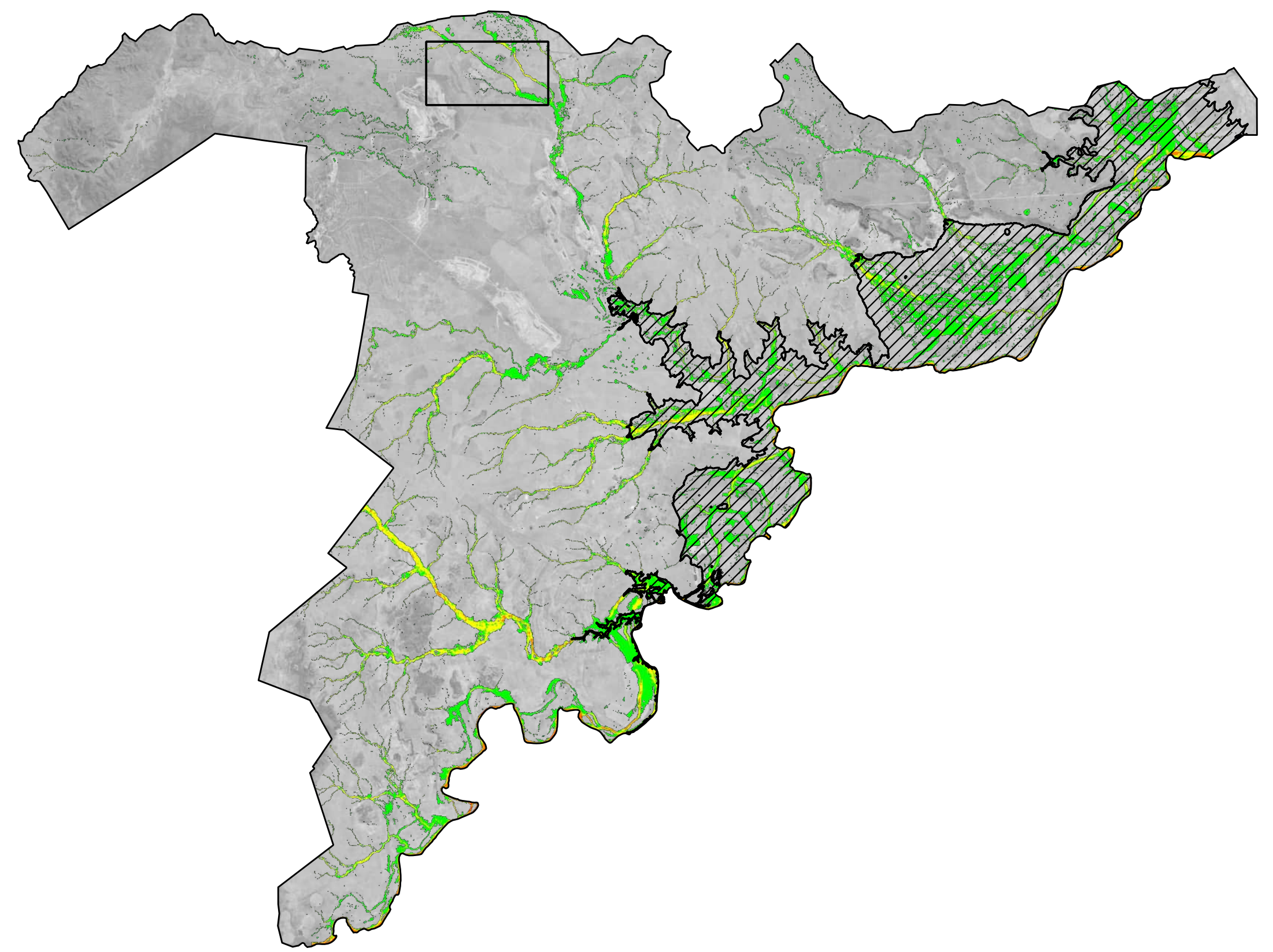
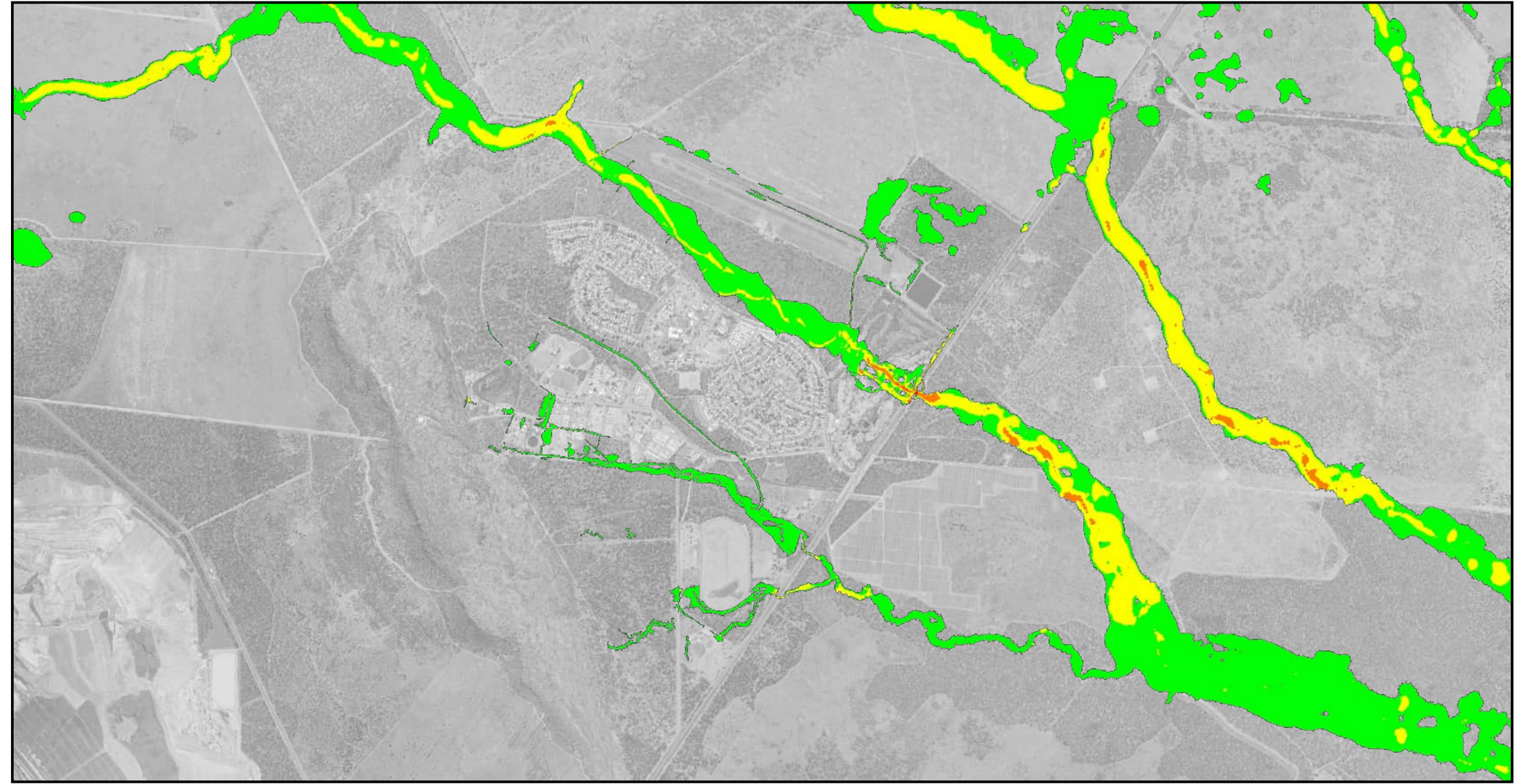


Figure:	D-21	Rev:	0
			



LEGEND

Peak Flood Velocities (m/s)

	≤ 0.5		2.0 - 4.0
	0.5 - 1.0		> 4.0
	1.0 - 2.0		Study Area
			Uncertainty Extent

Title:

2% AEP (2030) Event Peak Flood Velocities Upper Mackenzie River (Middlemount)

Scale at A3
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File: \\perfile001\data\$\Water_Resources\Projects\BEW571 - Upper Nogoa and Mackenzie\G - GIS\Workspaces\260630_Mapping_Atlas.qgz

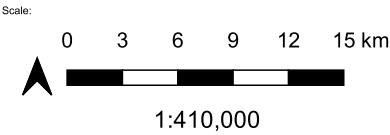
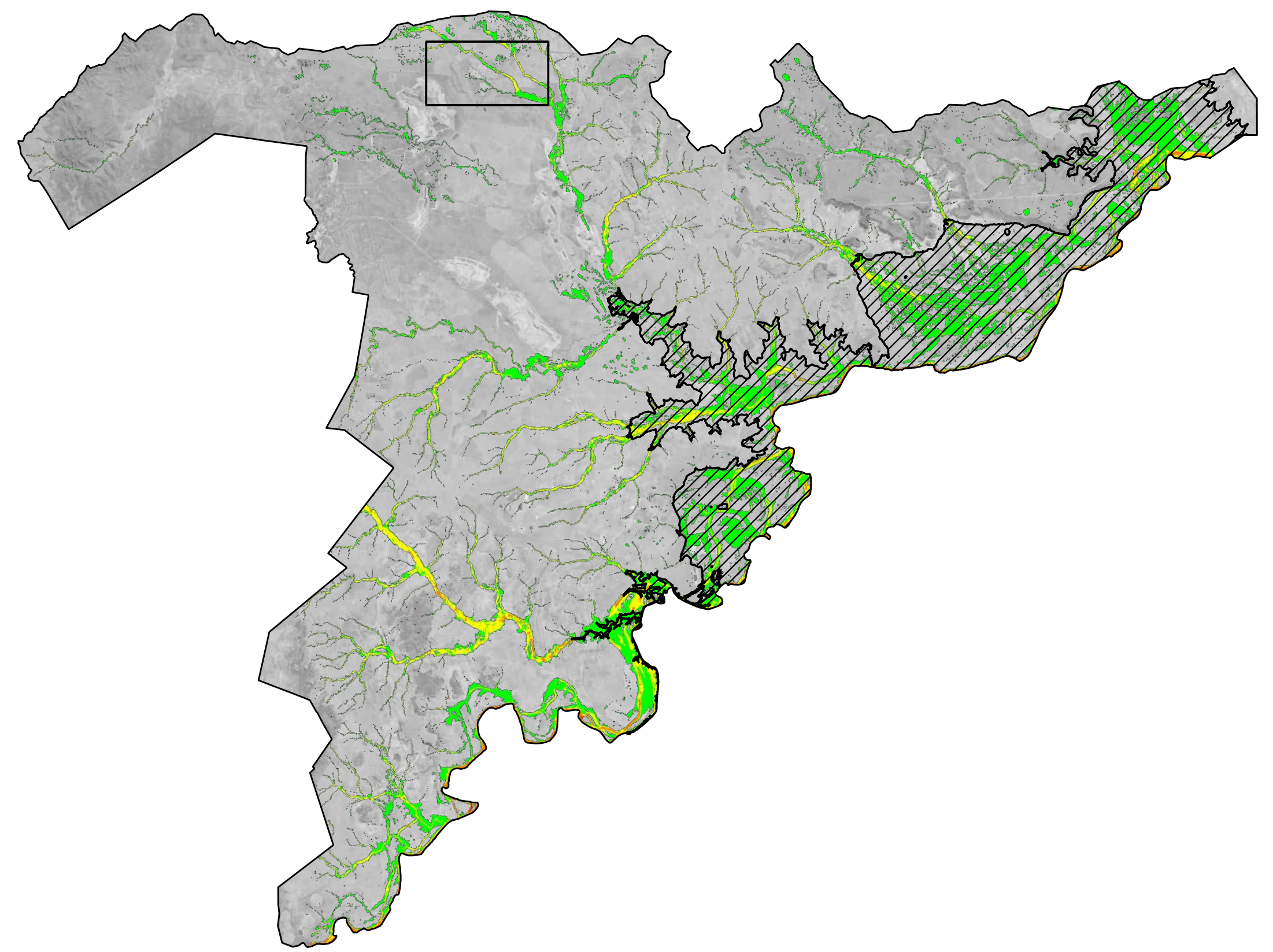
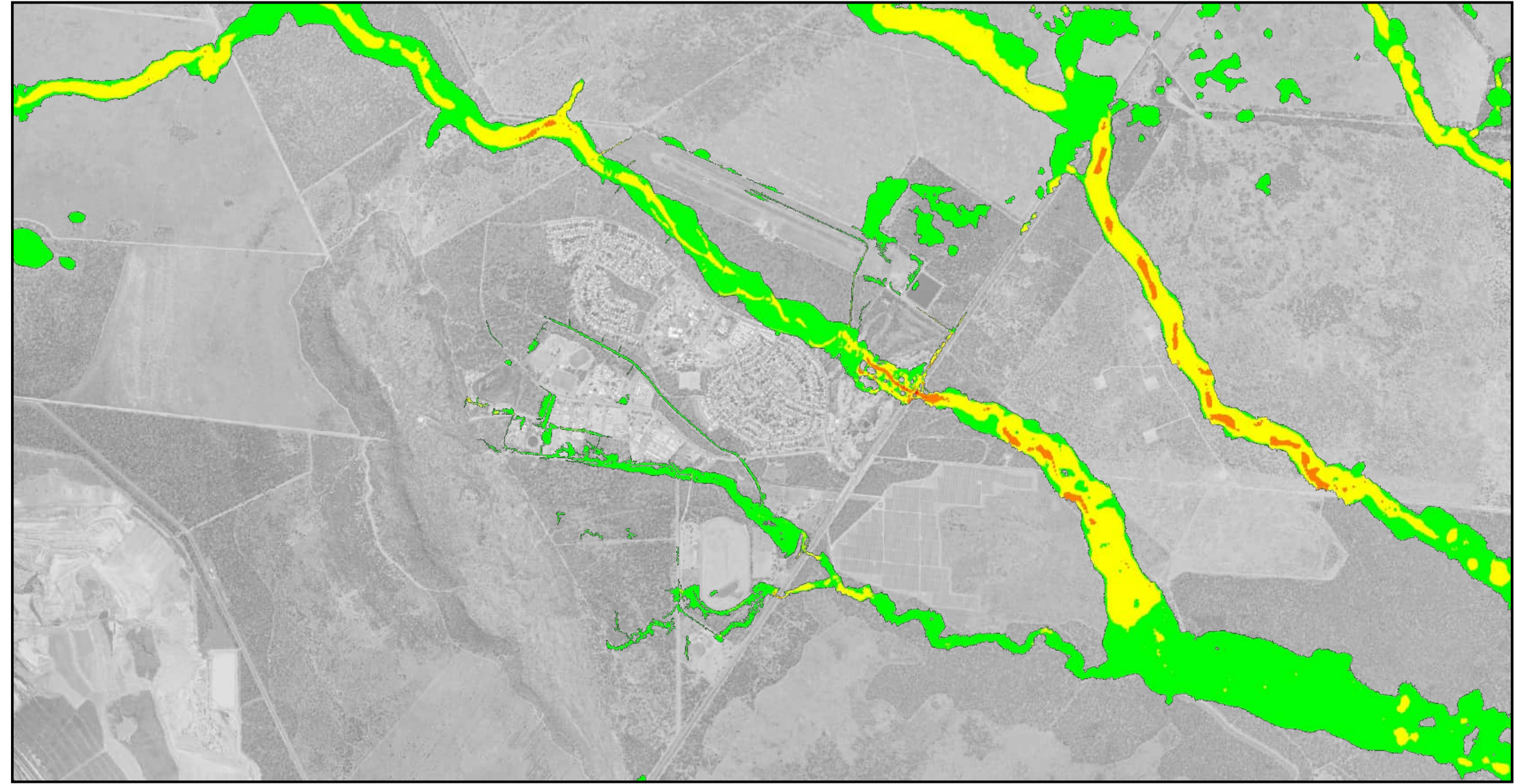


Figure:	D-22	Rev:	0
			



LEGEND

Peak Flood Velocities (m/s)

<= 0.5

0.5 - 1.0

1.0 - 2.0

2.0 - 4.0

> 4.0

Study Area

Uncertainty Extent

Title:

**1% AEP (2030) Event Peak Flood Velocities
Upper Mackenzie River (Middlemount)**

Scale at A3
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File: \\perfile001\data\$\Water_Resources\Projects\BEW571 - Upper Nogoa and Mackenzie\G - GIS\Workspaces\260630_Mapping_Atlas.qgz

Scale:

03691215 km

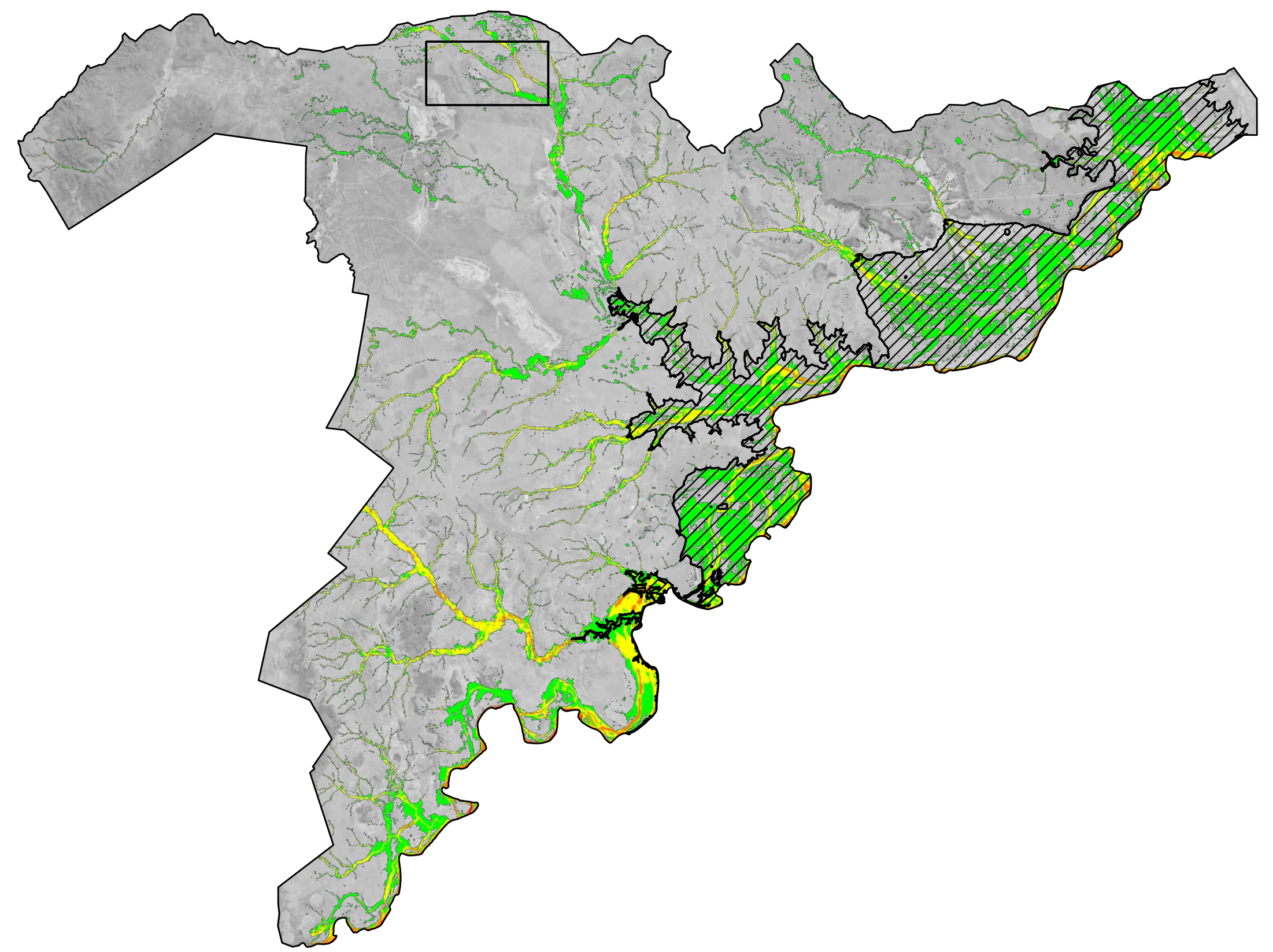
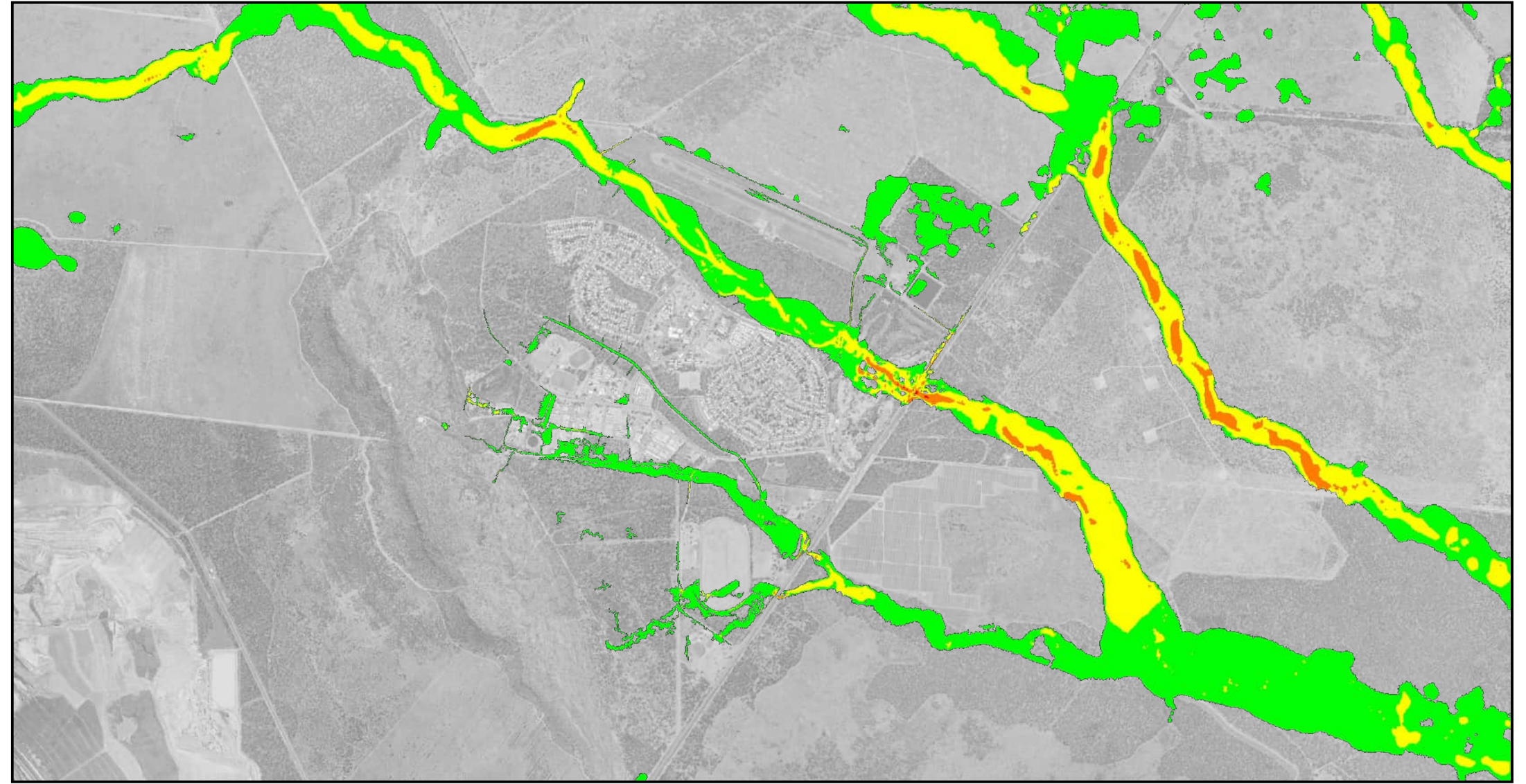
1:410,000

