IRC Clermont, Moranbah and Nebo Flood Model & Hazard Mapping 2022

Nebo

Isaac Regional Council

24 August 2023

→ **The Power of Commitment**

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The Power of Commitment

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1. Introduction

1.1 Overview

GHD Pty Ltd (GHD) was engaged by Isaac Regional Council (IRC) to update the flood models for the towns/townships of Clermont, Moranbah, and Nebo within the Isaac Regional Council Local Government Area (LGA). The intention of the project is to update the flood models to be in line with the latest Australian Rainfall and Runoff guidelines (2019), including the development of flood hazard mapping. The updated flood models are level 3 flood models for each study area, seen as suitable for urban zones within these points of interest, as defined by the Guide for Flood Studies and Mapping in Queensland (BMT-WBM, 2017). This report focusses on the Nebo study area as part of the overall project.

1.2 Purpose of this report

This study aims to provide IRC with a better understanding of flood behaviour in Nebo. It is envisaged that the outcomes presented in this report may assist Council in:

- Incorporating it's findings into the IRC Planning Scheme and disaster management purposes
- Improving their understanding regarding the flood resilience of residents and infrastructures located in the study areas by assessing locational risk profiles for a range of flood events.

1.3 Scope and limitations

This report: has been prepared by GHD for Isaac Regional Council and may only be used and relied on by Isaac Regional Council for the purpose agreed between GHD and Isaac Regional Council as set out in this report.

GHD otherwise disclaims responsibility to any person other than Isaac Regional Council arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report (refer section 1.5 of this report). GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared the RAFTS and TUFLOW model ("Model") for, and for the benefit and sole use of Isaac Regional Council to support the design and documentation of the works and must not be used for any other purpose or by any other person.

The model is a representation only and does not reflect reality in every aspect. The model contains simplified assumptions to derive a modelled outcome. The actual variables will inevitably be different to those used to prepare the model. Accordingly, the outputs of the model cannot be relied upon to represent actual conditions without due consideration of the inherent and expected inaccuracies. Such considerations are beyond GHD's scope.

GHD has prepared this report based on information provided by Isaac Regional Council and others who provided information to GHD (including Government authorities), which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

1.4 Clarifications

The following outlines clarifications associated with this report:

– The corresponding Annual Exceedance Probability (AEP) notation for the following events is as follows:

- 1 in 2 AEP, or 50% AEP
- 1 in 5 AEP, or 20% AEP
- 1 in 20 AEP, or 5% AEP
- 1 in 50 AEP, or 2% AEP
- 1 in 100 AEP, or 1% AEP
- 1 in 500 AEP, or 0.2% AEP
- PMF

1.5 Assumptions

The following identifies further assumptions made throughout the hydrological and hydraulic assessment:

– All data supplied is correct and/or suitable to IRC for use in this assessment (i.e., no data has been verified at this stage of the study, we recommend verification of data upon receipt of community feedback).

– Fraction impervious and Manning's 'n' values were selected based on a combination of the existing land use through review of aerial photography, zoning data and cadastral data.

  – Lag times were derived by applying velocities from the hydraulic model over each catchment's longest watercourse (or streamflow path where appropriate).

  – The accuracy of the modelling was based on the quality of LiDAR data provided. A key limitation of LiDAR is that in areas of dense vegetation the LiDAR may not accurately pick up significant flow paths.

  – It is required LiDAR may not account for any new developments since the LiDAR data was captured. Until then, all data provided is assumed accurate and up to date, with any development/changes since the data capture excluded from the modelling (i.e., the modelling was undertaken using the LiDAR data supplied as nothing newer was available).

  – The model assumed fully functioning stormwater infrastructure; however, IRC acknowledge that an incomplete dataset was provided. As such, assumptions were made regarding invert levels, cover, and grades of the 1D network. Should these assumptions not be sufficient to cover IRC's risk profile, it is recommended that a detailed survey of all the stormwater infrastructure is undertaken and remodelled in the hydraulic simulations.

  – The Nebo Creek flooding drove selection of the critical duration events informing this study. For any infrastructure development that could plausibly be impacted by flooding from the Nebo Creek tributaries and drainage lines, GHD assumes that Council will request bespoke flood studies for the subject site to define the flood risk at a local level.

2. Site information

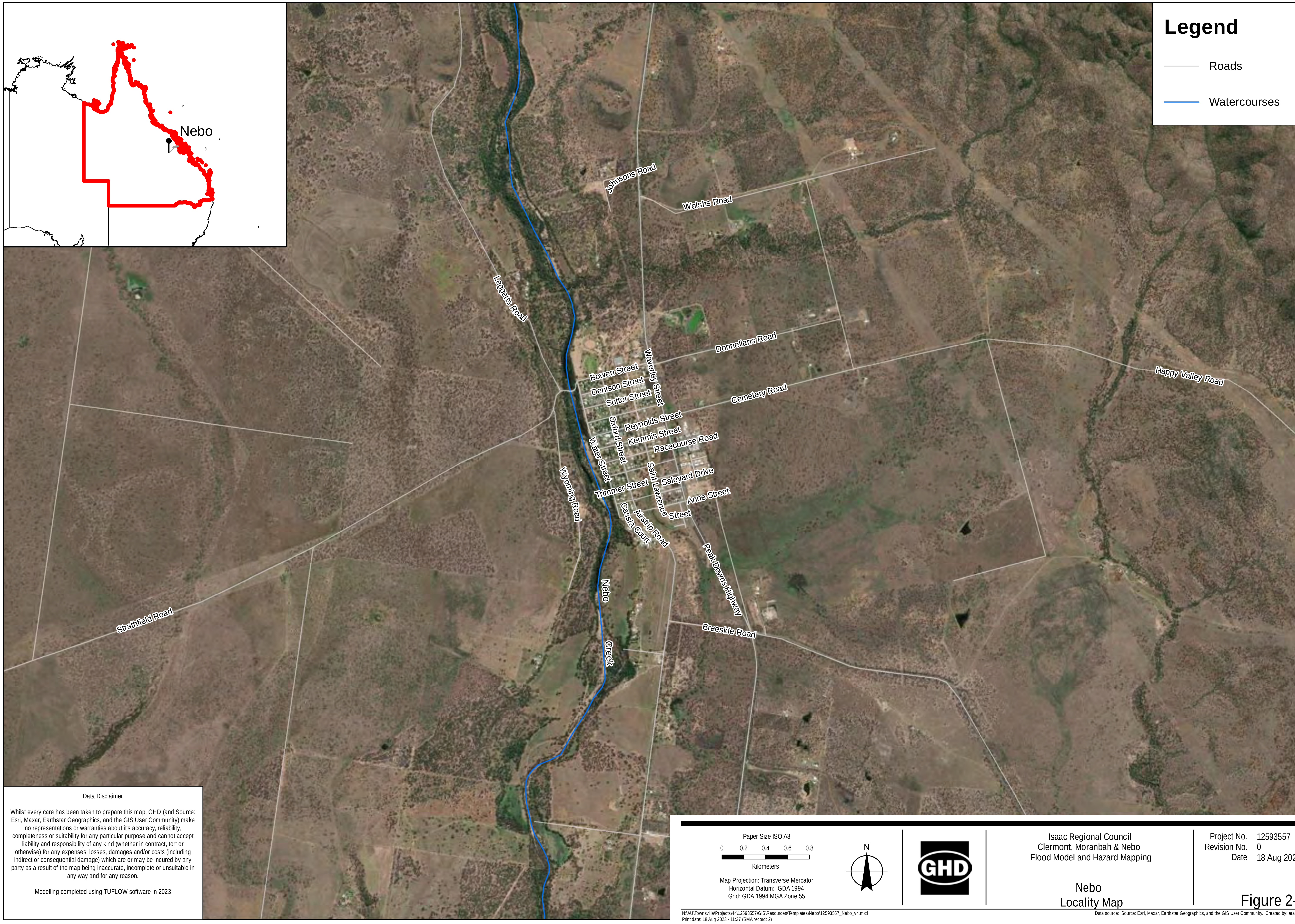
2.1 The study area

This study is focussed on Nebo including Nebo Creek that flows north to south on the western side of the township and forms part of the Fitzroy Basin. The areas consist of the Nebo township that includes urban areas with minimal stormwater collection systems, the upstream catchment of Nebo Creek, and the surrounding areas of the township. The Nebo township is bounded by Peak Downs Highway at the east, and Wyoming and Leggetts Roads at the west. This study has been developed considering the current township flood study and other previous studies. Level 3 hazard mapping has been produced for this study. The study area is presented in Figure 2.1.

2.2 Review of catchments

Upon initial review of the study catchments and major flow paths, it was observed that the study area predominantly includes rural and pastoral land along with state forest forming different land use. Within the study area, the zonings including industrial, community facilities, township, open space and recreation and special purpose accompany residential lots. This has been assessed as per the Isaac Regional Planning Scheme 2021 (Zoning) ZM 1.7 mapping, see Figure 2.3 current development and planning scheme only and any future development has not been considered.