Figure:

D-23

Rev:

0



LEGEND

Peak Flood Velocities (m/s)

	≤ 0.5		2.0 - 4.0
	0.5 - 1.0		> 4.0
	1.0 - 2.0		Study Area
			Uncertainty Extent

Title:

0.5% AEP (2030) Event Peak Flood Velocities Upper Mackenzie River (Middlemount)

Scale at A3
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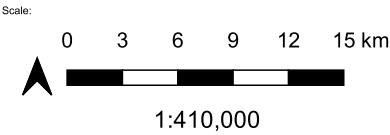
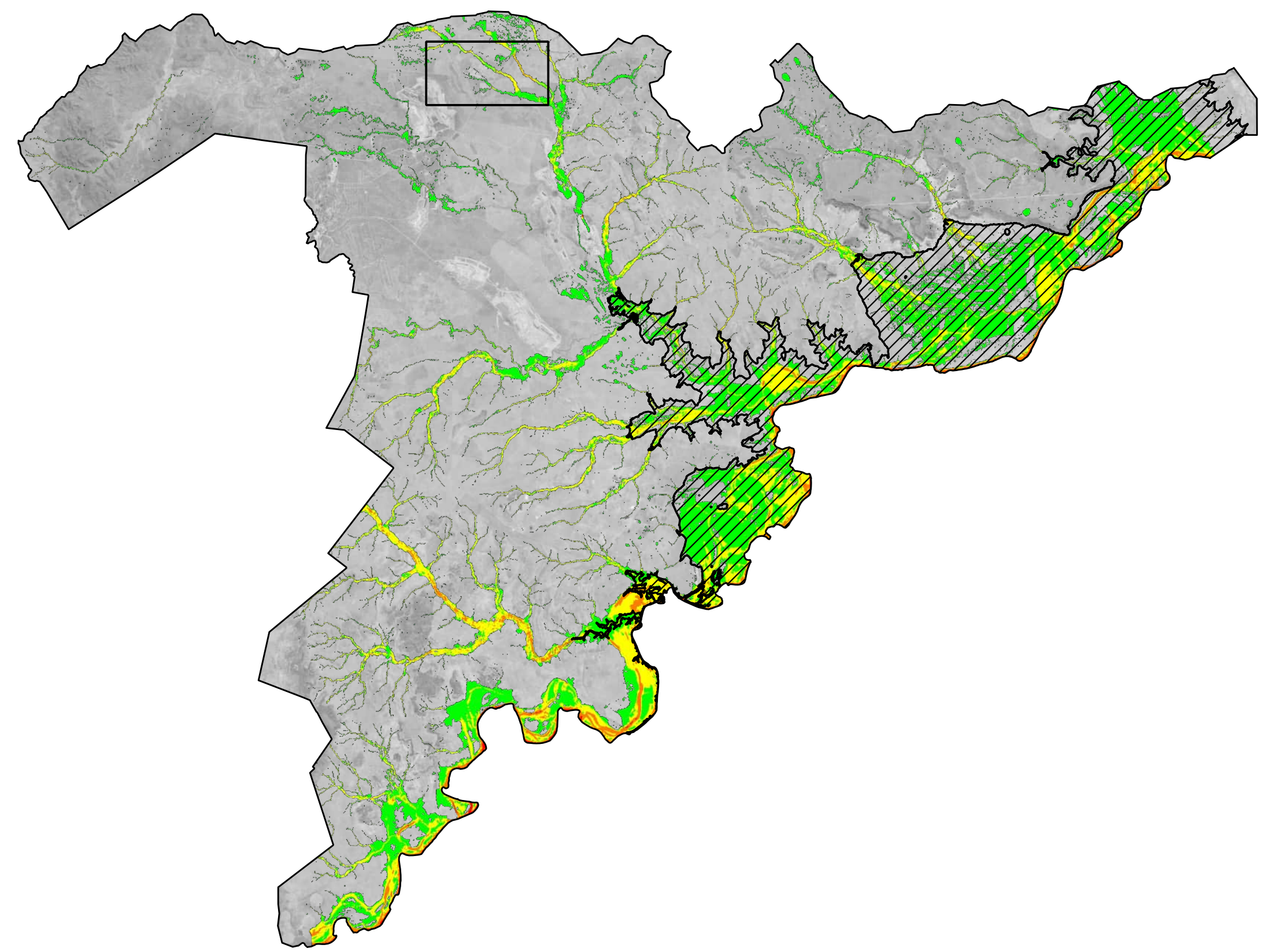


Figure:	D-24	Rev:	0
			



LEGEND

Peak Flood Velocities (m/s)

	≤ 0.5		2.0 - 4.0
	0.5 - 1.0		> 4.0
	1.0 - 2.0		Study Area
			Uncertainty Extent

Title:

0.2% AEP (2030) Event Peak Flood Velocities Upper Mackenzie River (Middlemount)

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File: \\perfile001\data\$\Water_Resources\Projects\BEW571 - Upper Nogoa and Mackenzie\G - GIS\Workspaces\260630_Mapping_Atlas.qgz

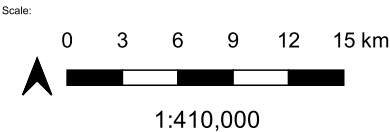
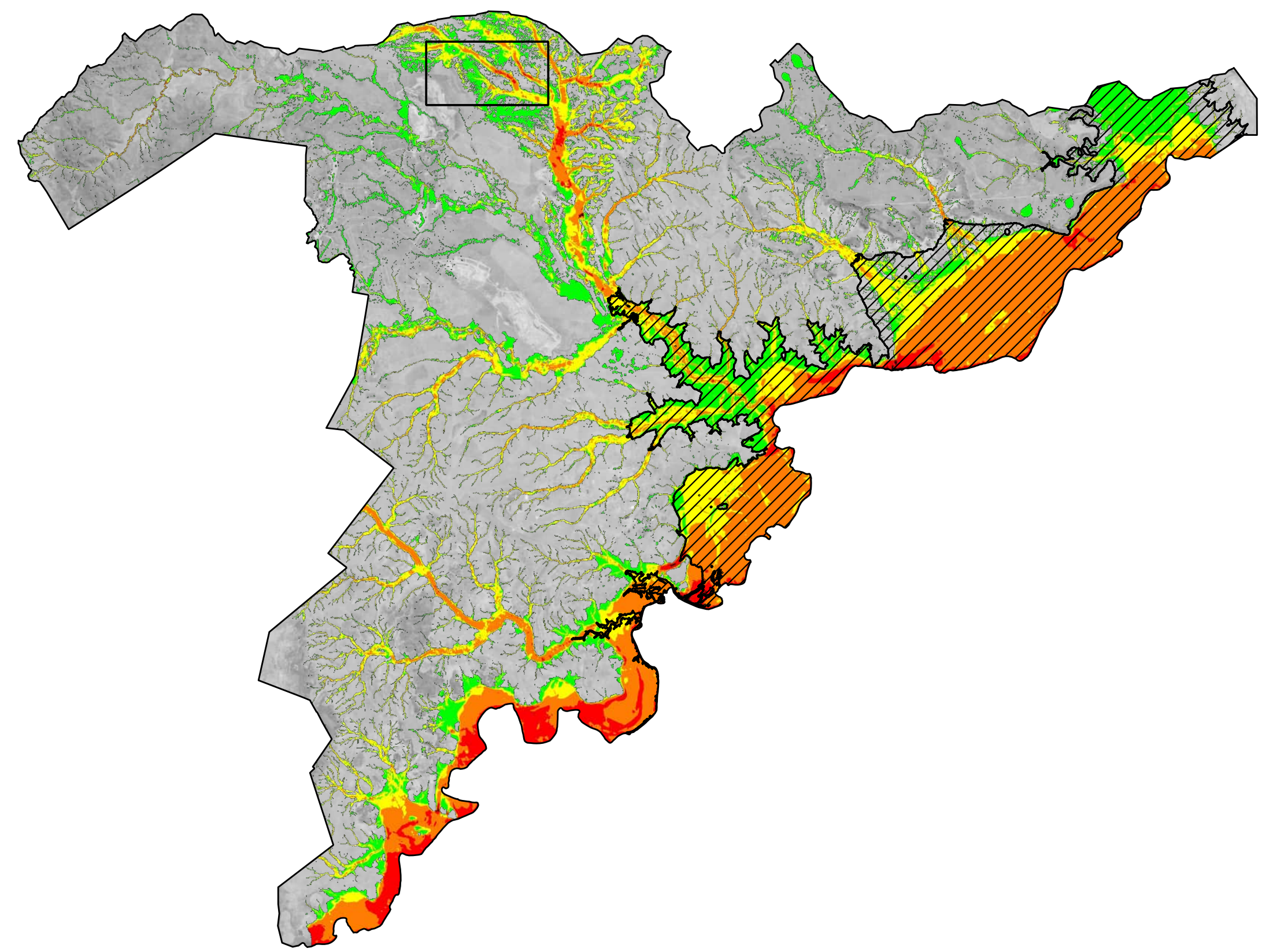
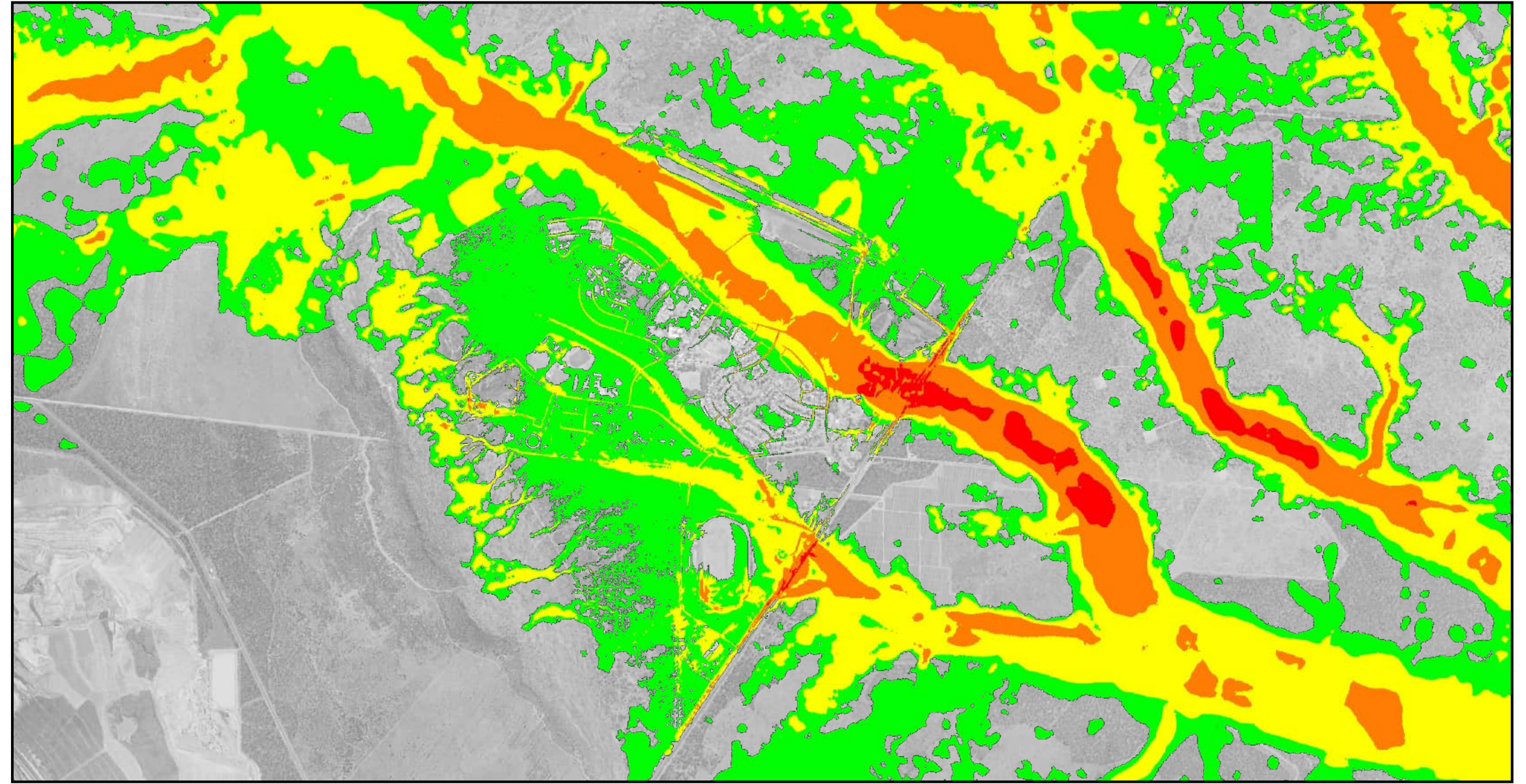


Figure:	D-25	Rev:	0
			



LEGEND

Peak Flood Velocities (m/s)

<= 0.5

0.5 - 1.0

1.0 - 2.0

2.0 - 4.0

> 4.0

Study Area

Uncertainty Extent

Title:

**PMF Event (2030) Peak Flood Velocities
Upper Mackenzie River (Middlemount)**

Scale at A3
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File: \\perfile001\data\$\Water_Resources\Projects\BEW571 - Upper Nogoa and Mackenzie\G - GIS\Workspaces\260630_Mapping_Atlas.qgz

Scale:

03691215 km

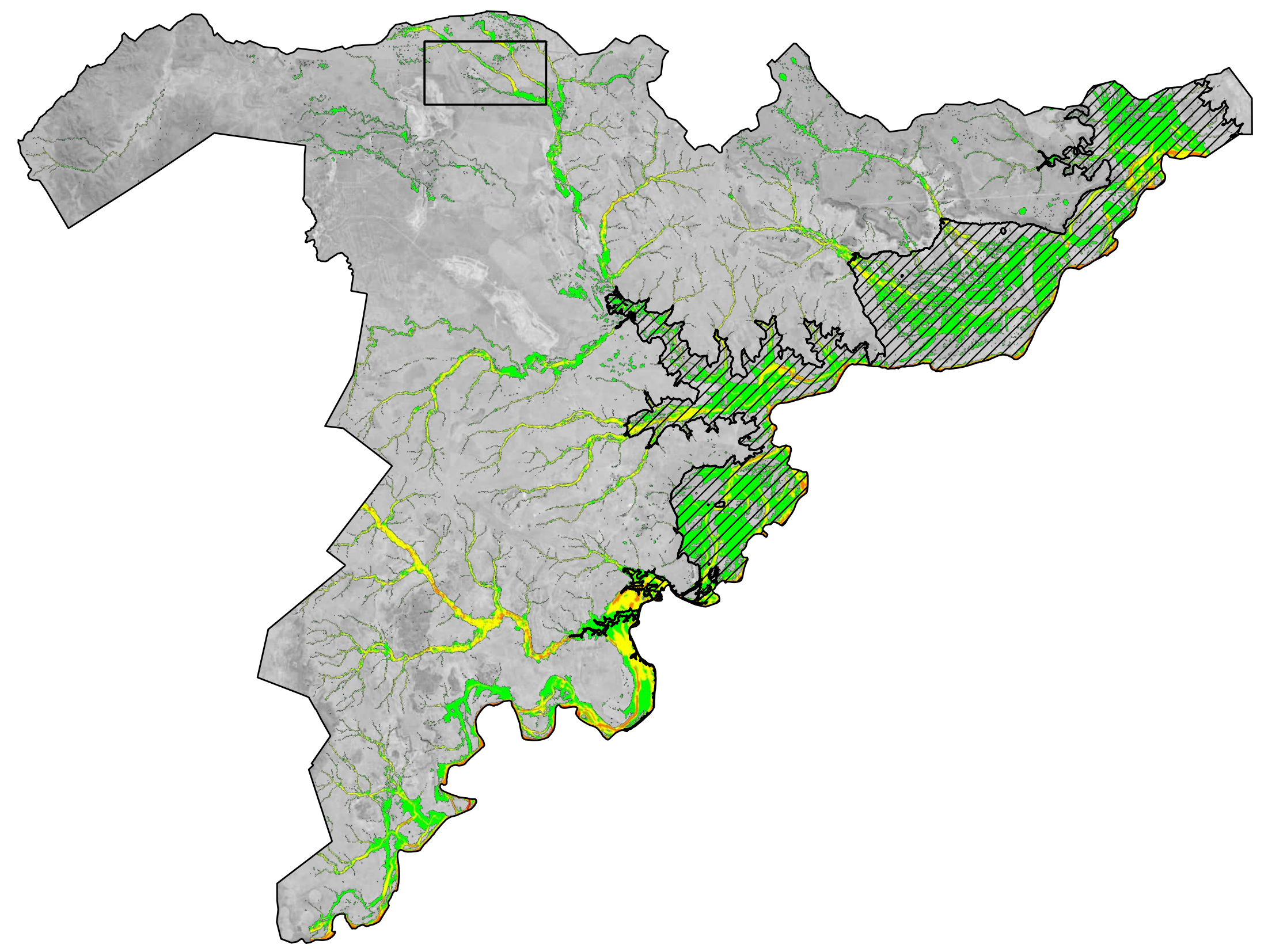
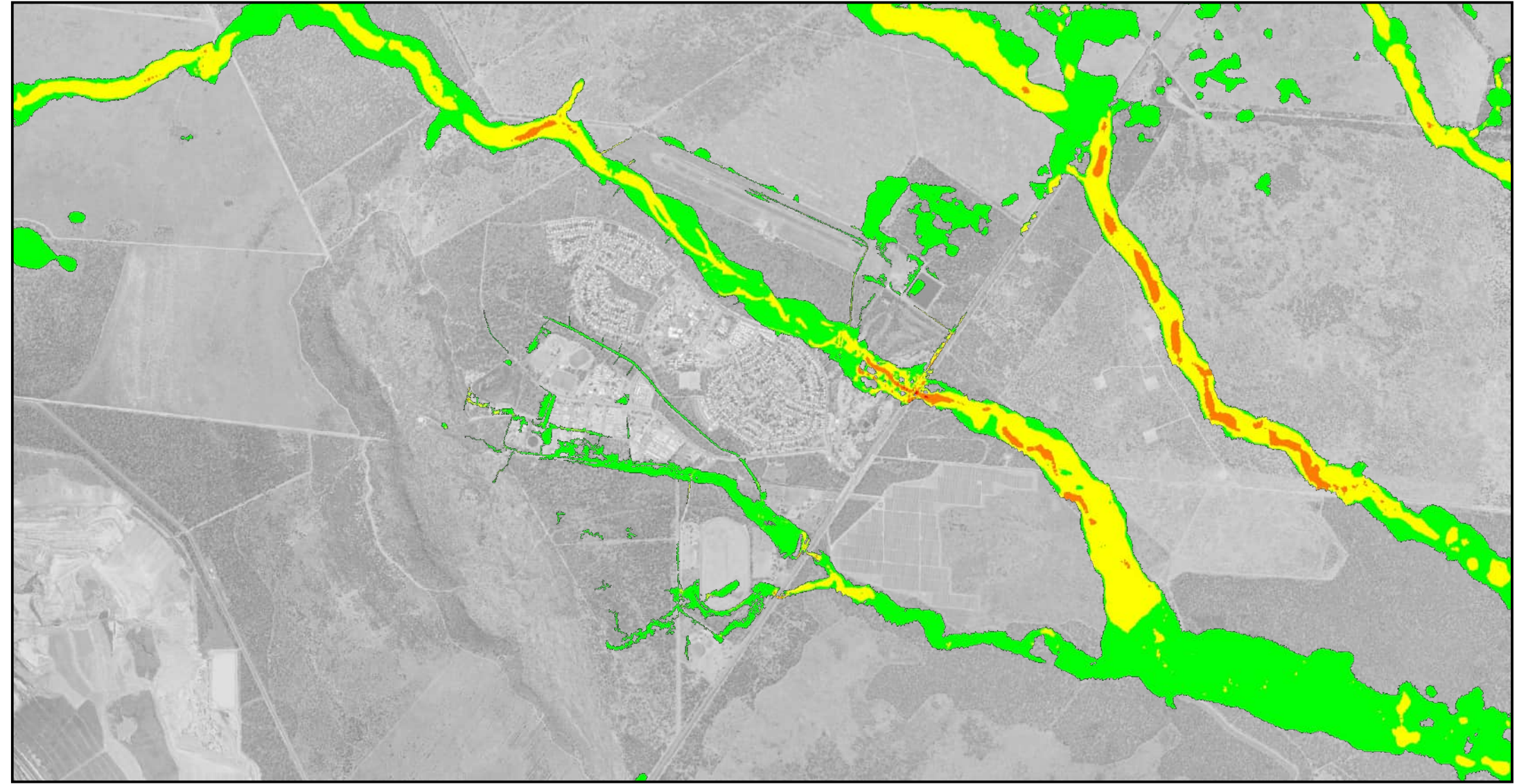
1:410,000

Figure:

D-26

Rev:

0



LEGEND

Peak Flood Velocities (m/s)

<= 0.5

0.5 - 1.0

1.0 - 2.0

2.0 - 4.0

> 4.0

Study Area

Uncertainty Extent

Title:

**1% AEP (2100) Event Peak Flood Velocities
Upper Mackenzie River (Middlemount)**

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File: \\profile001\data\$\Water_Resources\Projects\BEW571 - Upper Nogoa and Mackenzie\G - GIS\Workspaces\260630_Mapping_Atlas.qgz

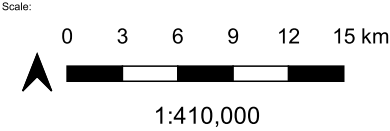
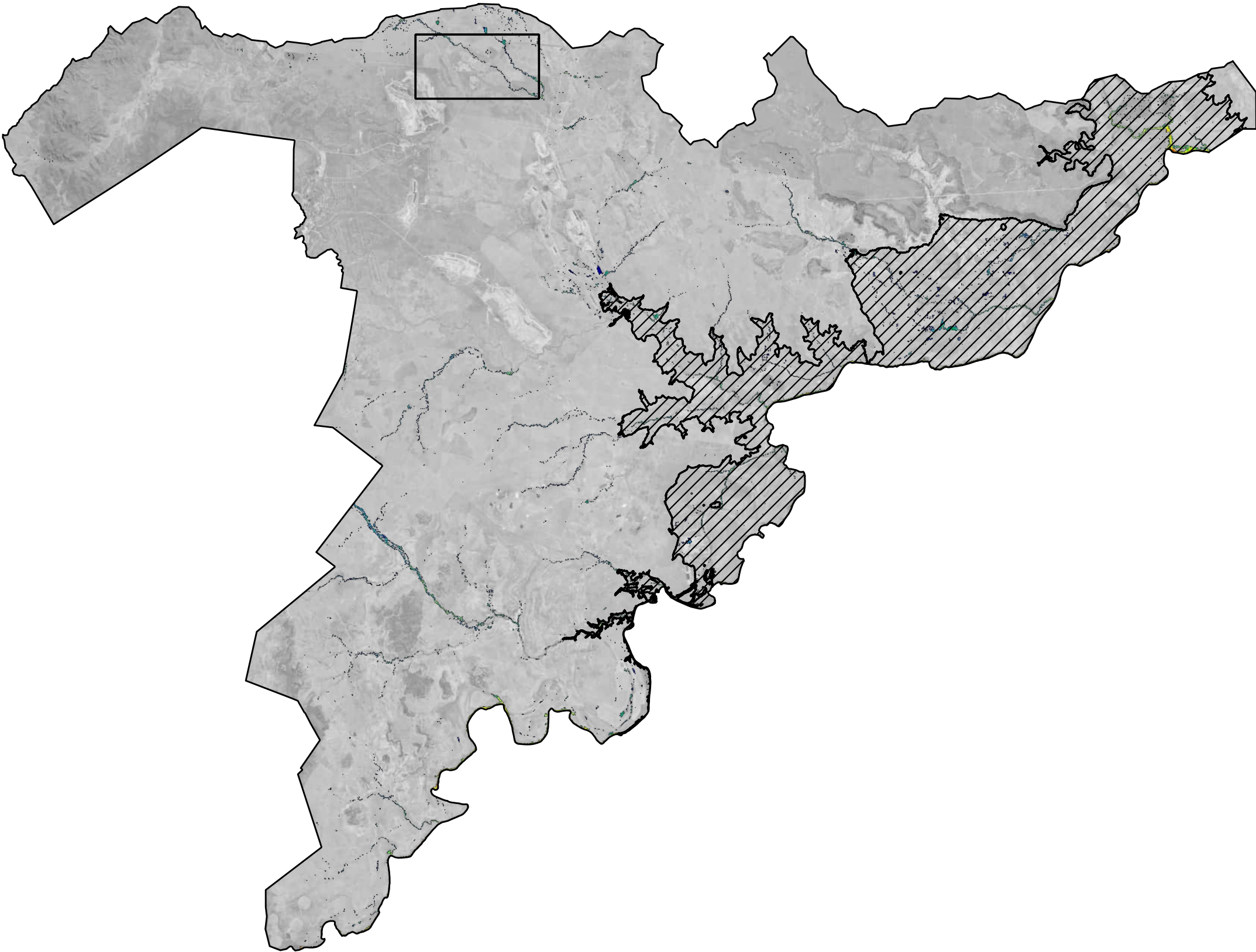
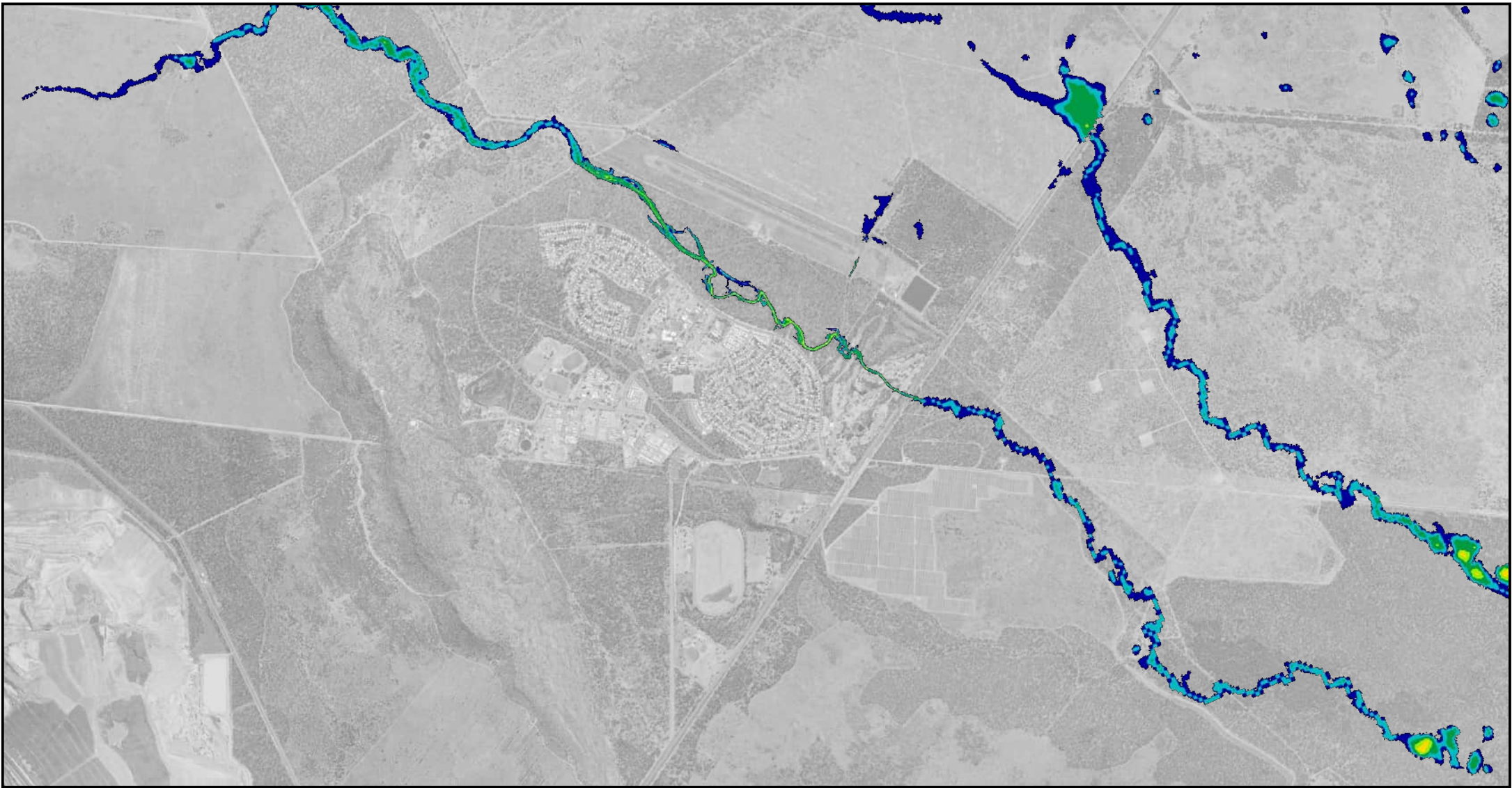


Figure:

D-27

Rev:

0



LEGEND

Flood Hazards (AIDR)

H1

H2

H3

H4

H5

H6

Study Area

Uncertainty Extent

Title:

50% AEP (2030) Event Peak Flood Hazards (AIDR)

Upper Mackenzie River (Middlemount)

Scale at A3
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File: \\profile001\data\$\\Water_Resources\\Projects\\BEW571 - Upper Nogoa and Mackenzie\\G - GIS\\Workspaces\\260630_Mapping_Atlas.ggz

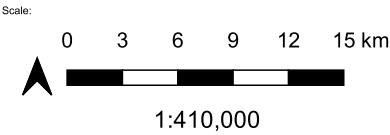
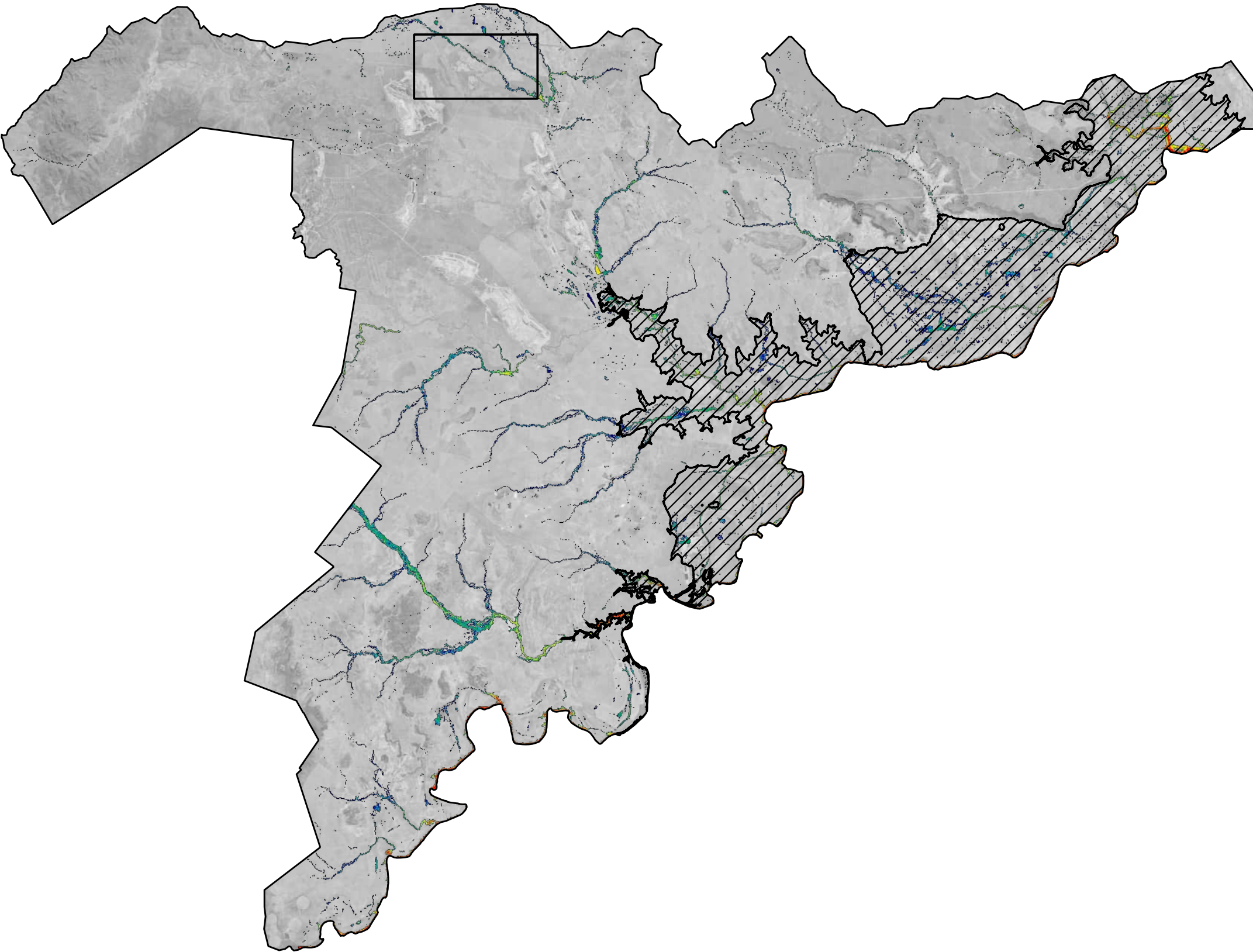
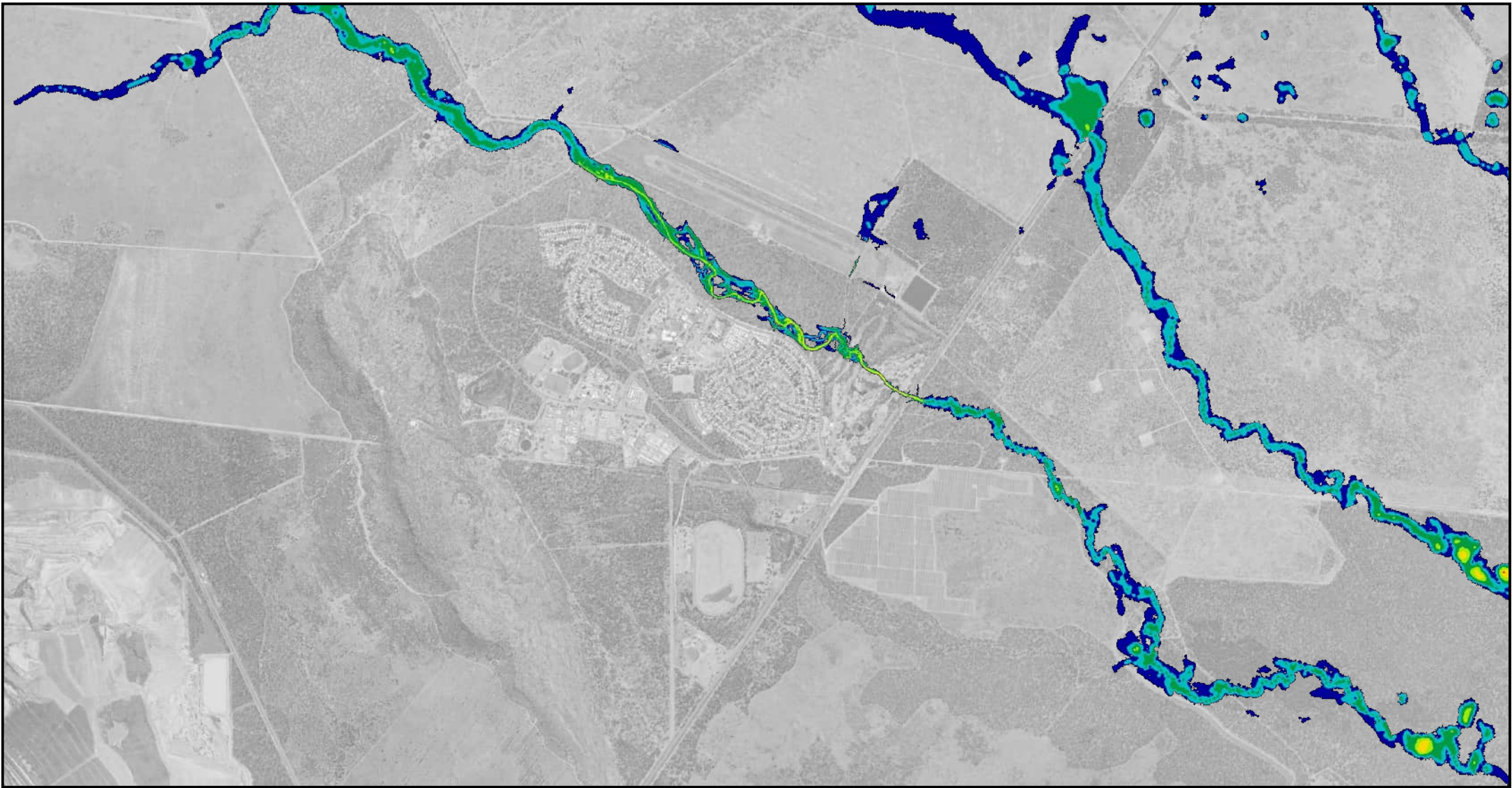


Figure:

D-28

Rev:

0



LEGEND

Flood Hazards (AIDR)

H1	H5
H2	H6
H3	Study Area
H4	Uncertainty Extent

Title:

20% AEP (2030) Event Peak Flood Hazards (AIDR)

Upper Mackenzie River (Middlemount)

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File: \\perfile001\data\$\\Water_Resources\\Projects\\BEW571 - Upper Nogoa and Mackenzie\\G - GIS\\Workspaces\\260630_Mapping_Atlas.qgz

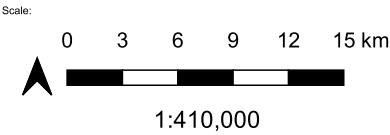
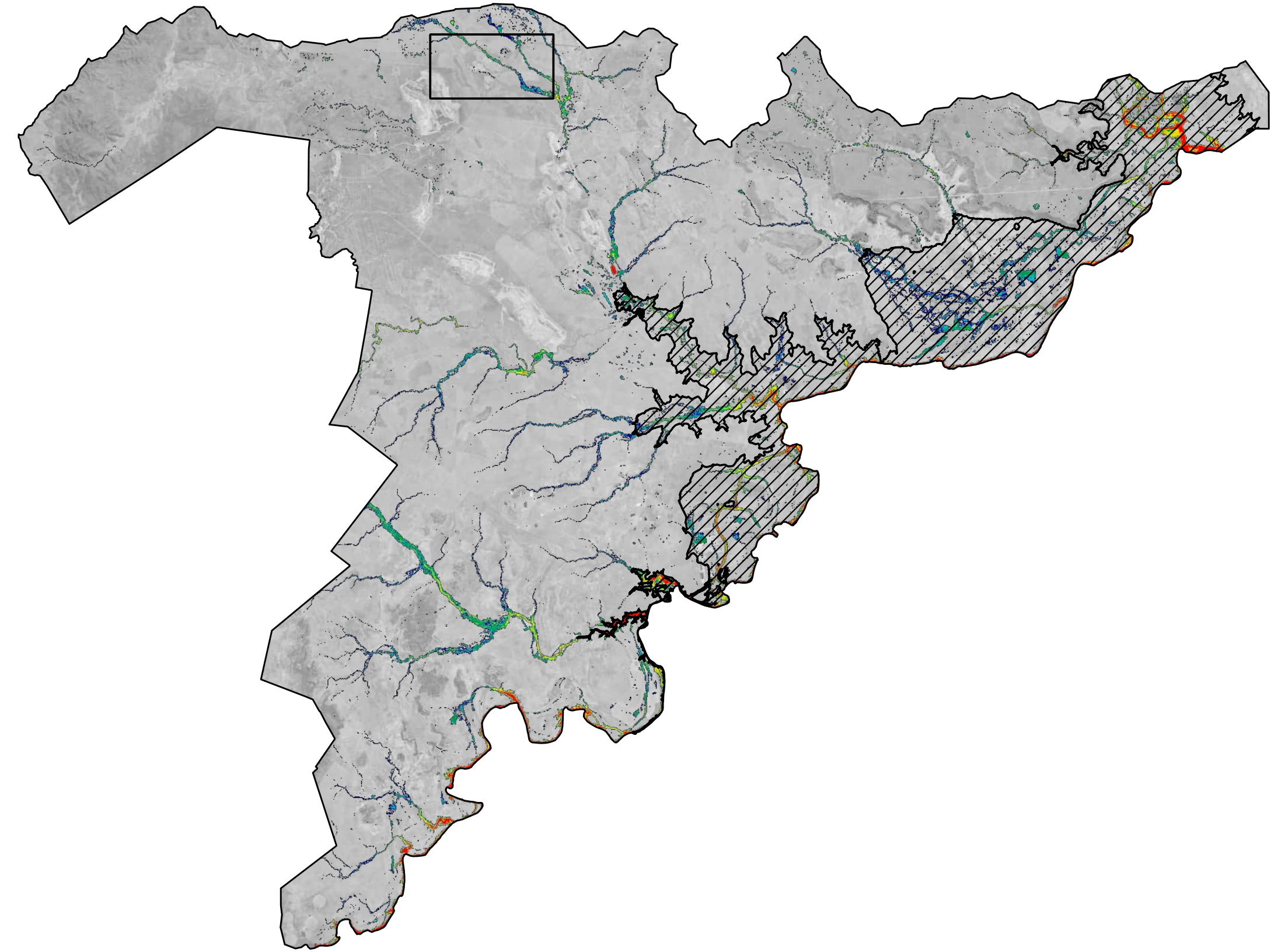
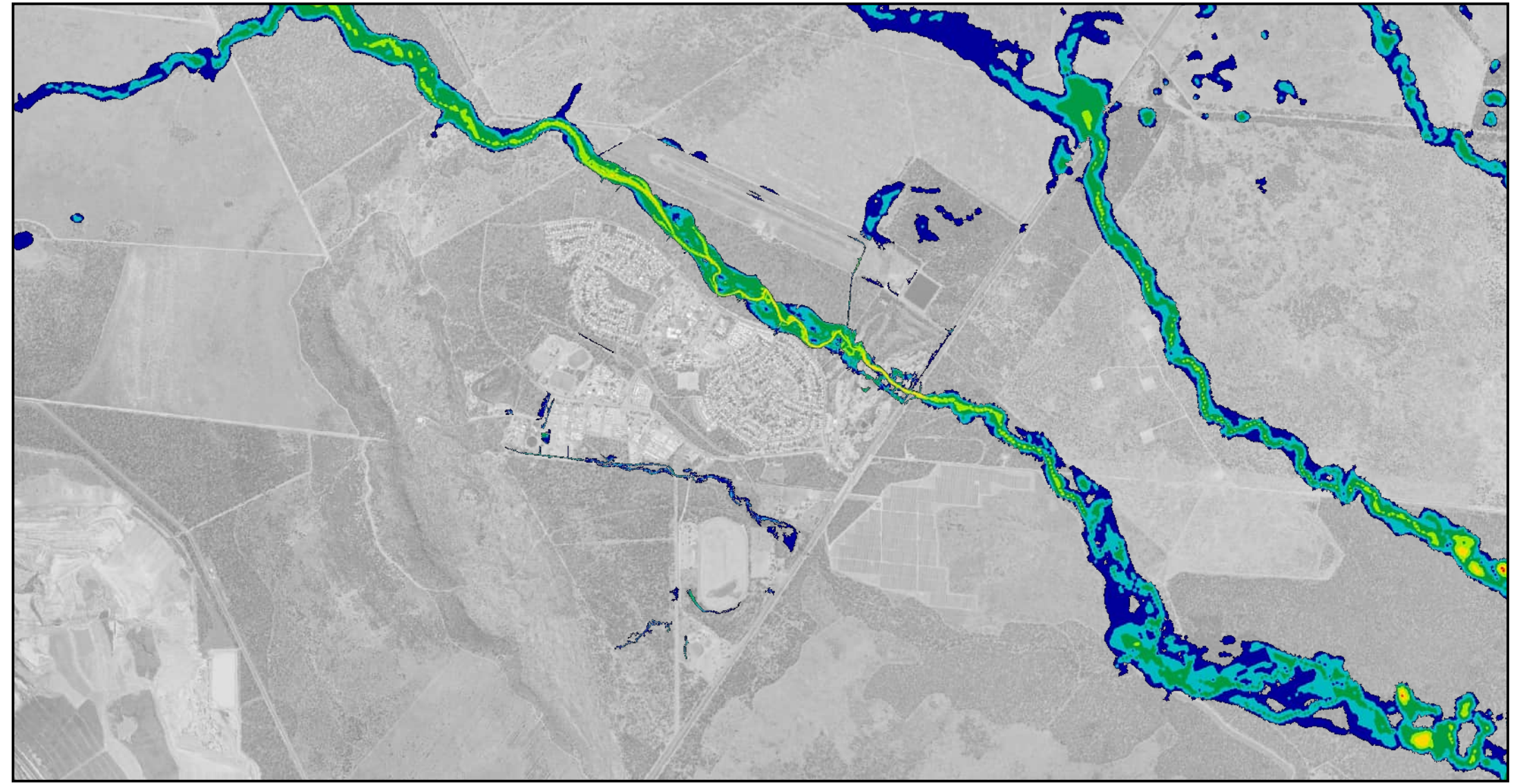


Figure:	Rev:
D-29	0



LEGEND

Flood Hazards (AIDR)

H1	H5
H2	H6
H3	Study Area
H4	Uncertainty Extent

Title:

5% AEP (2030) Event Peak Flood Hazards (AIDR)

Upper Mackenzie River (Middlemount)