The Nebo Creek catchment extends roughly 345 km^2 upstream of the township and generally flows north to south past Nebo. Beyond the study areas, Nebo Creek intersects with Denison Creek roughly 25 kilometres downstream of Nebo (past the Peak Downs Highway crossing of Nebo Creek). The upper reaches of the catchment consists of forest and mountain range, with water collecting in the valley below, reaching a flatter plain just upstream of the township of Nebo. A catchment map has been presented in Figure 2.2.



Data Disclaimer

Whilst every care has been taken to prepare this map, GHD (and Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community) make no representations or warranties about it's accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any kind (whether in contract, tort or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damage) which are or may be incured by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.

Modelling completed using TUFLOW software in 2023

Paper Size ISO A3

0 0.2 0.4 0.6 0.8

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping

Nebo
Locality Map

Project No. 12593557
Revision No. 0
Date 18 Aug 2023

Figure 2-1

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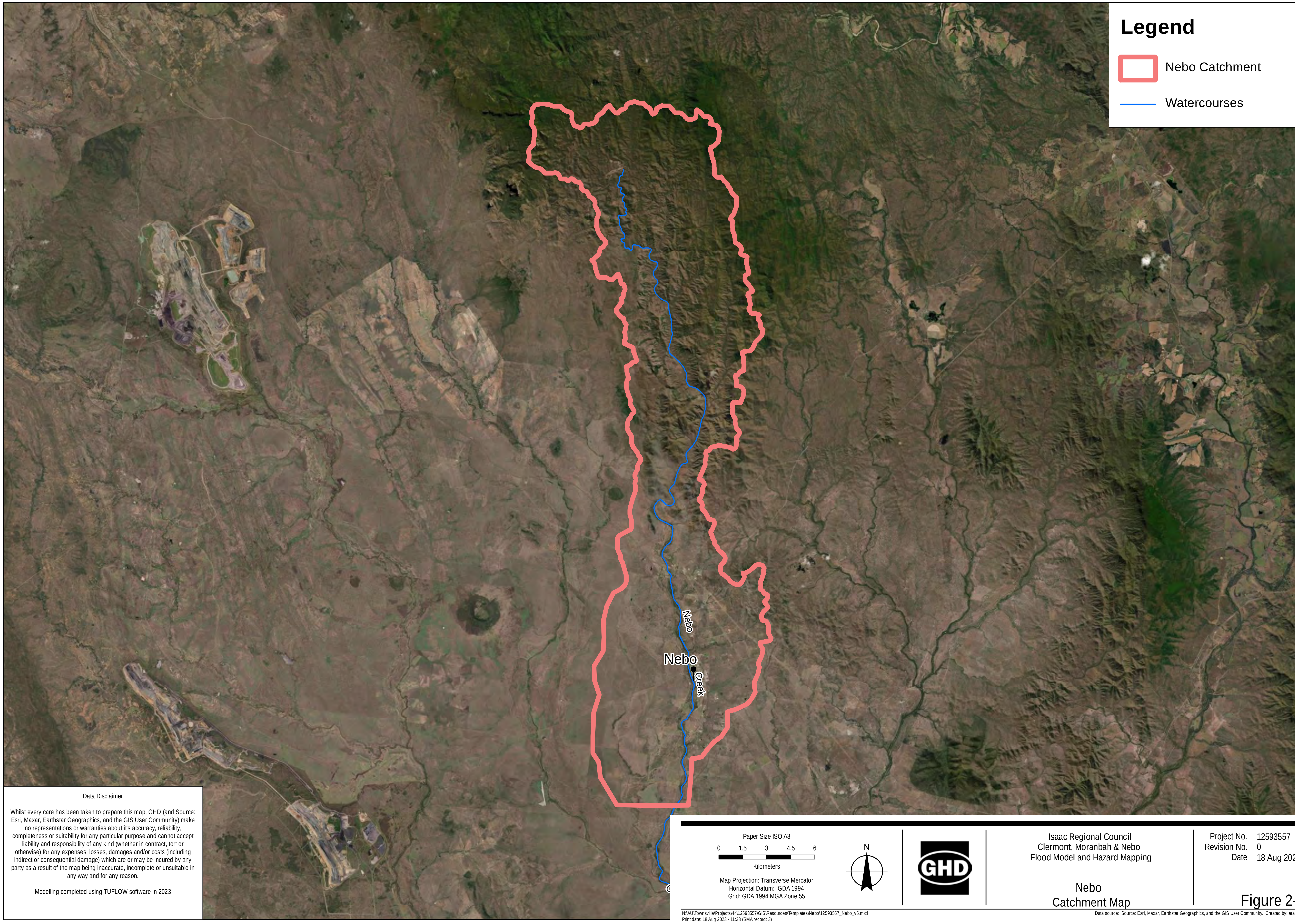