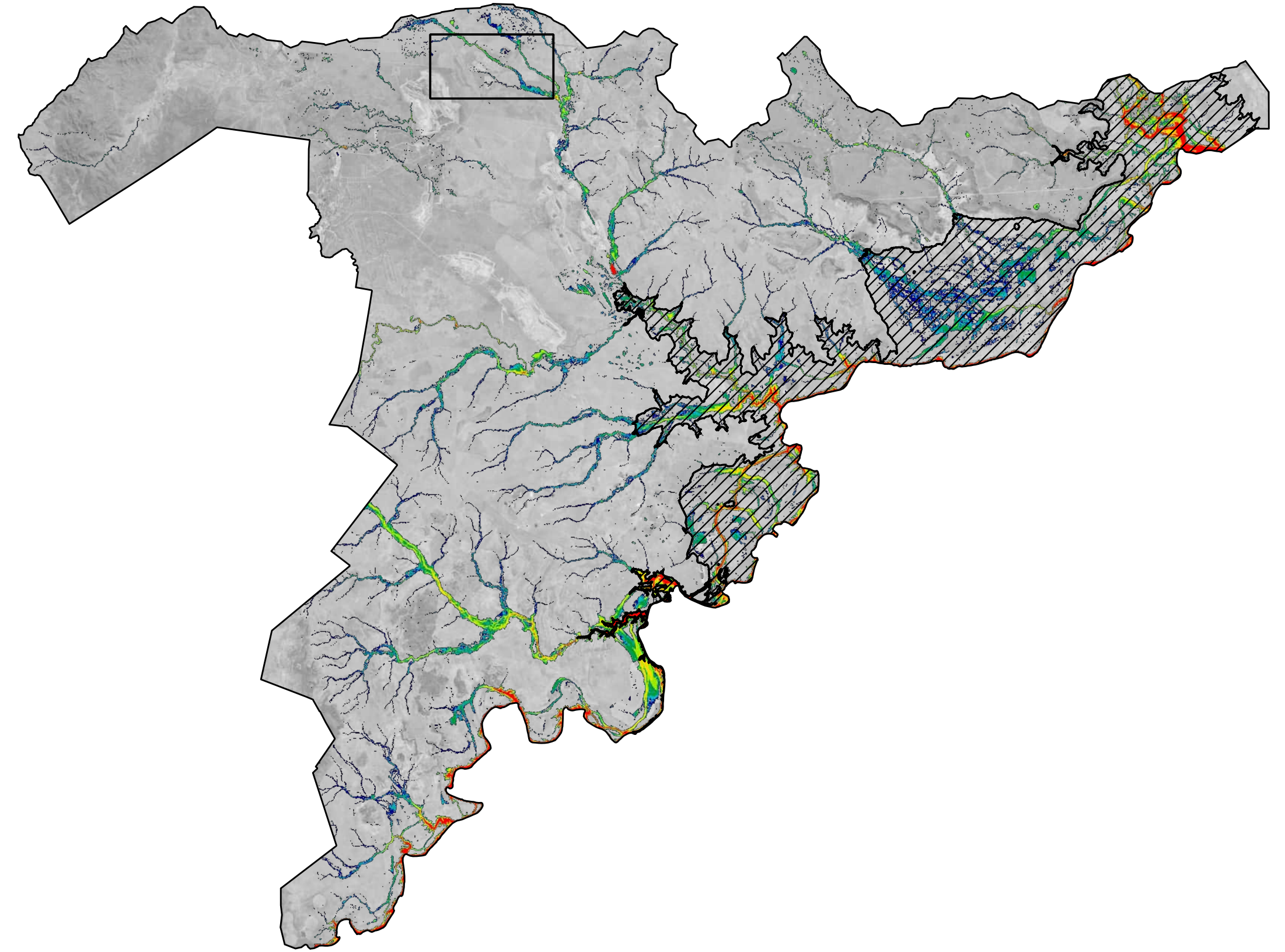
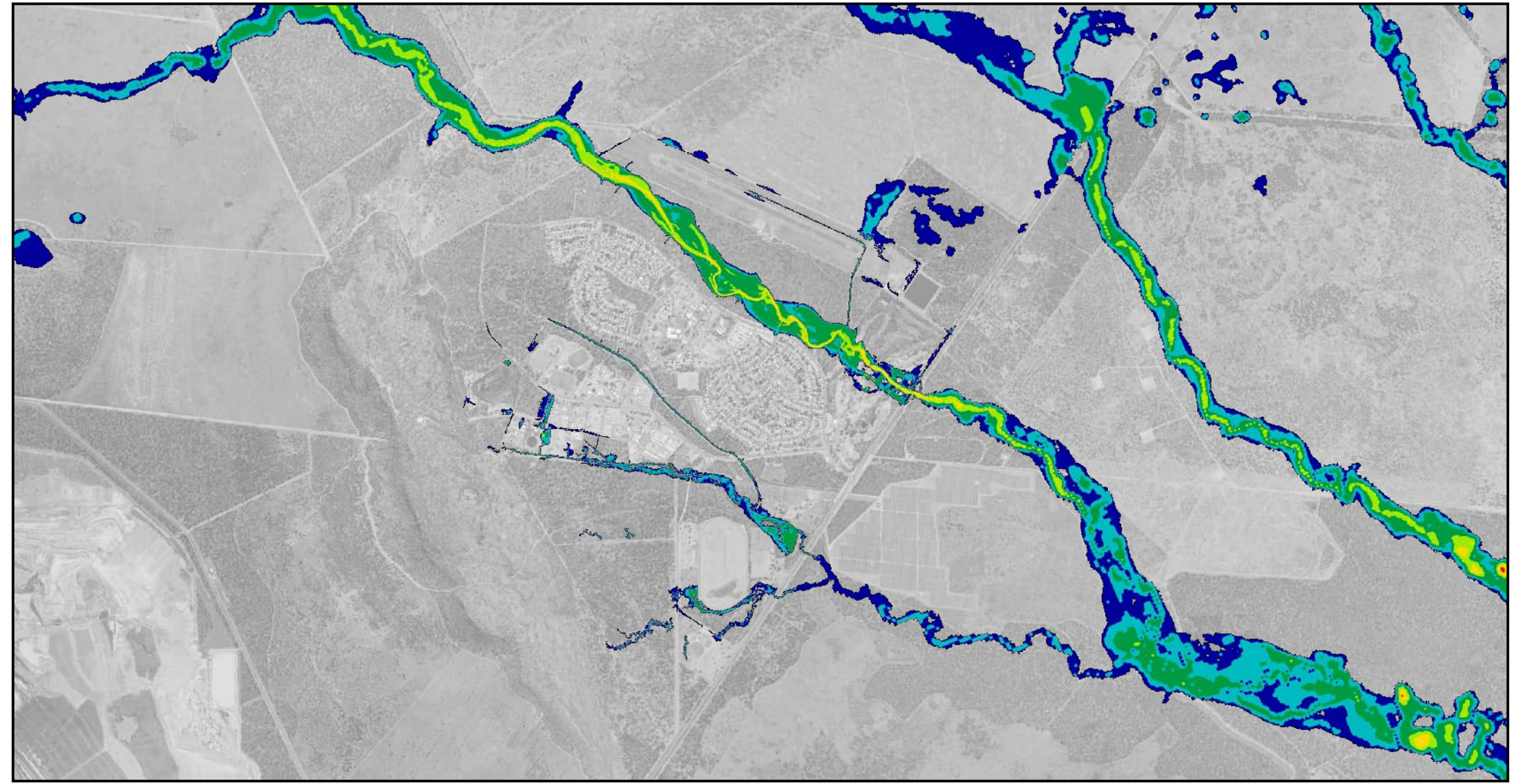
Scale at A3
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File: \\profile001\data\Water_Resources\Projects\BEW571 - Upper Nogoa and Mackenzie\G - GIS\Workspaces\260630_Mapping_Atlas.qgz

Scale:

0 3 6 9 12 15 km

1:410,000

Figure:	Rev:
D-30	0



LEGEND

Flood Hazards (AIDR)

- H1
- H2
- H3
- H4
- H5
- H6
- Study Area
- Uncertainty Extent

Title:

2% AEP (2030) Event Peak Flood Hazards (AIDR)

Upper Mackenzie River (Middlemount)

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File: \\perfile001\data\Water_Resources\Projects\BEW571 - Upper Nogoa and Mackenzie\G - GIS\Workspaces\260630_Mapping_Atlas.qgz

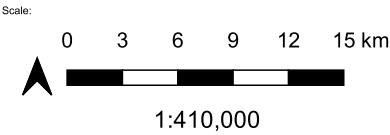
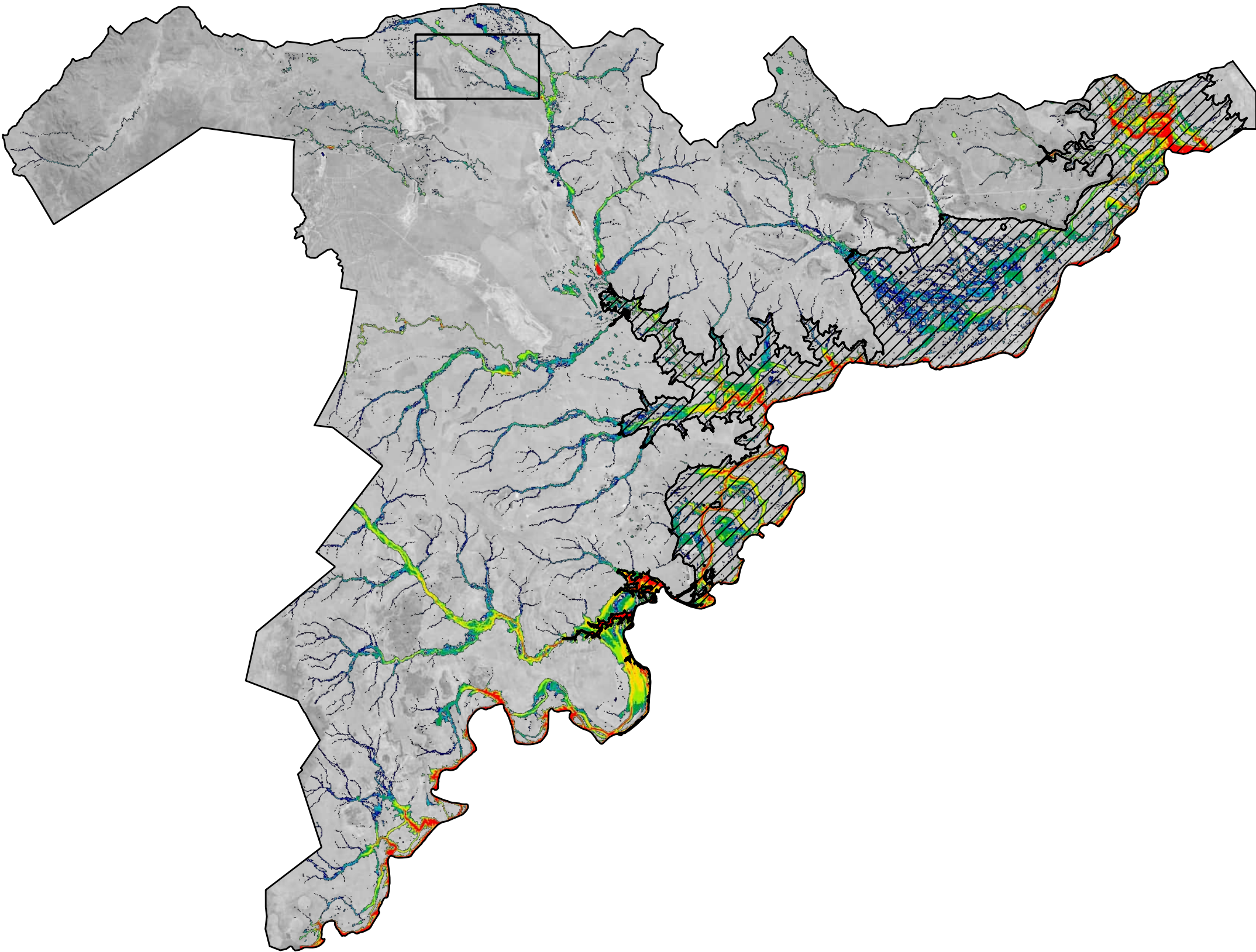
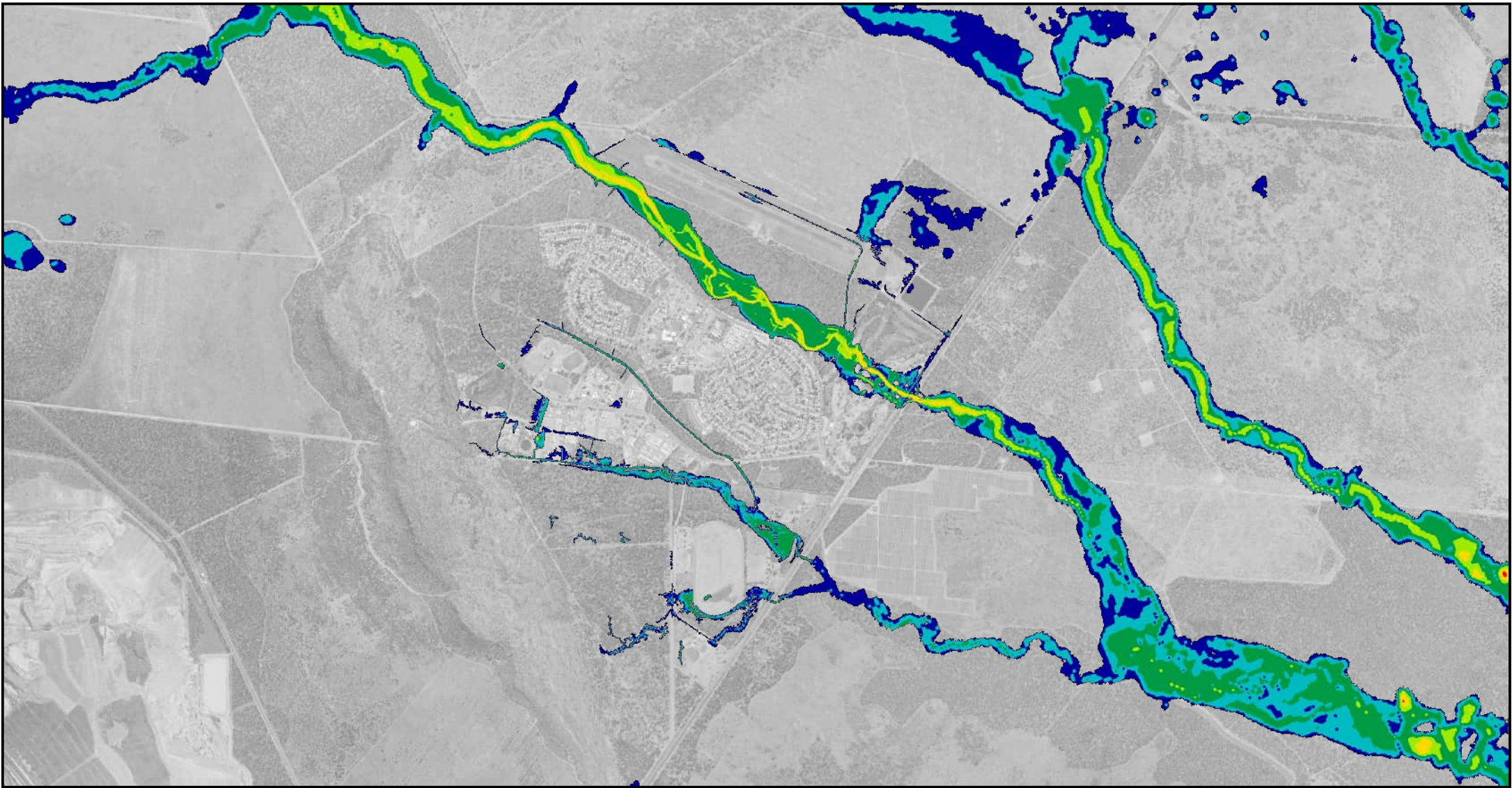


Figure: **D-31**

Rev: **0**



LEGEND

Flood Hazards (AIDR)

H1	H5
H2	H6
H3	Study Area
H4	Uncertainty Extent

Title:

1% AEP (2030) Event Peak Flood Hazards (AIDR) Upper Mackenzie River (Middlemount)

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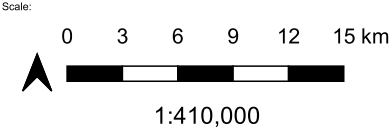
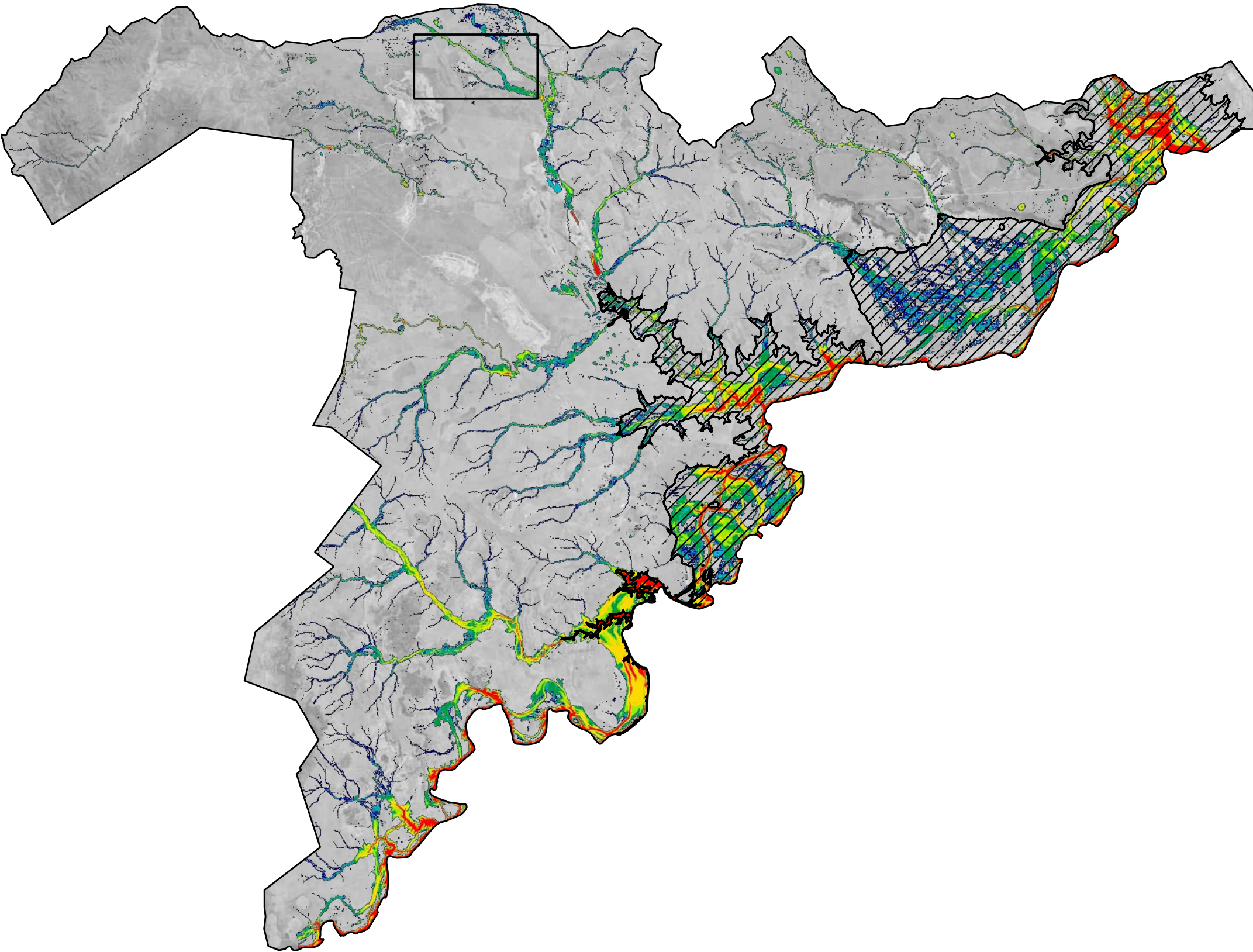
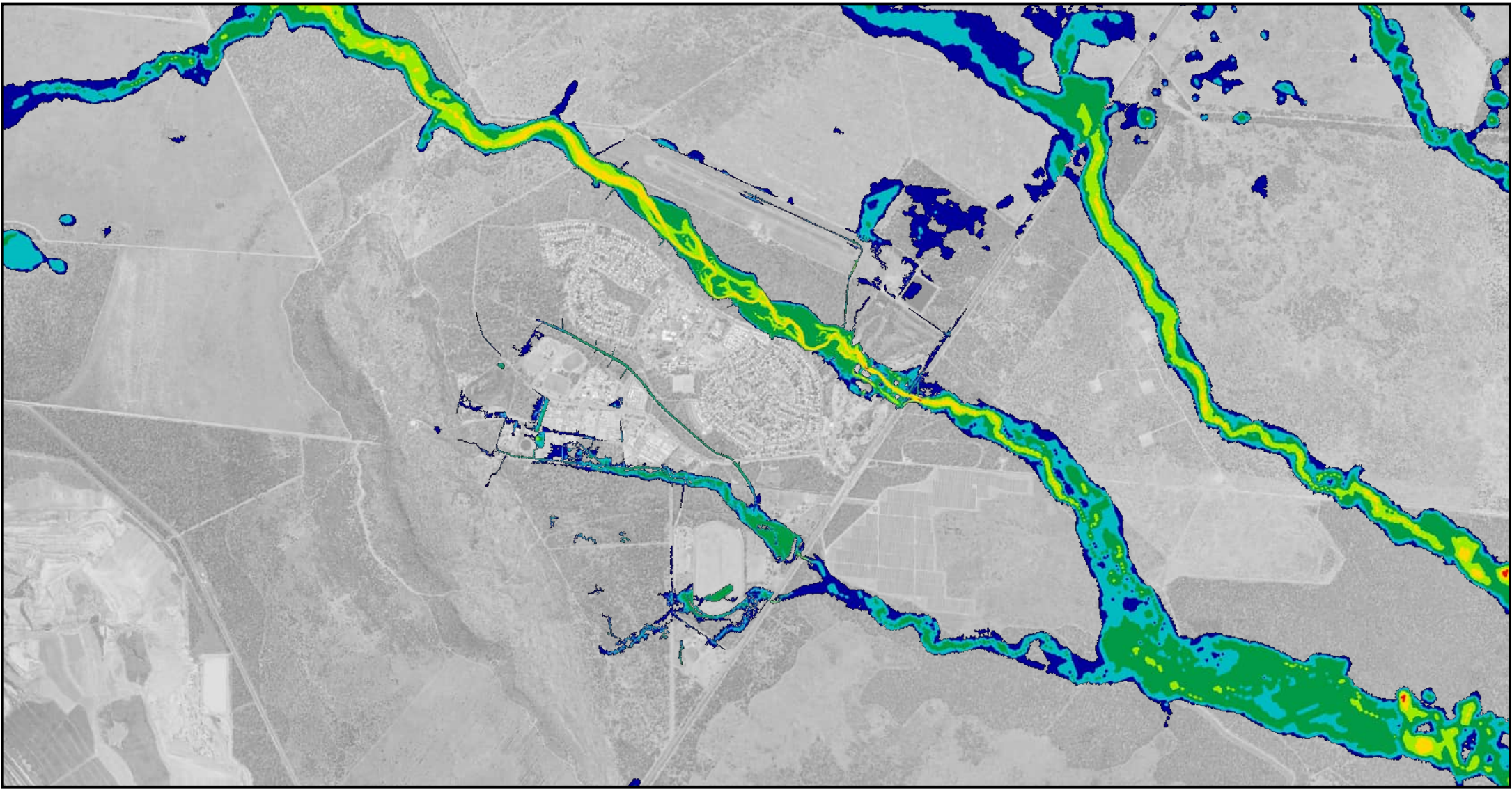


Figure:	Rev:
D-32	0



LEGEND

Flood Hazards (AIDR)

H1	H5
H2	H6
H3	Study Area
H4	Uncertainty Extent

Title:

0.5% AEP (2030) Event Peak Flood Hazards (AIDR)

Upper Mackenzie River (Middlemount)

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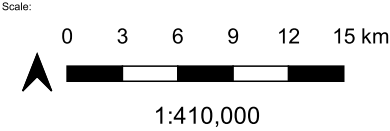
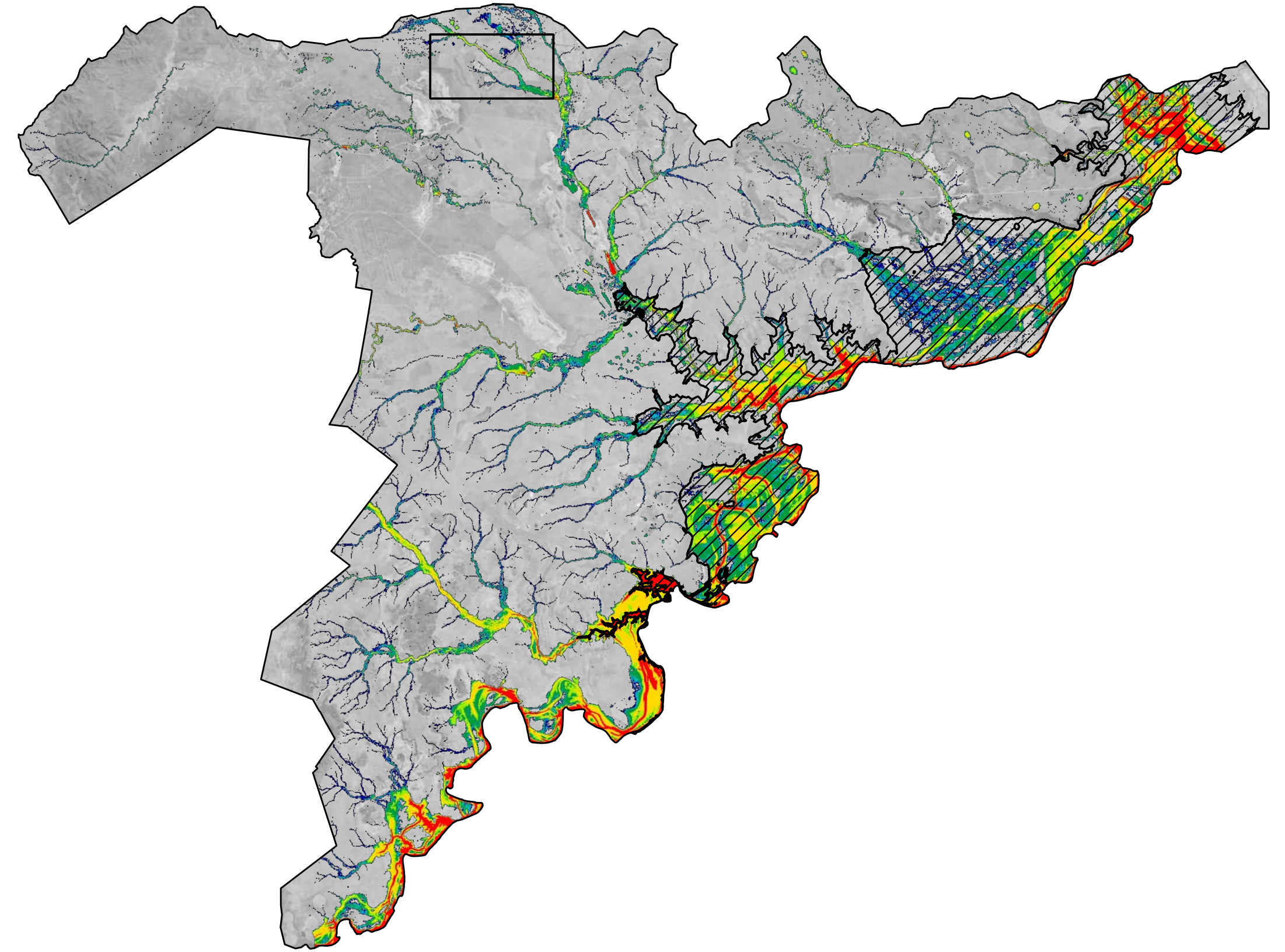
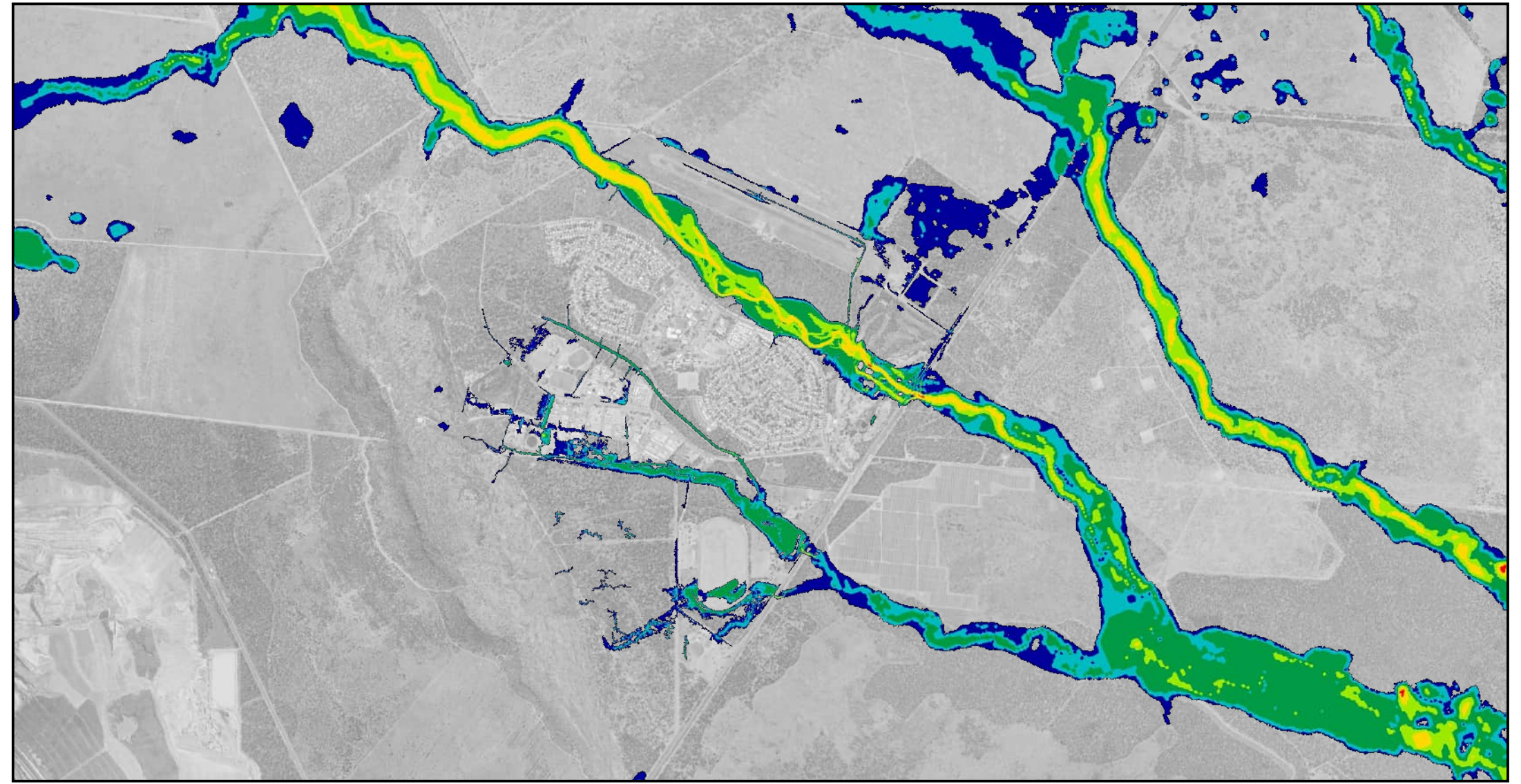


Figure:	Rev:
D-33	0



LEGEND

Flood Hazards (AIDR)

	H1		H5
	H2		H6
	H3		Study Area
	H4		Uncertainty Extent

Title:

0.2% AEP (2030) Event Peak Flood Hazards (AIDR)

Upper Mackenzie River (Middlemount)

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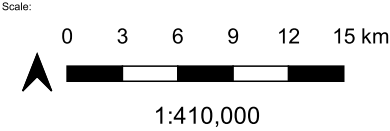
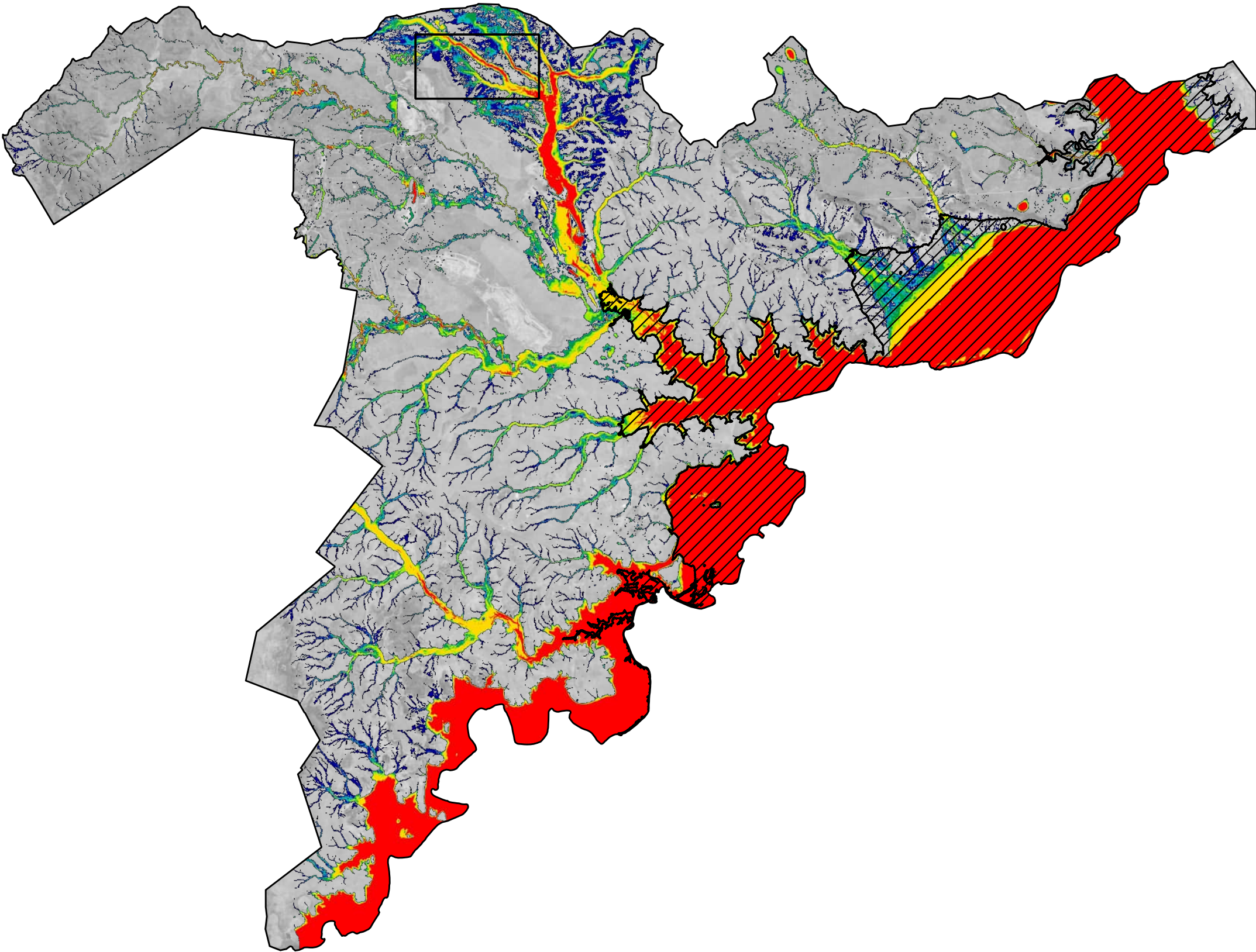
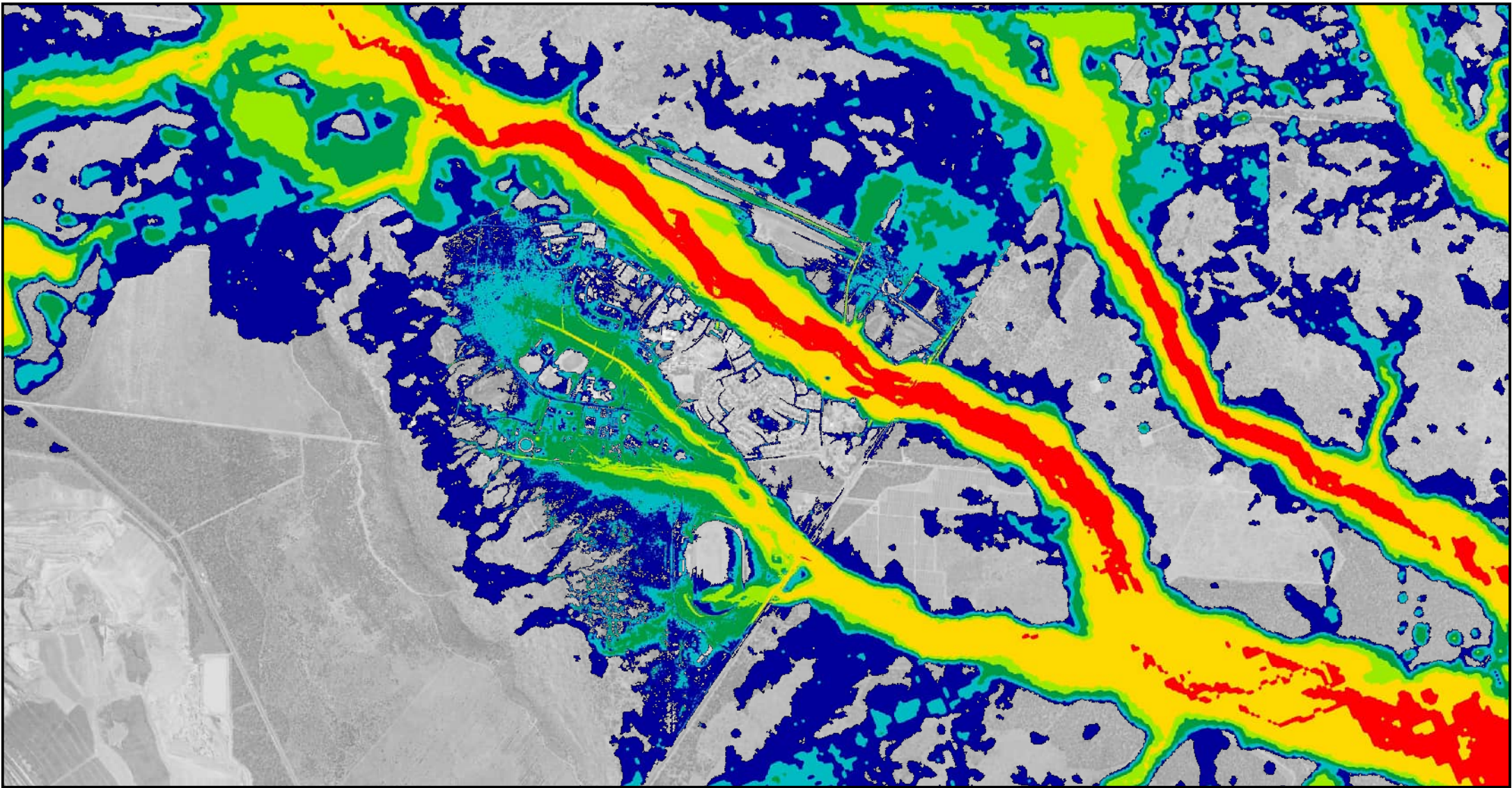


Figure:	D-34	Rev:	0



LEGEND

Flood Hazards (AIDR)

H1	H5
H2	H6
H3	Study Area
H4	Uncertainty Extent

Title:

PMF Event (2030) Peak Flood Hazards (AIDR) Upper Mackenzie River (Middlemount)

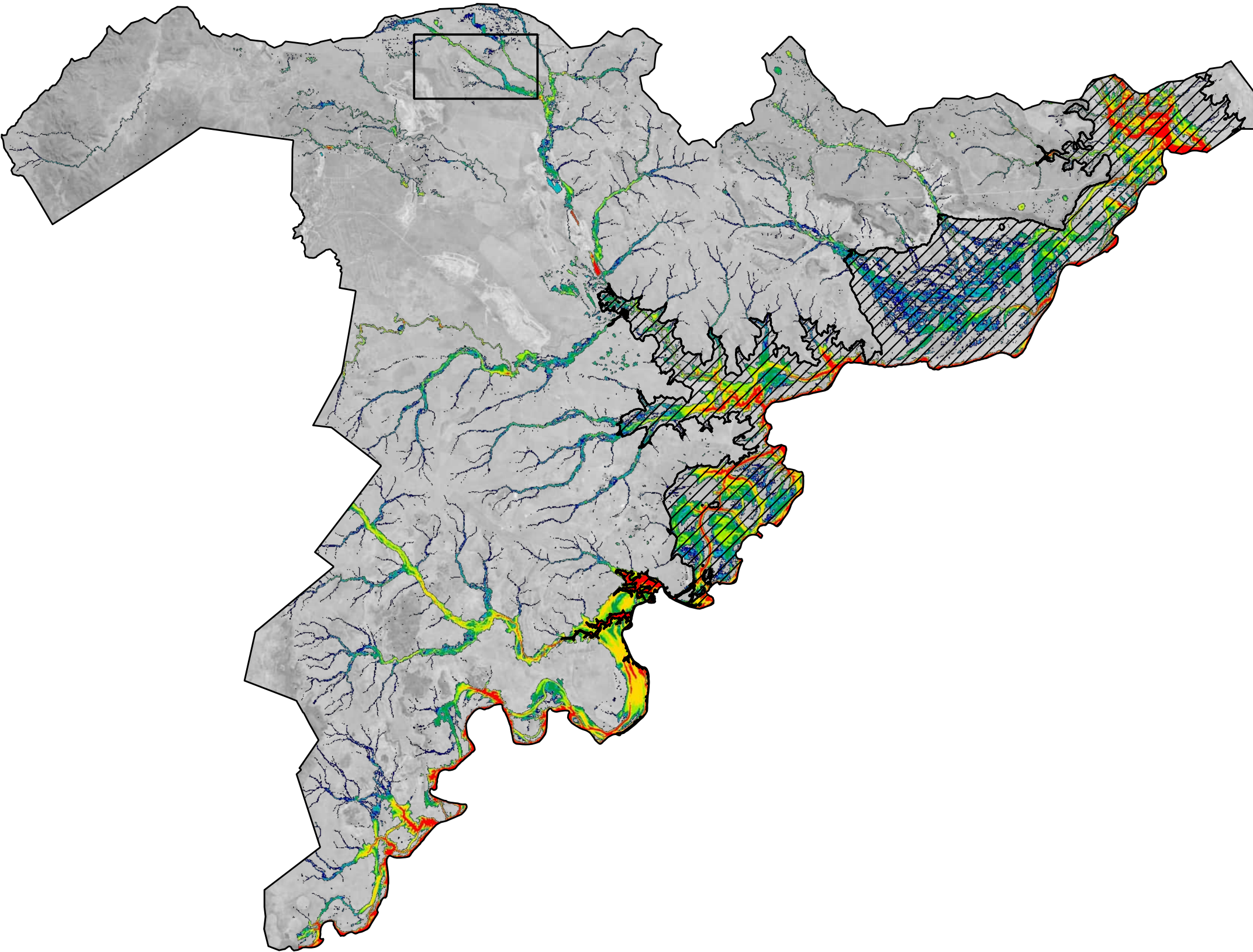
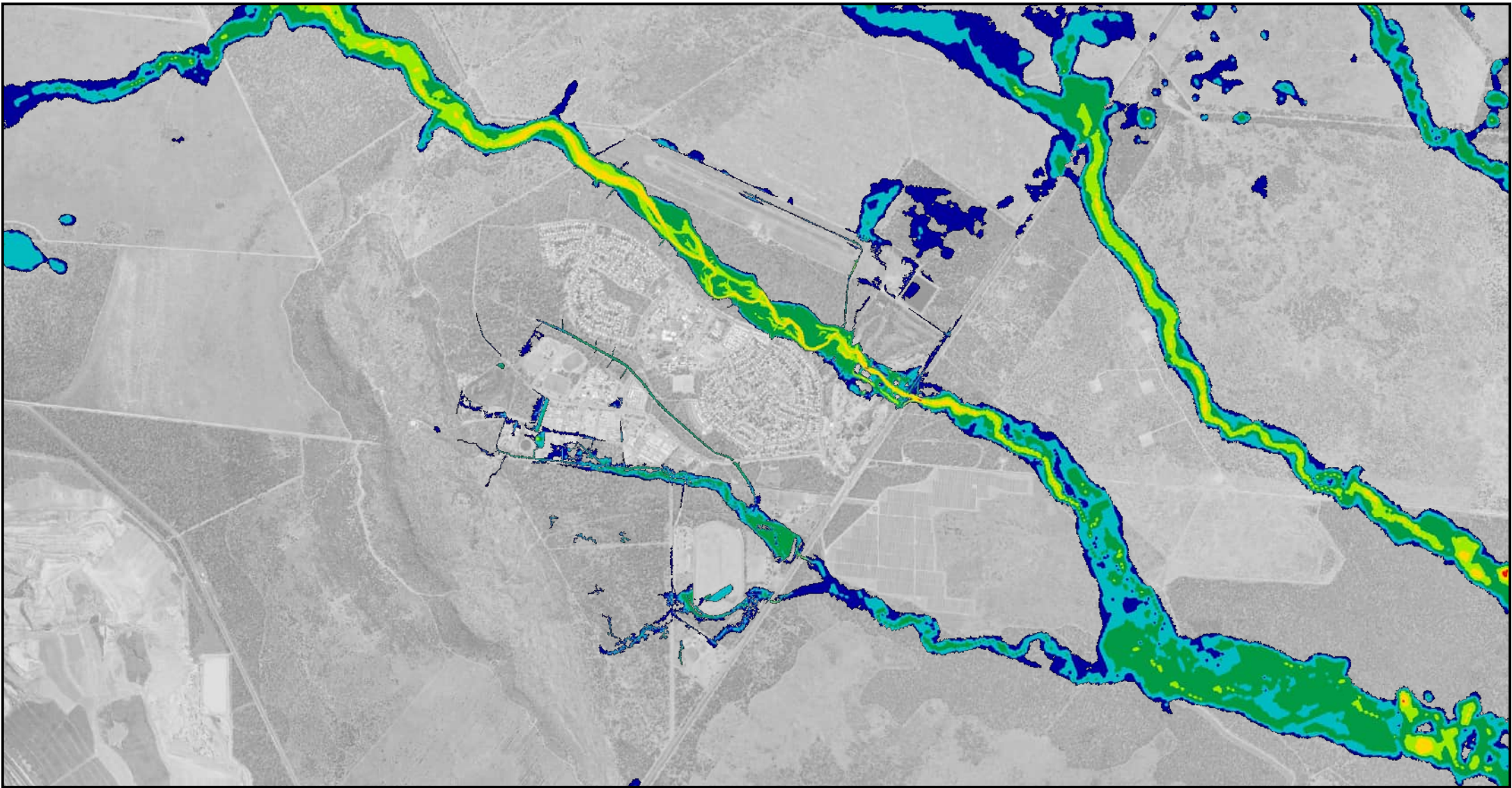
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Scale:

0 3 6 9 12 15 km

1:410,000

Figure:	Rev:
D-35	0



LEGEND

Flood Hazards (AIDR)

H1	H5
H2	H6
H3	Study Area
H4	Uncertainty Extent

Title:

1% AEP (2100) Event Peak Flood Hazards (AIDR) Upper Mackenzie River (Middlemount)