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Modelling completed using TUFLOW software in 2023

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping

Nebo
Catchment Map

Project No. 12593557
Revision No. 0
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Figure 2-2

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Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: aramos2

2.3 Land use assessment

A review of the latest IRC Planning Scheme 2021 documentation also produced the IRC nominated land used zone, which are proposed to form the basis of land use allocations for the hydraulic modelling. The land use zones for the study are depicted in Figure 2.3.

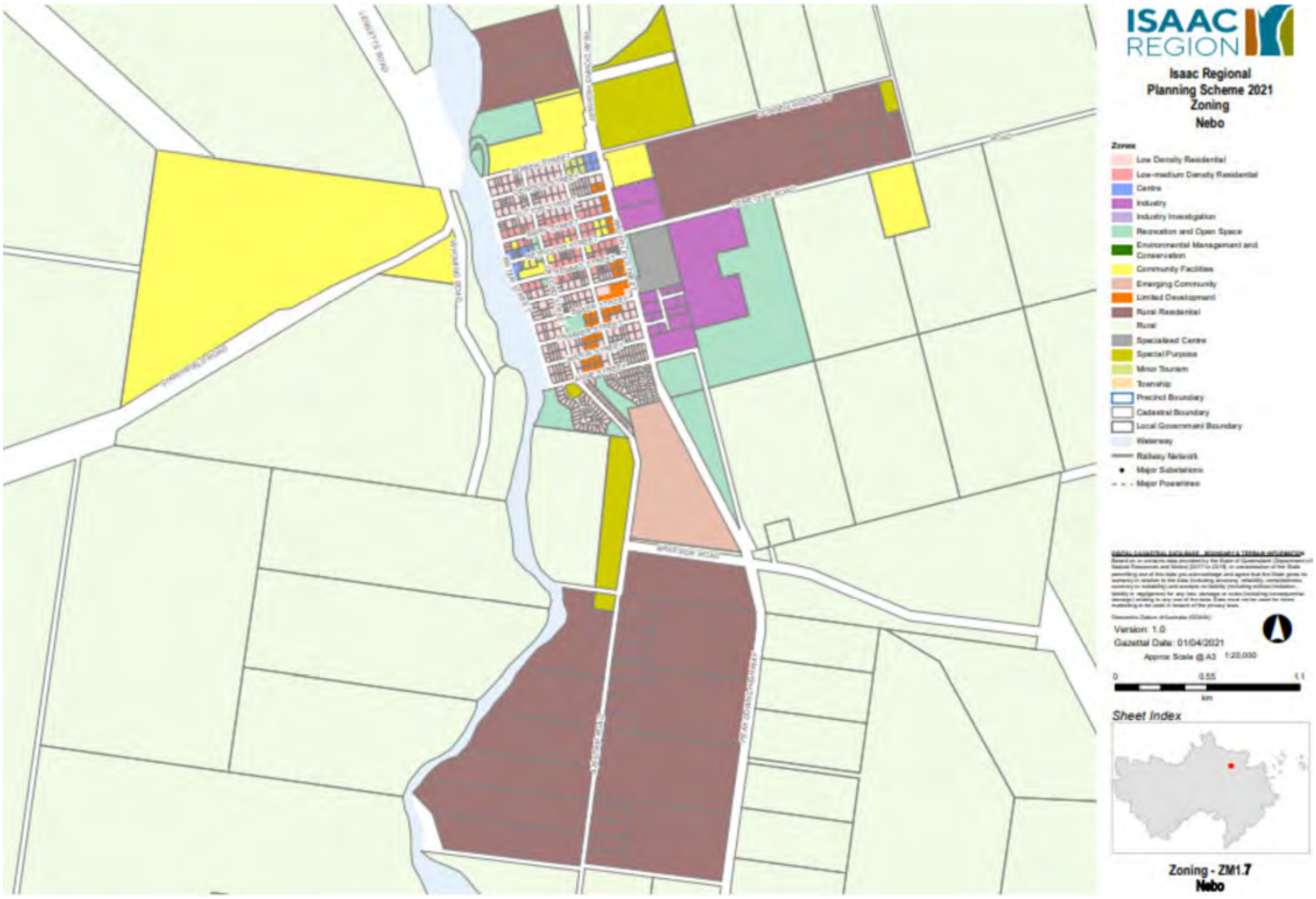


Figure 2.3 Isaac Regional Planning Scheme Zoning – Nebo (IRC,2021)

2.4 Available information

2.4.1 Previous studies

IRC provided GHD with the following existing studies for the points of interest:

1. Nebo Flood and Drainage Assessment (VDM, 2012)

This study generated a flood model using a runoff routing modelling program XP2D for the township of Nebo. It modelled 0.2%, 1%, and 2% AEP design flood event was incorporated to analyse flood proneness and improvements for the Nebo Road network and infrastructure. A set of hazard mapping for 0.2%, 1%, and 2% AEP AEP was also provided.

Further to these previous studies, there also exists the Isaac River Flood Study for the wider basin. This study incorporates the three study areas/towns and was completed using a TUFLOW model. The study also produced hazard mapping suitable for disaster planning and amendment to the IRC current Planning Scheme.

2. Flood Hazard Mapping – Nebo (Bundle 2) (Water Technology, 2014)

This study undertook flood modelling including TUFLOW simulations for the Nebo area. The project involved using stream gauged data to derive inflows into the TUFLOW model for the 2%, 1% and 0.2% AEP events for the Nebo

Creek catchment by scaling and flows from recorded flood events. Flood extent and hazard mapping was delivered as part of the reporting.

3. Isaac River Flood Study (July 2021)

This study generated a TUFLOW flood model for the Isaac River catchment that covers the Nebo Creek catchment, containing all the points of interest in question. It modelled scenarios for the 5%, 2%, 1%, 0.5%, 0.1% AEP and Probable Maximum Flood (PMF) events. It was calibrated with the 2017 Cyclone Debbie flood event. The study also produced hazard mapping suitable for disaster planning and amendment to the IRC current Planning Scheme.

2.4.2 Design Rainfall Data

Australian Rainfall and Runoff 2019 (ARR 2019) design rainfall Intensity Frequency Duration (IFD) data for the catchment was obtained from the Bureau of Meteorology (BoM). The IFD data is attached in Appendix A for frequent, infrequent and rare design rainfalls, for the catchment centroid for reference. Rainfall data for the Probable Maximum Flood (PMF) event was calculated using the Generalised Short Duration Method (GSDM) and the Guidebook to the Estimation of Probable Maximum Precipitation in Australia: Generalised Tropical Storm Method Revised (GTSMR).

The RAFTS model approach to apply rainfall directly for the different AEP events was as follows:

– For the 50% AEP to the 0.2% AEP, the gridded rainfall cell nearest to the sub-catchment centroid was applied to the sub-catchment
– For the PMF event, the rainfall estimates derived from the guideline have been adopted for all sub-catchments as these are already spatially distributed by following the guideline procedures.

2.4.3 Topographic data

Specified in the proposal, although all the previous studies had topographic data attached in their respective files, GHD completed an assessment of the validity of this detailed LiDAR topographic data against known topographic features to comment on any limitations (if any) that are present in the data provided. Detailed LiDAR topographic data was sourced from the ELVIS spatial data portal with a grid cell size of one metre for the Nebo township and one second Shuttle Radar Topographic Mission (SRTM) Digital Elevation Model (DEM) for the upper reaches of the catchment where the detailed one metre data was not available.

3. Hydrologic analysis

This section summarises the hydrologic investigations undertaken on the catchment. The scope of work included:

– Data collection and review of available hydrological information including the validity of the topographic data for this assessment
– Hydrologic model setup (Geographical Information Systems (GIS) and XP-RAFTS)
– Estimation of design event flow rates , hydrographs and validation of flows.

The hydrologic assessment is based on a delineated regional catchment for Nebo Creek that has been delineated to roughly 25 kilometres downstream of the town of Nebo.

3.1 Data collection

The following data was used to undertake this assessment:

– LiDAR derived elevation data – obtained from ELVIS Spatial (including detailed 1 m LiDAR as well as 1 second SRTM LiDAR data)
– IFD Rainfall Data – obtained from Bureau of Meteorology (BoM), ARR (2019) Data System
– Other design inputs (e.g., temporal patterns, losses, pre-bursts) – ARR (2019) Data Hub
– Council supplied information including:
  - Nebo Flood Hazard Mapping report (2014) prepared by Water Technology
  - Nebo Flooding and Drainage Assessment (November 2012) prepared by VDM
  - Isaac River Flood Study (July 2021) prepared by KBR.