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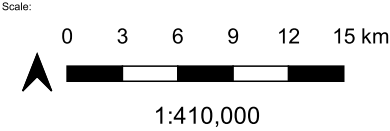
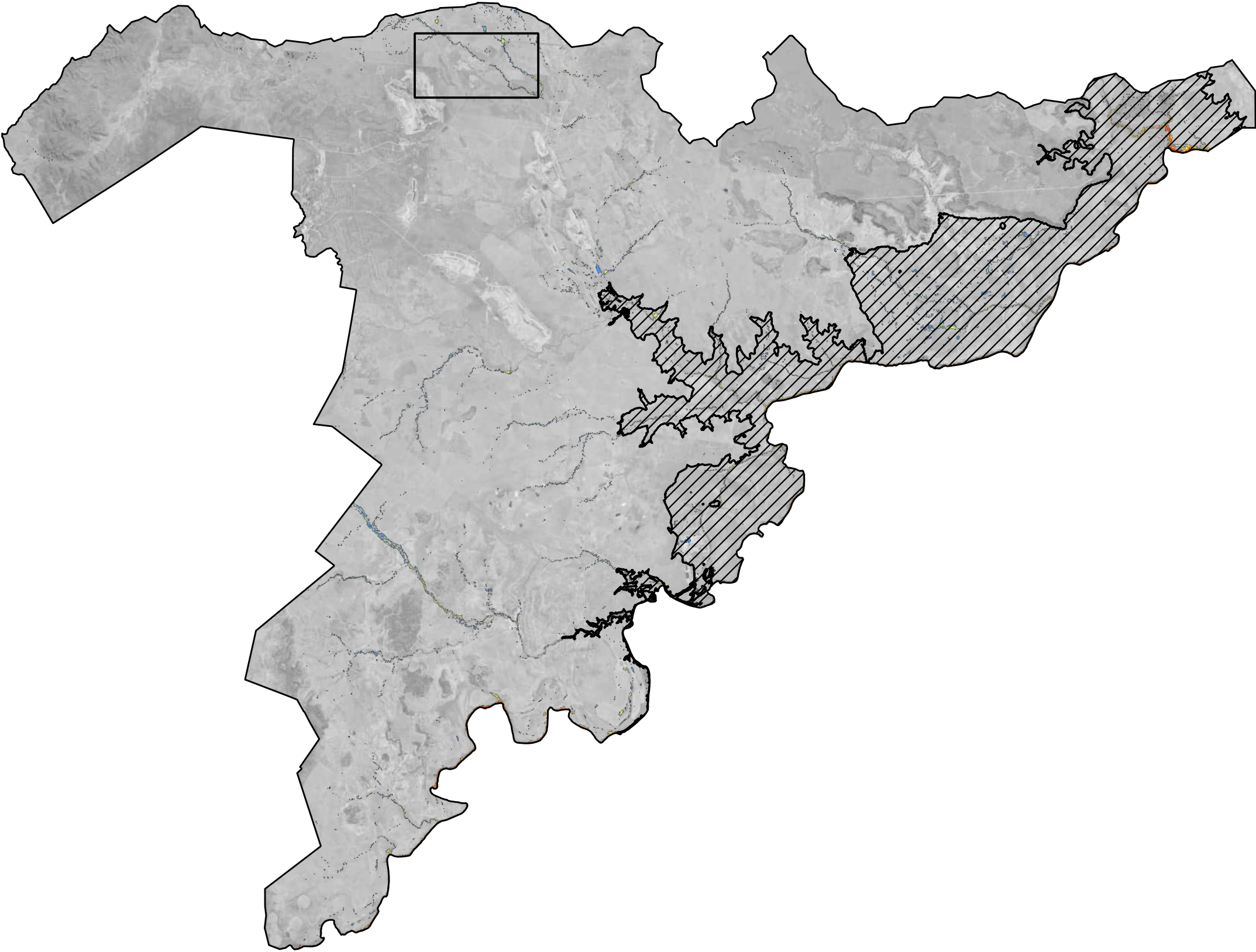
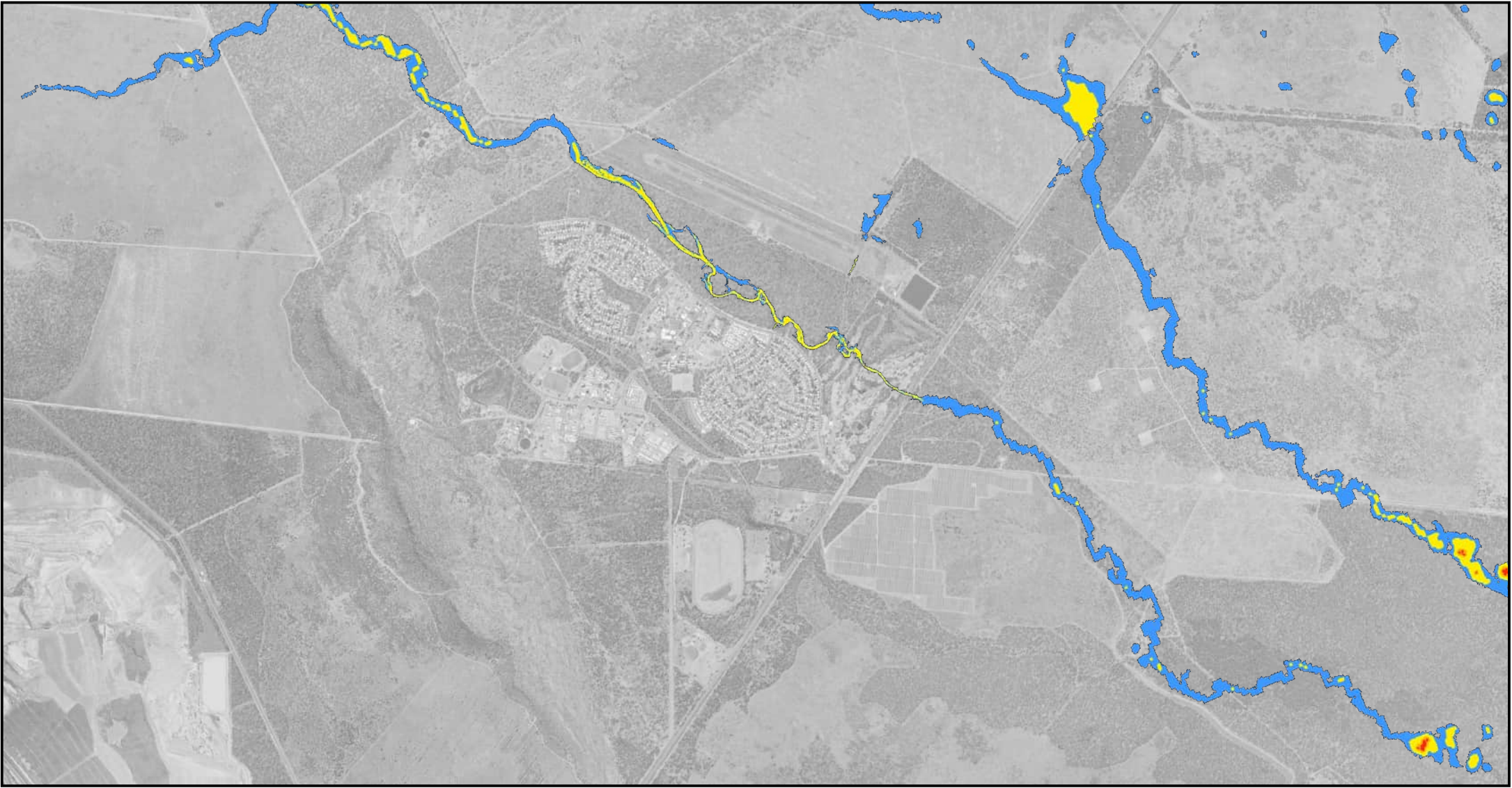


Figure:	Rev:
D-36	0



LEGEND
Flood Hazards (QRA)

Low

Significant

High

Extreme

Study Area

Uncertainty Extent

Title:

50% AEP (2030) Event Peak Flood Hazards (QRA)
Upper Mackenzie River (Middlemount)

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Scale:

03691215 km

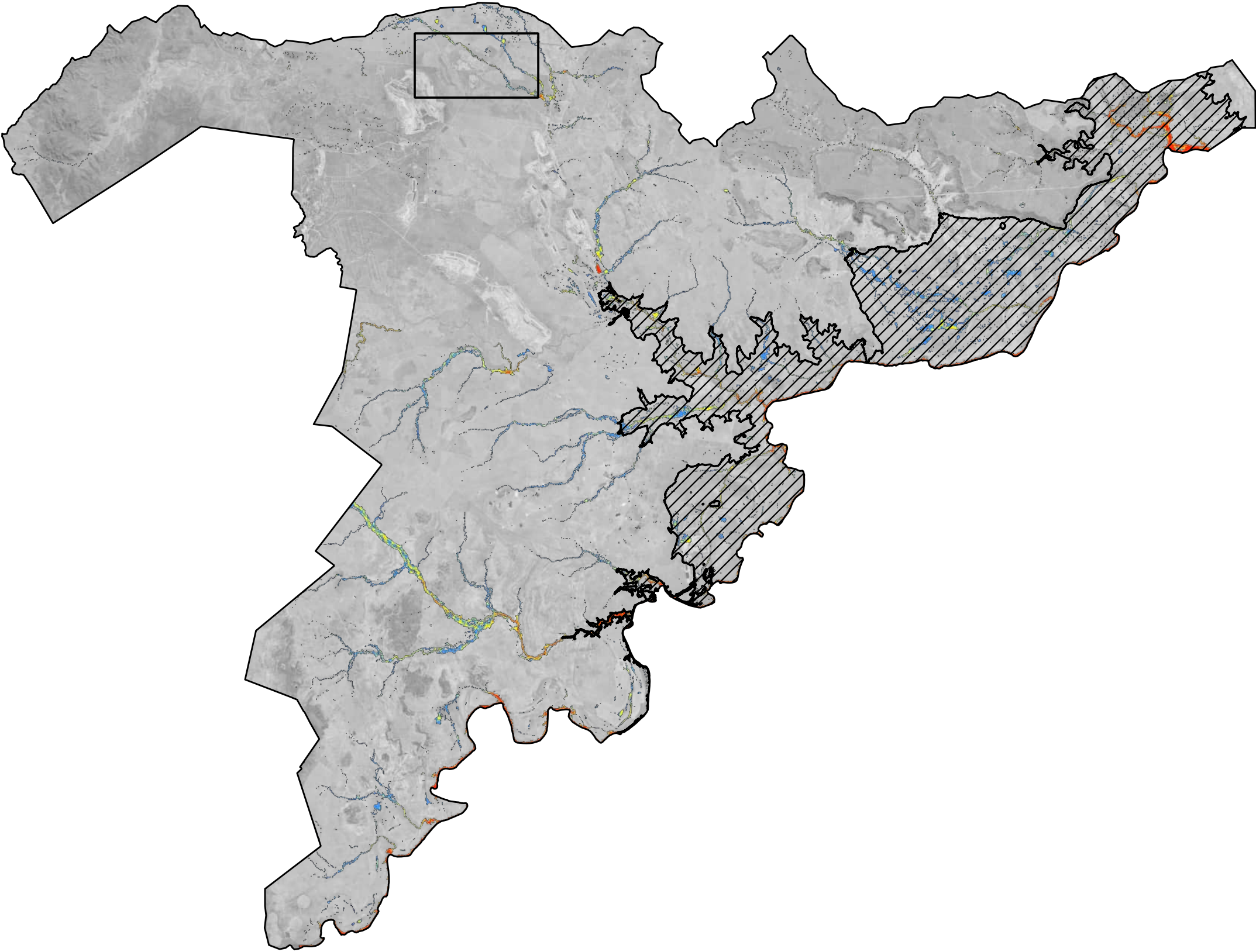
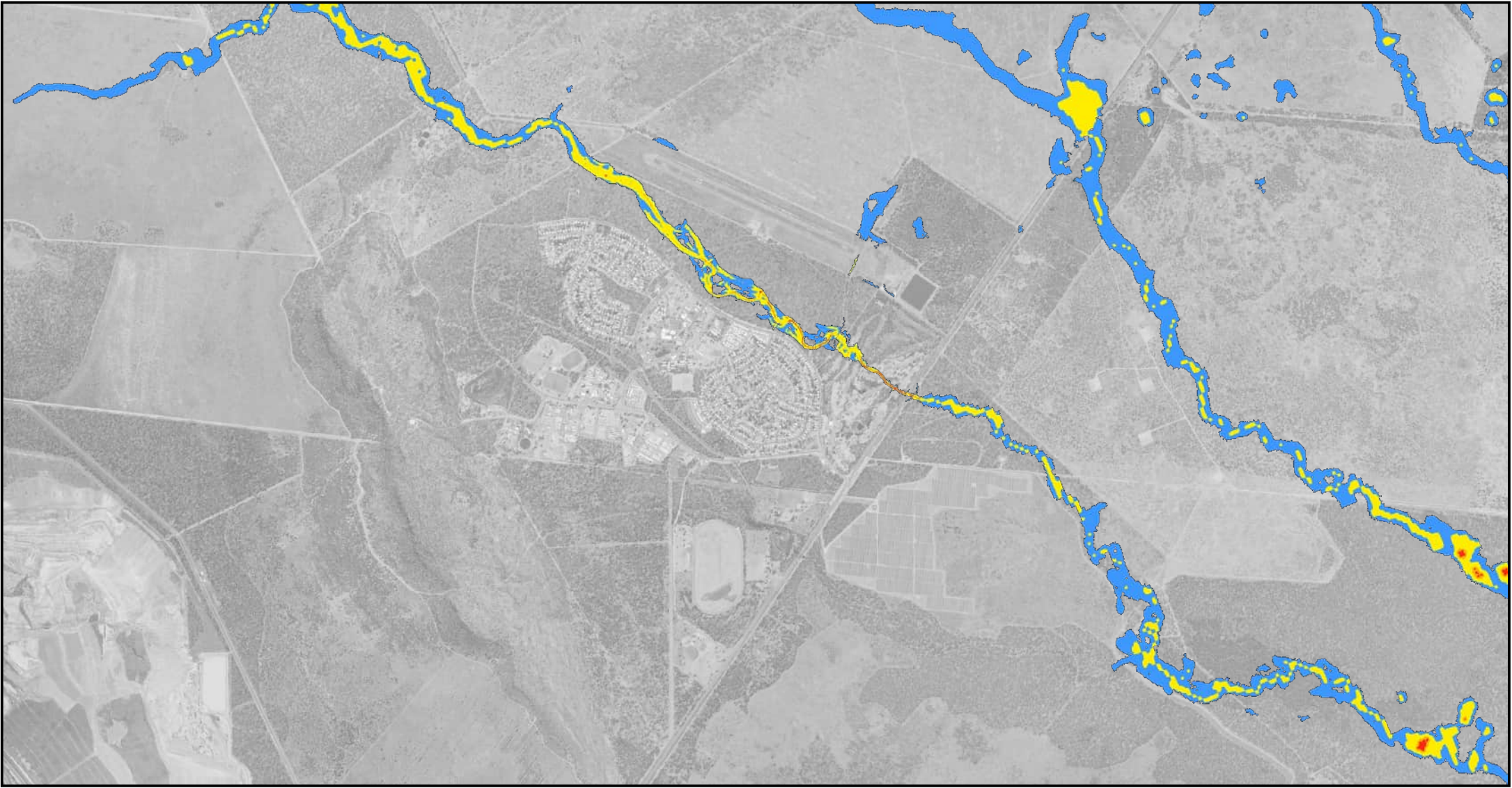
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Figure:

D-37

Rev:

0



LEGEND

Flood Hazards (QRA)

Low

Significant

High

Extreme

Study Area

Uncertainty Extent

Title:

20% AEP (2030) Event Peak Flood Hazards (QRA)
Upper Mackenzie River (Middlemount)

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File: \\profile001\data\$\Water_Resources\Projects\BEW571 - Upper Nogoa and Mackenzie\G - GIS\Workspaces\260630_Mapping_Atlas.qgz

Scale:

03691215 km

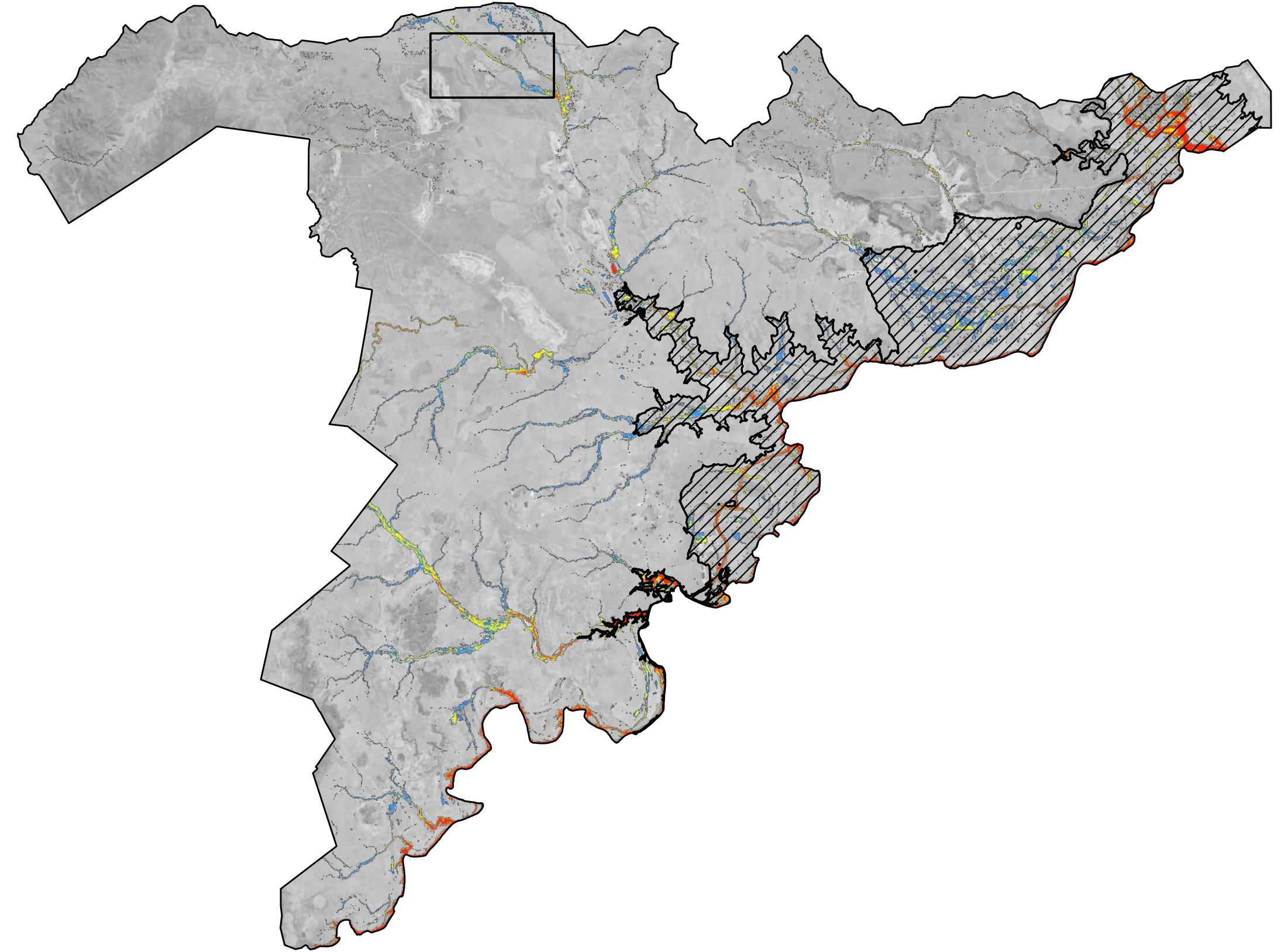
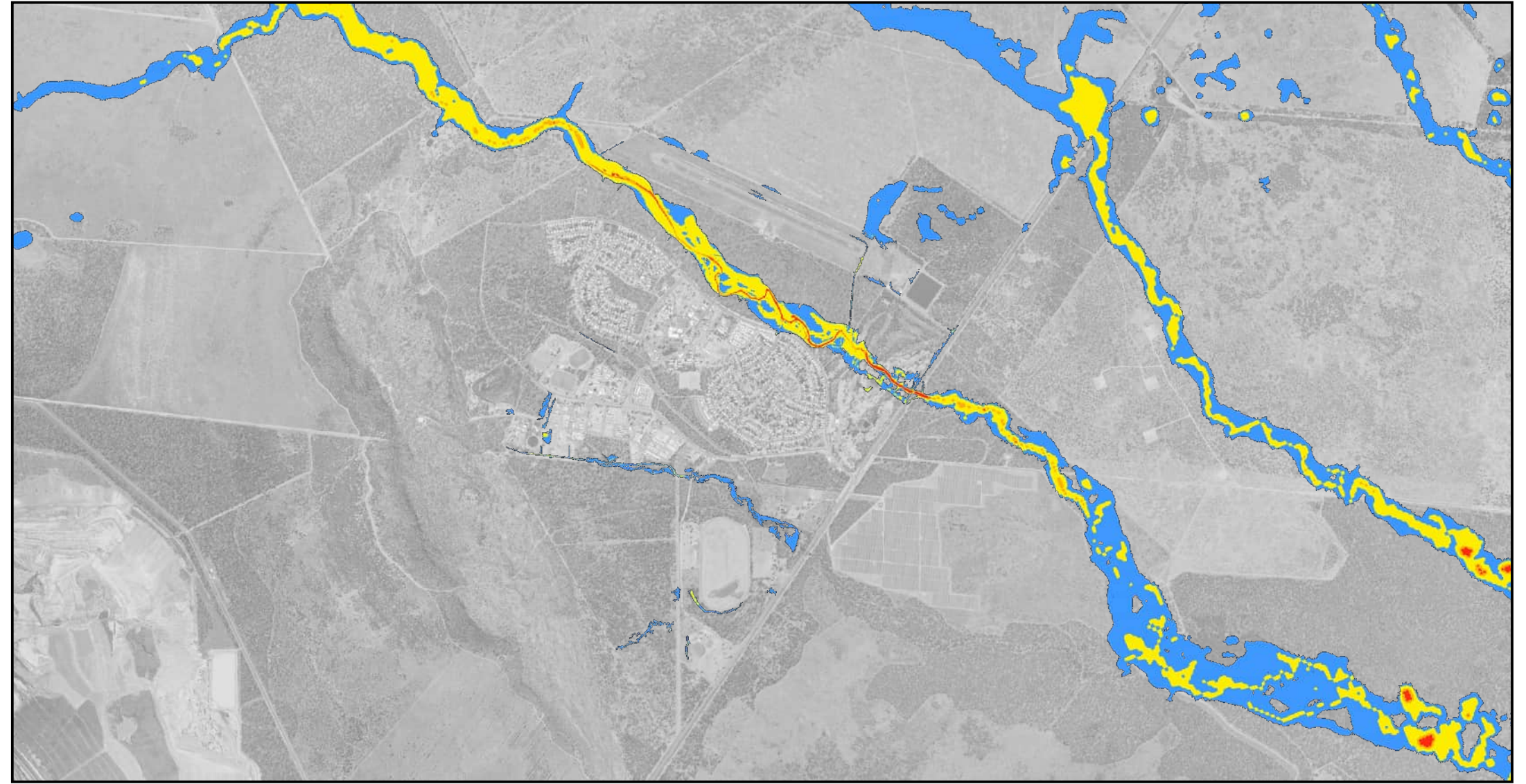
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Figure:

D-38

Rev:

0



LEGEND

Flood Hazards (QRA)

- Low
- Significant
- High
- Extreme
- Study Area
- Uncertainty Extent

Title:

5% AEP (2030) Event Peak Flood Hazards (QRA) Upper Mackenzie River (Middlemount)

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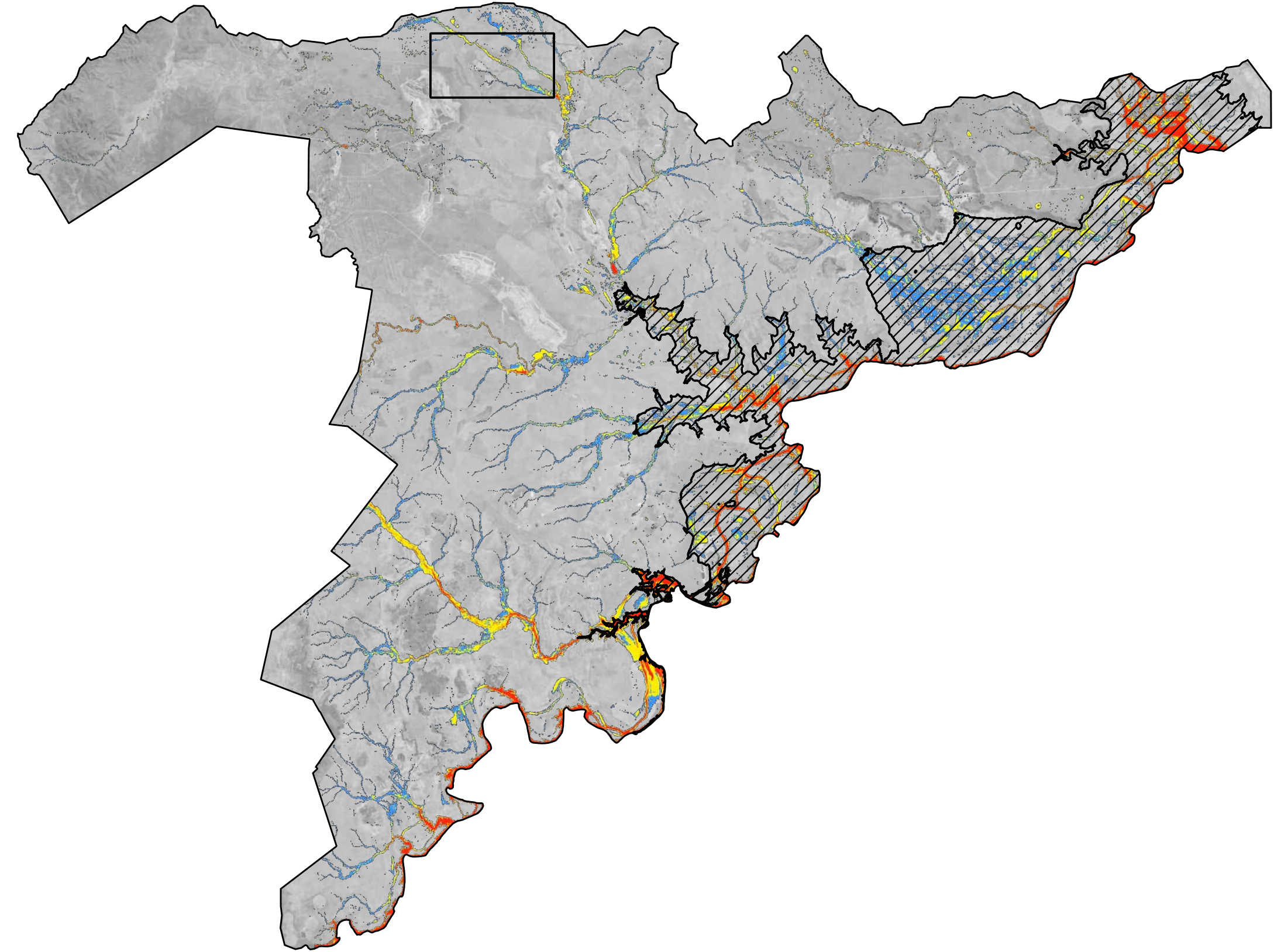
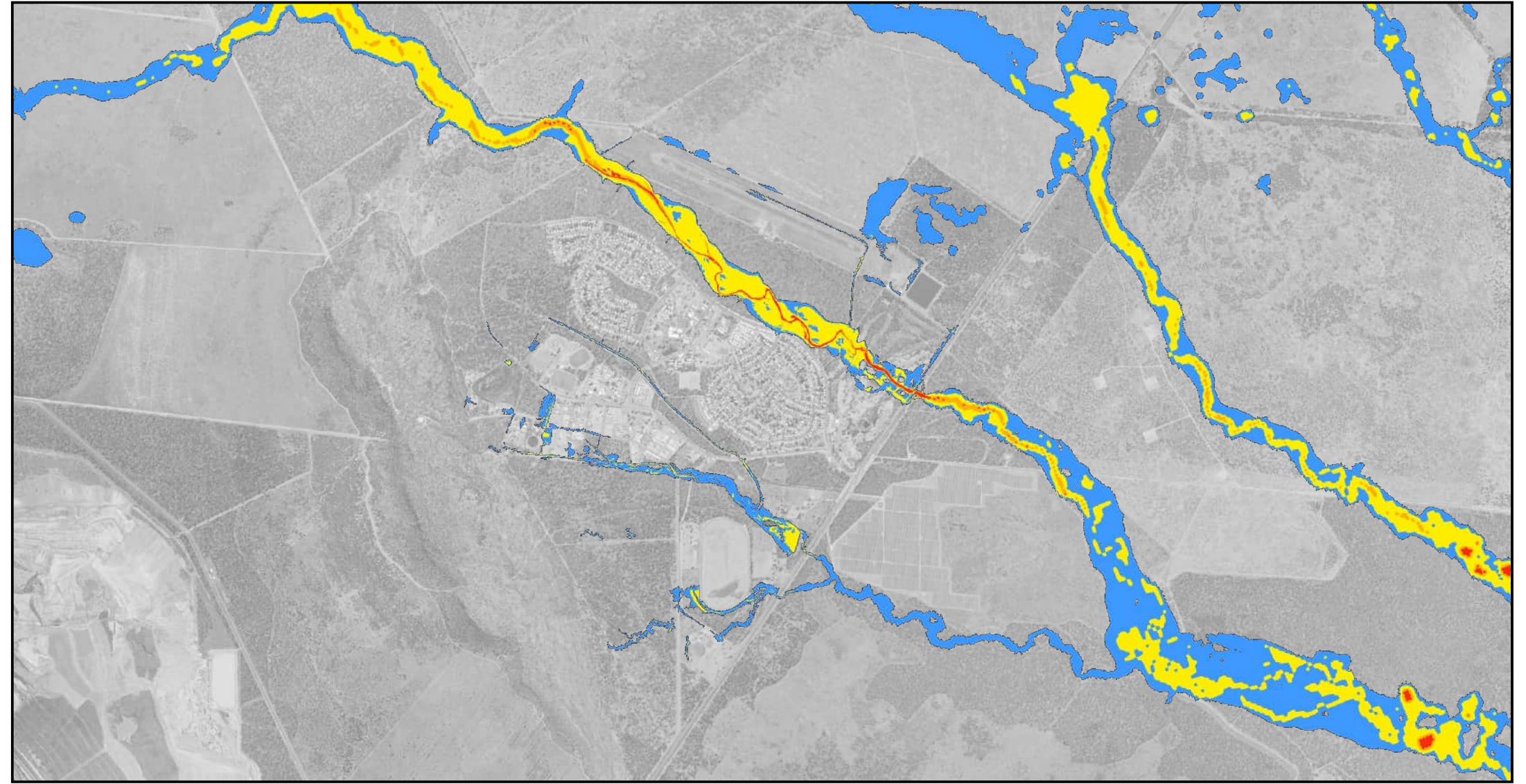
Scale:

0 3 6 9 12 15 km

1:410,000

Figure: D-39

Rev: 0



LEGEND

Flood Hazards (QRA)

Low

Significant

High

Extreme

Study Area

Uncertainty Extent

Title:

2% AEP (2030) Event Peak Flood Hazards (QRA)
Upper Mackenzie River (Middlemount)

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Scale:

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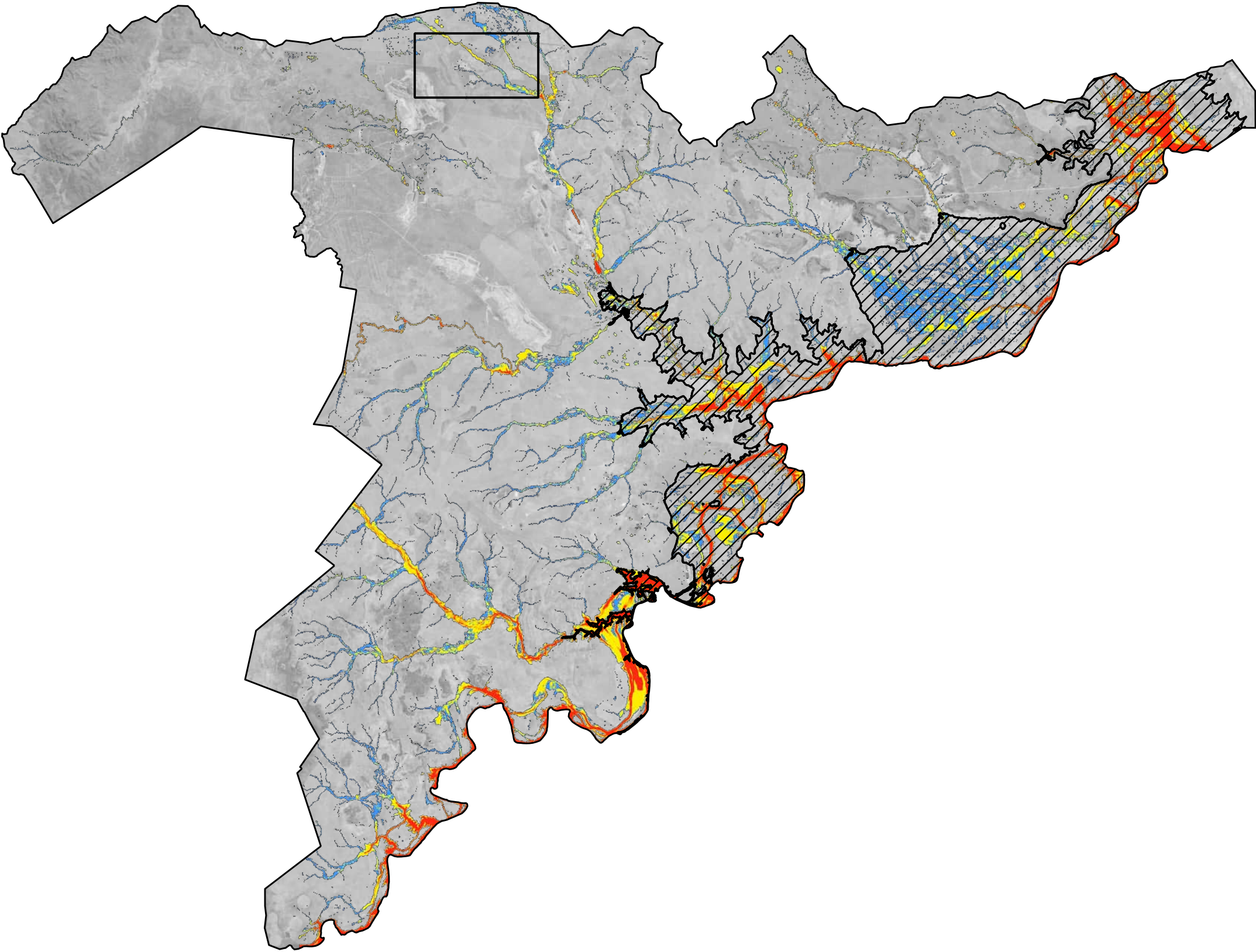
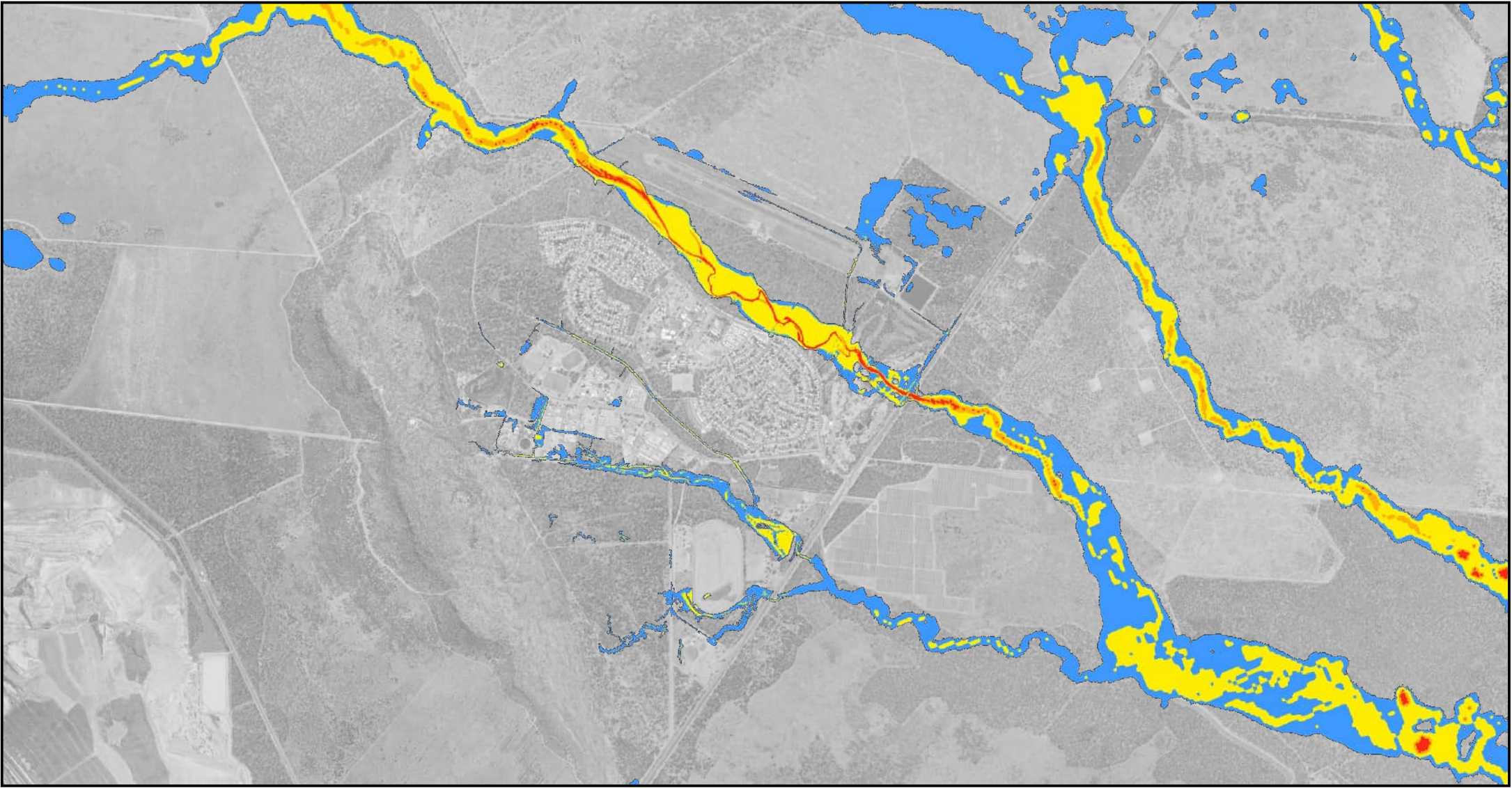
1:410,000

Figure:

D-40

Rev:

0



LEGEND

Flood Hazards (QRA)

Low

Significant

High

Extreme

Study Area

Uncertainty Extent

Title:

1% AEP (2030) Event Peak Flood Hazards (QRA)
Upper Mackenzie River (Middlemount)

Scale at A3
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File: \\perfile001\data\$\Water_Resources\Projects\BEW571 - Upper Nogoa and Mackenzie\G - GIS\Workspaces\260630_Mapping_Atlas.qgz

Scale:

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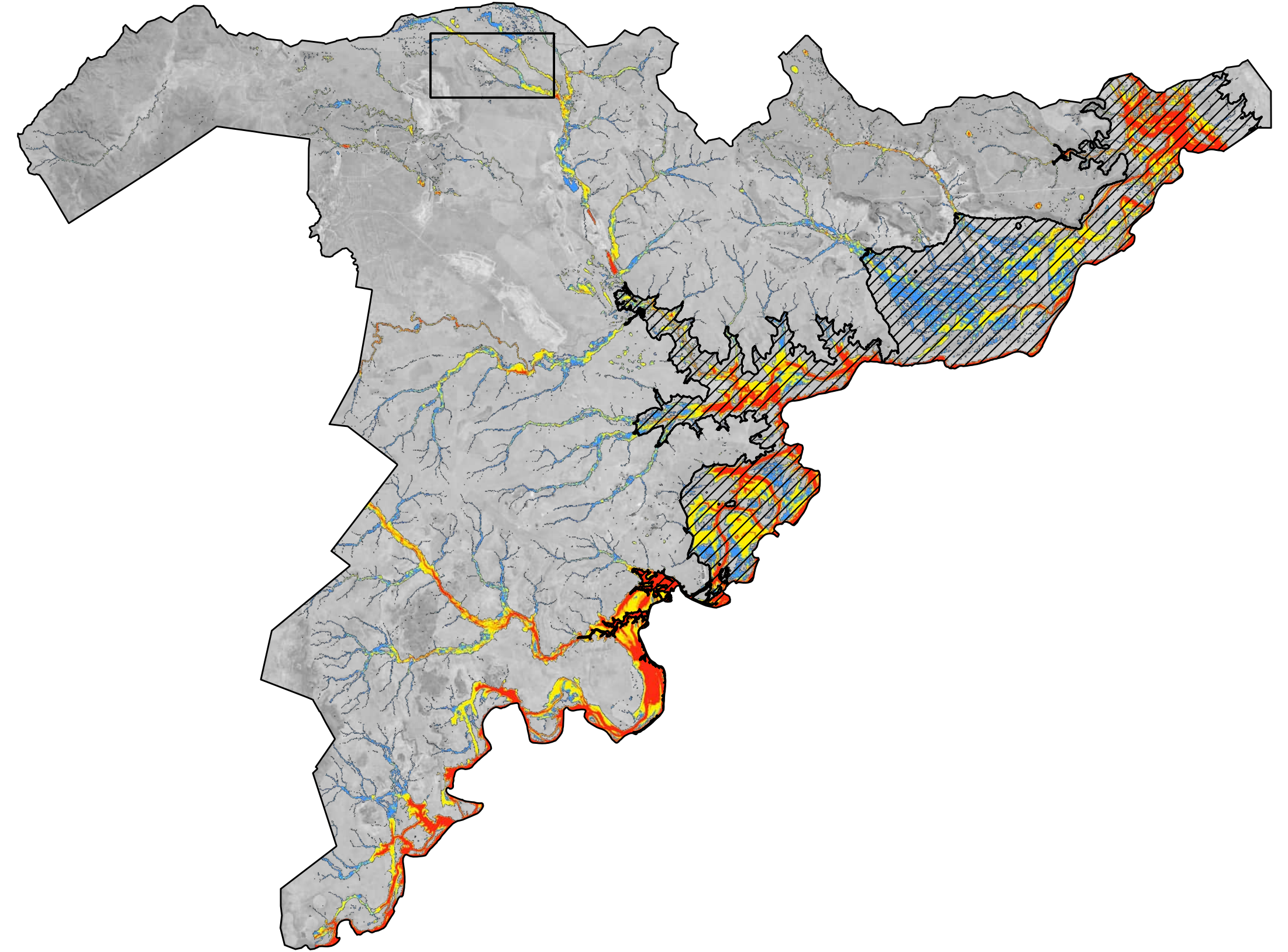
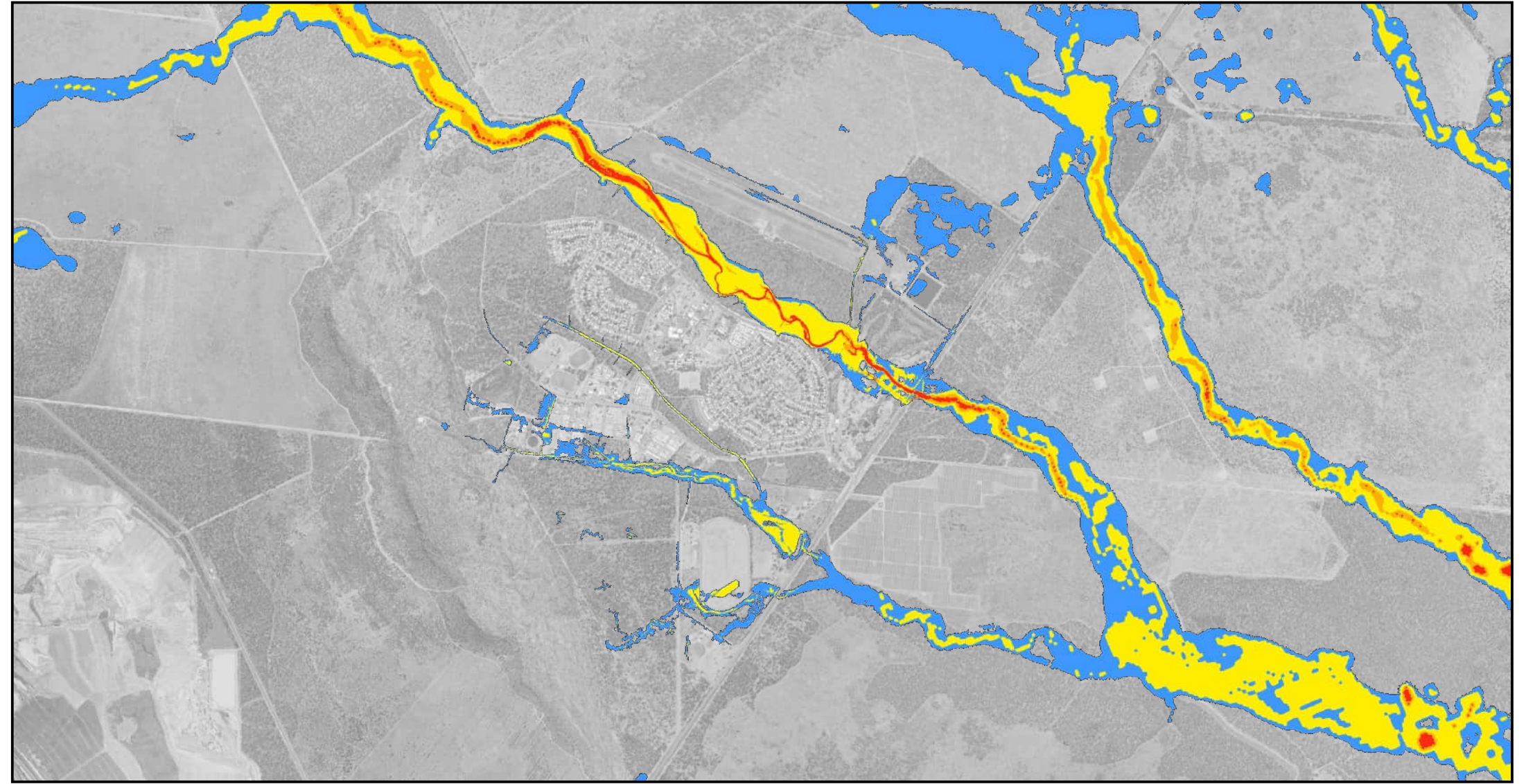
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Figure:

D-41

Rev:

0



LEGEND

Flood Hazards (QRA)

Low

Significant

High

Extreme

Study Area

Uncertainty Extent

Title:

0.5% AEP (2030) Event Peak Flood Hazards (QRA)
Upper Mackenzie River (Middlemount)

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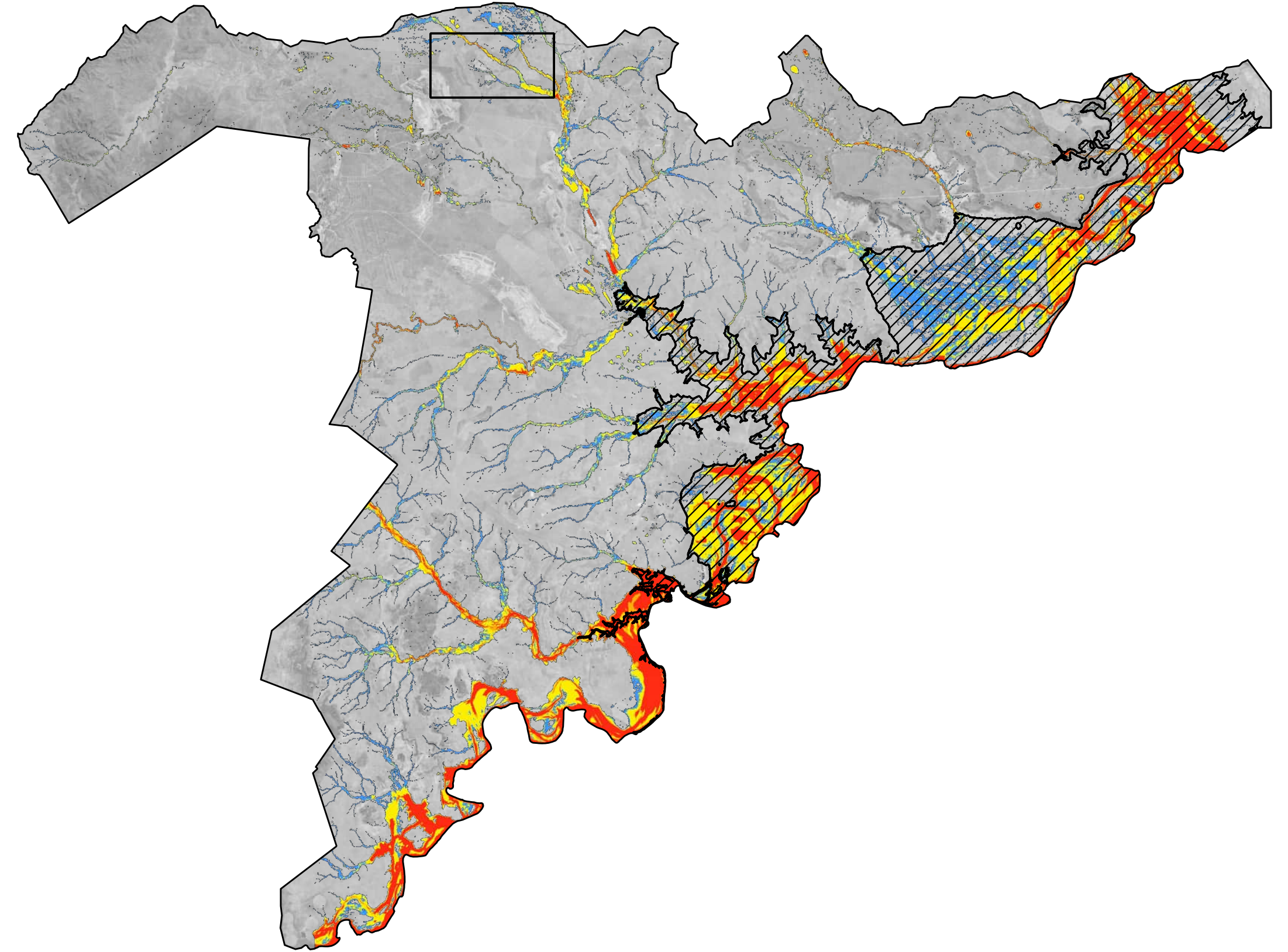
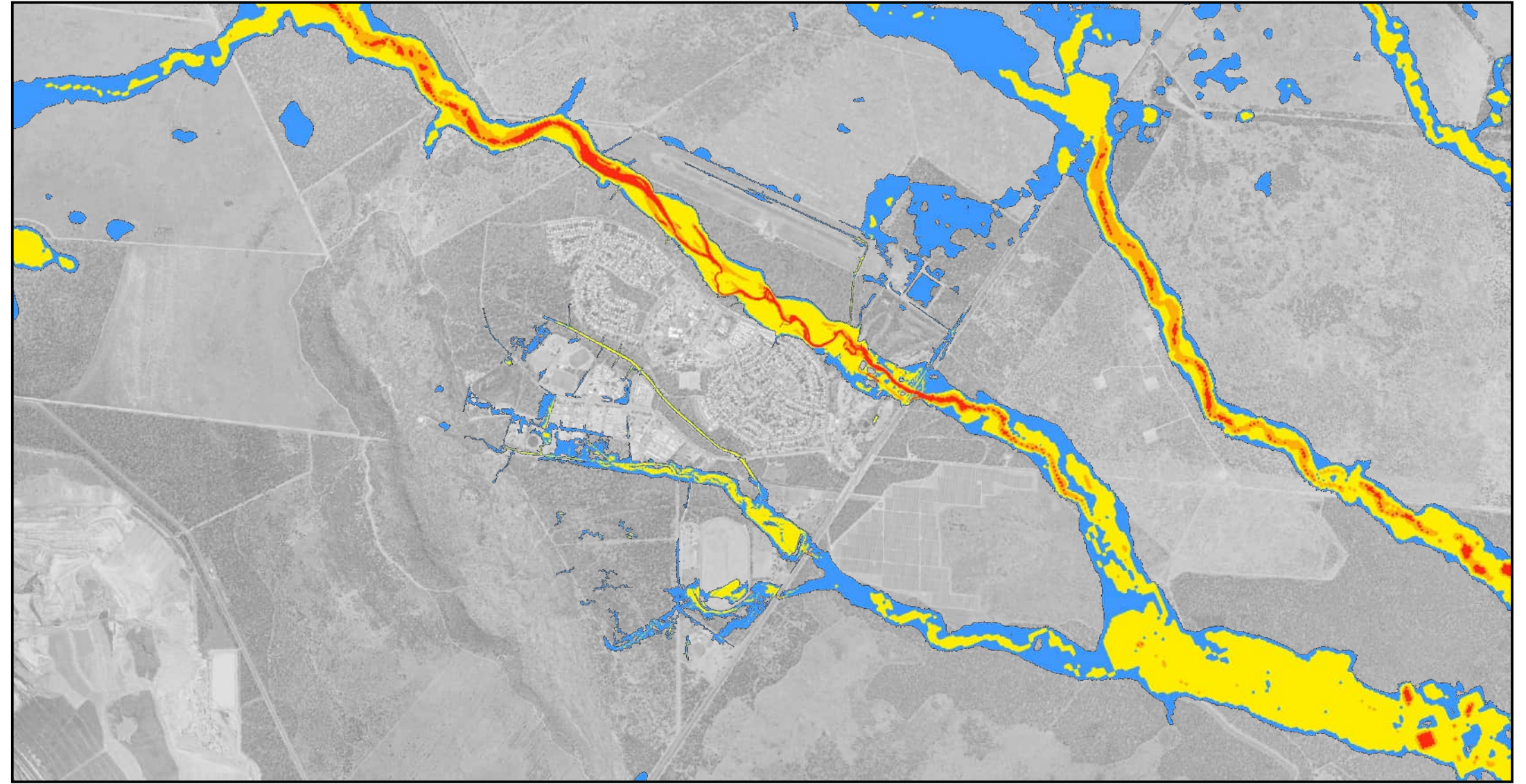
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Figure:

D-42

Rev:

0



LEGEND

Flood Hazards (QRA)

	Low
	Significant
	High
	Extreme
	Study Area
	Uncertainty Extent

Title:

0.2% AEP (2030) Event Peak Flood Hazards (QRA)

Upper Mackenzie River (Middlemount)

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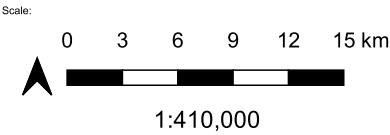
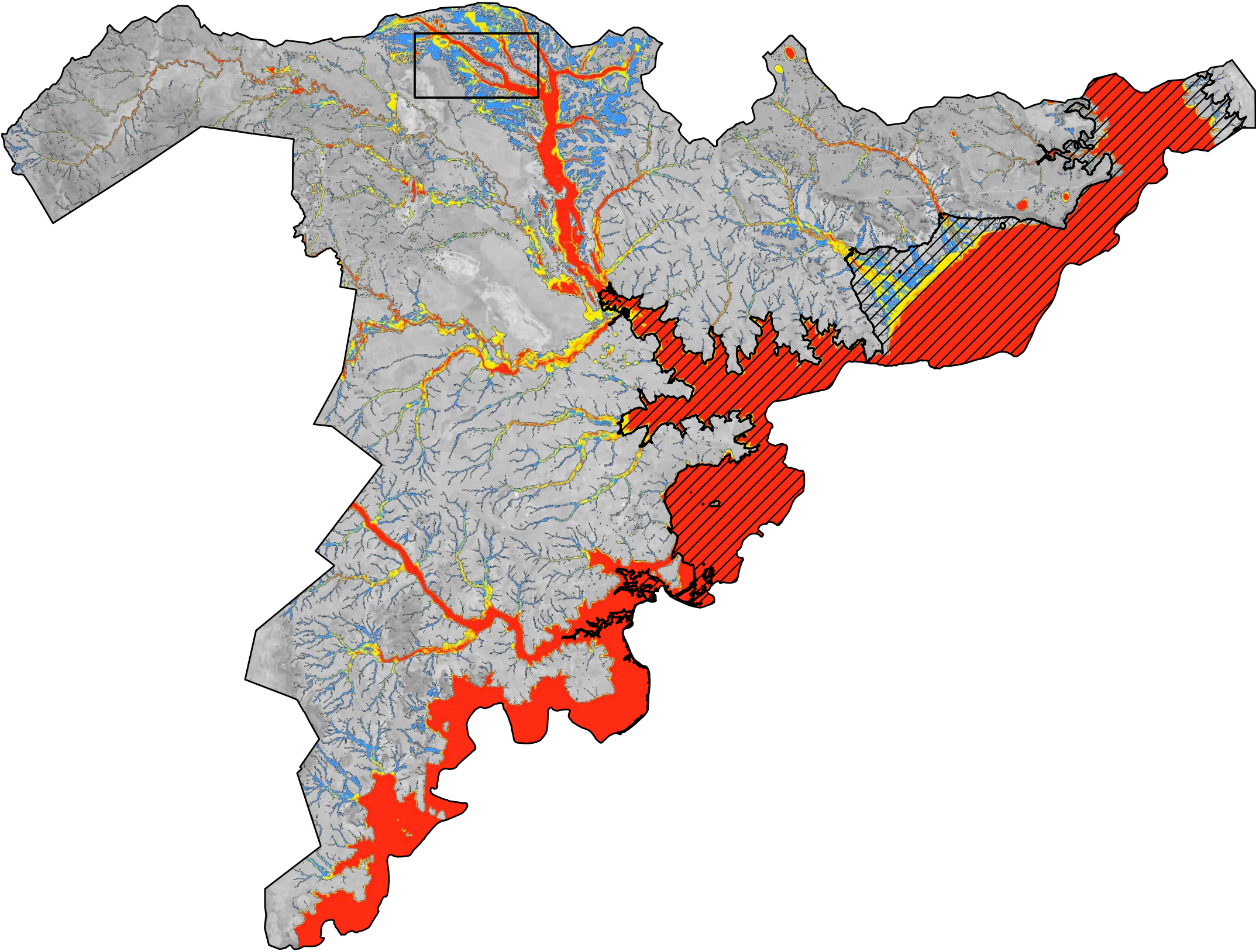
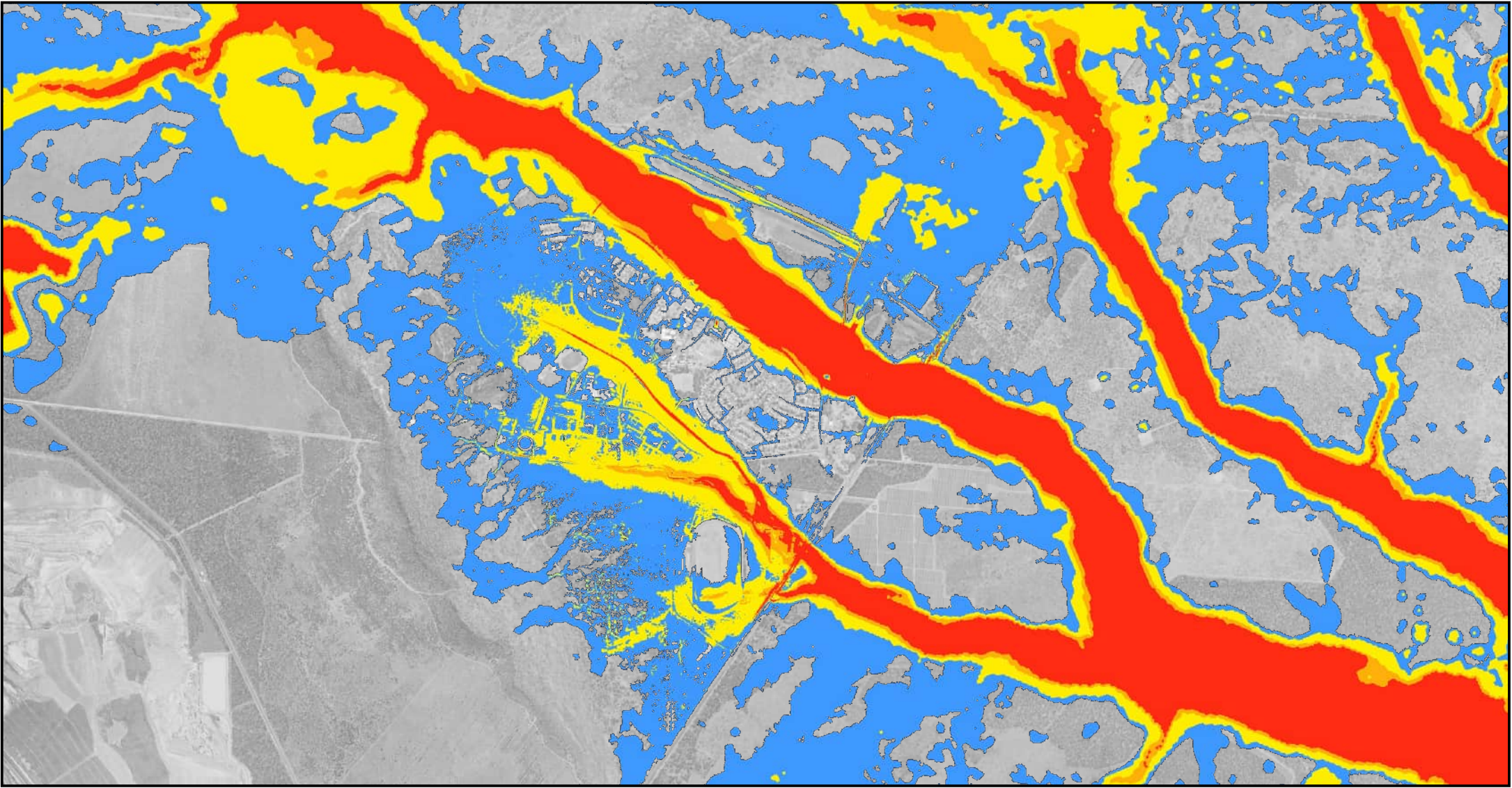


Figure:	D-43	Rev:	0
			



LEGEND
Flood Hazards (QRA)

Low

Significant

High

Extreme

Study Area

Uncertainty Extent

Title:

PMF Event (2030) Peak Flood Hazards (QRA)
Upper Mackenzie River (Middlemount)

Scale at A3
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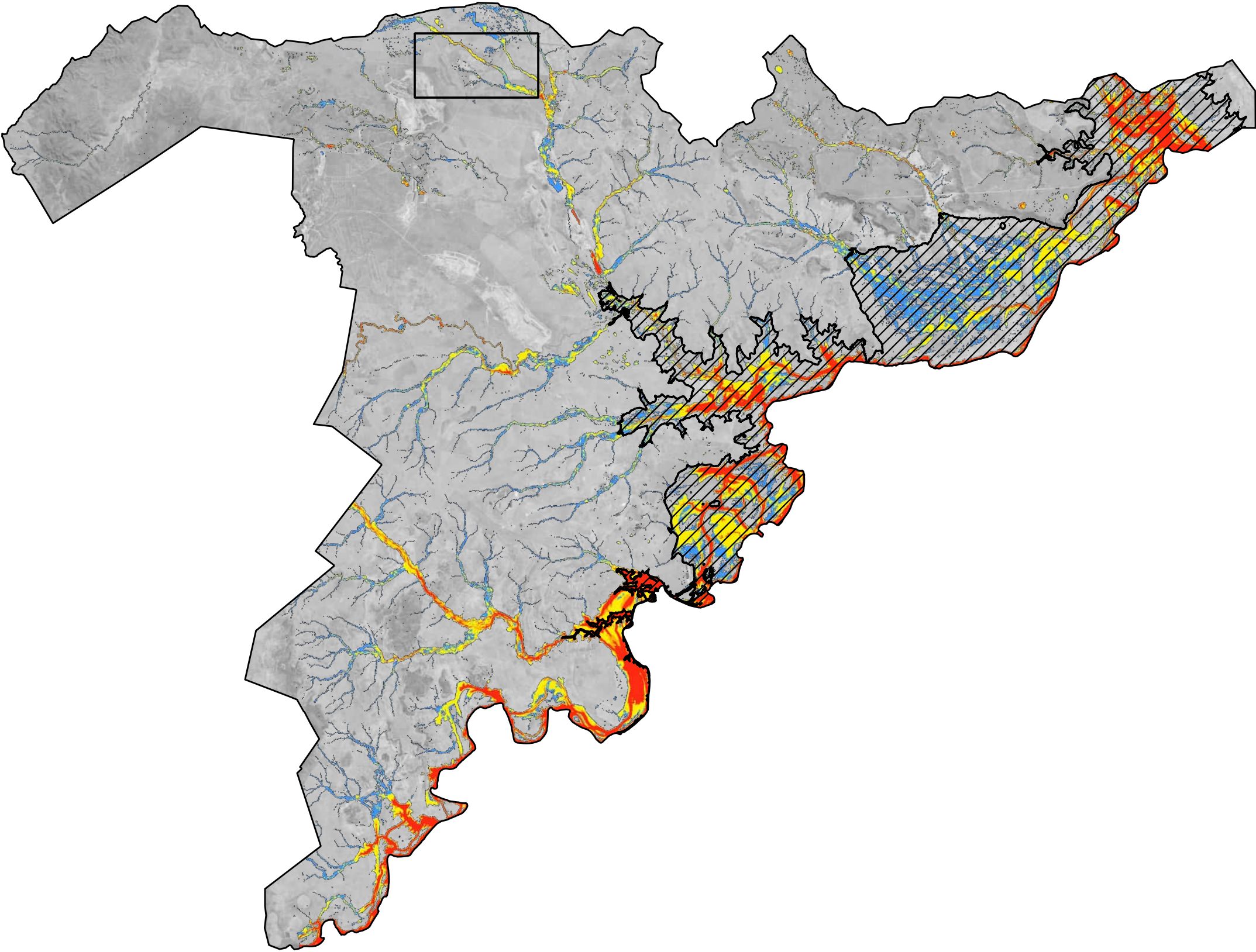
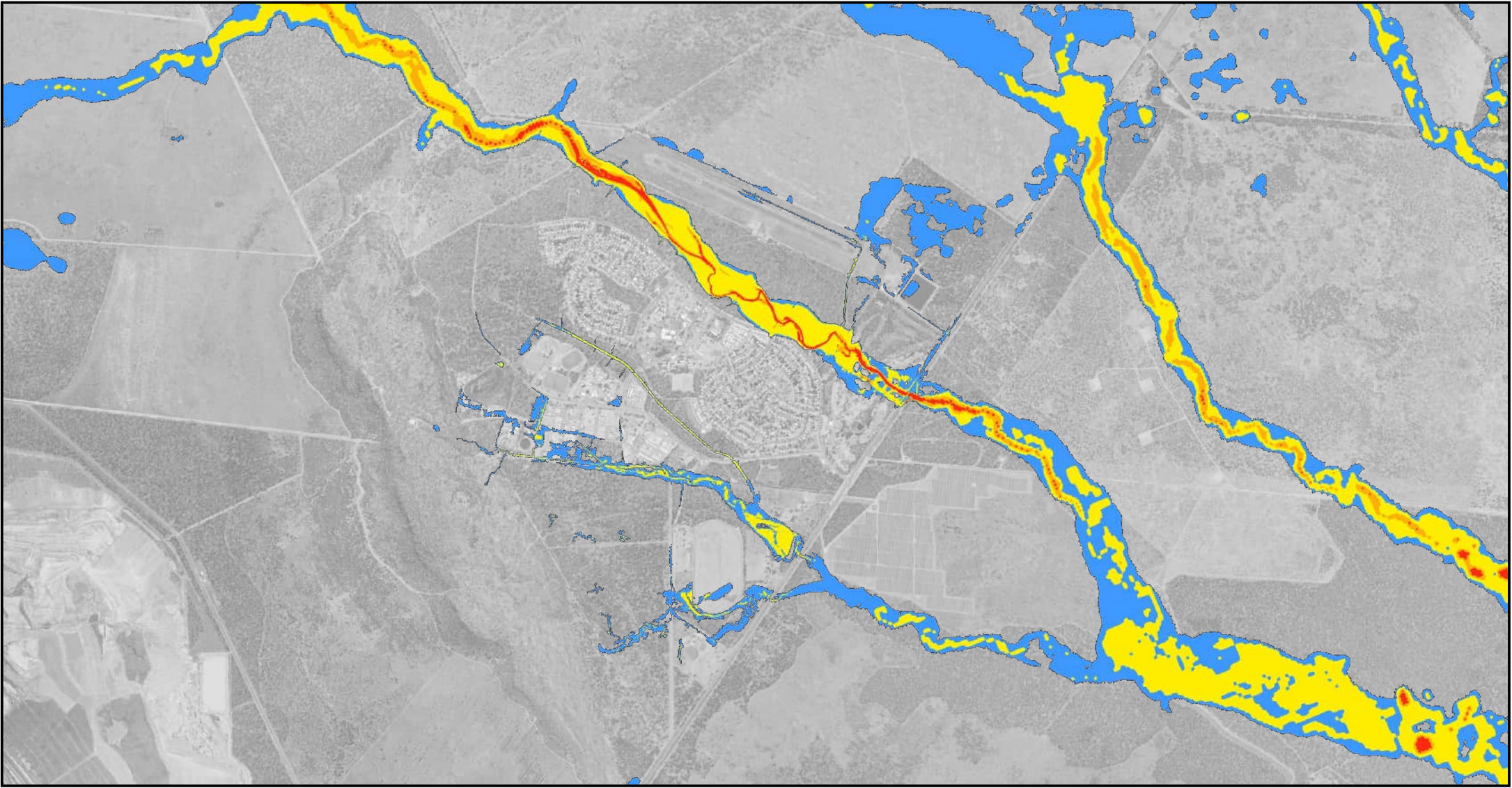
Rev:

03691215 km

1:410,000

D-44

0



LEGEND
Flood Hazards (QRA)

Low

Significant

High

Extreme

Study Area

Uncertainty Extent

Title:

1% AEP (2100) Event Peak Flood Hazards (QRA)
Upper Mackenzie River (Middlemount)

Scale at A3
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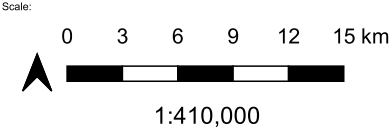


Figure:

D-45

Rev:

0



ZERO^{24/7} HARM

Our Zero Harm culture has been hugely successful throughout KBR and has led to year-over-year improvements in safety. We now emulate this success as it relates to sustainability. Just as with the Zero Harm practice, we outline commitments and responsibilities for every KBR employee to apply to their daily lives. Our sustainability vision is underpinned by KBR's Zero Harm and Courage to Care culture — doing zero harm to the planet and zero harm to all people.

As a company, we believe that zero workplace incidents is an achievable goal. We commit to a Zero Harm policy and approach to safety for our employees and those we work with, including customers, partners, subcontractors, suppliers and visitors. Our commitment to health, safety, security and environment (HSSE) has resulted in unprecedented safety performance throughout the organization and across our global footprint. KBR's journey to Zero Harm is driven by our employees' commitment to safety 24/7. To achieve that goal, we use our internationally recognized transactional HSSE management systems and transformational leadership. KBR's transactional HSSE management systems are ISO 14001 and OSHA 18001 certified.