3.2 Hydrologic model setup

3.2.1 Model selection

There are several methods that can be used to undertake hydrologic analysis, with Figure 3.1 identifying the common methods for hydrologic analysis and their level of accuracy.

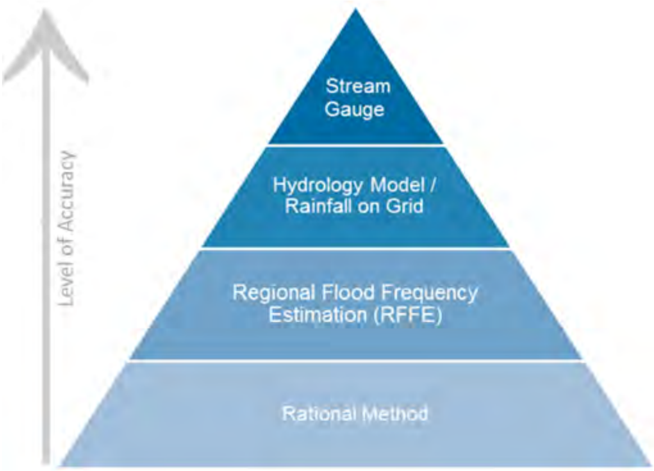


Figure 3.1 Methods of hydrologic analysis

Stream gauges are the preferred method of choice as they collect real time data from stream flow events. Hydrologic models can be calibrated with the stream gauge data to represent the site's historic rainfall events if detailed enough data from recorded rainfall and stream events exist. From the Queensland Government Water Monitoring Portal there exists stream gauge data for Nebo Creek (gauge number 130407A – Nebo Creek at Nebo) within the study area. This gauging station opened in 1966 and ceased operating in 2019 (with a 20 year break in operation between 1987 and 2007), roughly 35 years of recordings in total. The stream gauge recordings from this gauge were attempted to be used for validation of the hydrologic model (RAFTS) used for this study, though the stream gauge recordings obtained from the gauge were considered unreliable. Further discussion on the stream gauging and validation against the RAFTS model is included in Section 4.

Based on hierarchy presented in Figure 3.1 and the unreliability of the stream gauge recordings, the XP-RAFTS (RAFTS) hydrologic model (rainfall-runoff model) was utilised as the preferred option for deriving rainfall-runoff hydrographs from the catchment. The RAFTS hydrologic modelling software is based on the Regional Stormwater Drainage Model (RSWM) developed by the Snowy Mountains Engineering Corporation (SMEC) and is an industry standard rainfall-runoff routing analysis package. It is capable of modelling changes due to development for both rural and urban sub-catchments and is an accepted model used to quantify flood flows from catchments as specified in the ARR (2019) guidelines.

Given the unreliability of the stream gauge recording, validation of the RAFTS model was sought against alternate methods. For this, the Regional Flood Frequency Estimation (RFFE) technique from ARR was sought as it is the next preferred method as shown in Figure 3.1. As such this method is often used as a validation to the adopted hydrologic method, providing an order of magnitude check.

Summarising the approach, RAFTS was used in this study to estimate the rainfall-runoff hydrographs from individual sub-catchments based on rainfall intensities, temporal patterns, catchment losses and the definition of parameters describing the sub-catchment characteristics. These parameters include the sub-catchment area, slope, roughness, and fraction of impervious area. Sub-catchment outflow hydrographs are routed downstream through the model via links (either lag links or routing links) that connect these sub-catchments. Once the RAFTS model was configured, Storm Injector was used to simulate the model within a storm-management framework that allows for the easy application and assessment of the multitude of simulated design flood results from RAFTS. The results from the RAFTS model simulations were them validated against the RFFE peak flow estimates for different AEPs. Further to this flow estimates from previous studies for the catchment were compared to the results of this study as an additional comparison to further gain confidence in the results from this study.

3.2.2 Model development

For the catchment area, the development of the RAFTS model entailed:

– Sub-dividing the catchment into a series of sub-areas to suit the catchment topography and other key features, such as the location of culverts and subterranean drainage networks where applicable
– Determination of model parameters including design rainfall and initial/continuing loss rates based on available guidelines
– Hydrologic model simulations using the Initial Loss-Continuing Loss approach based on the Ensemble Method, as outlined in ARR (2019)
– Review and validation of model results.

3.2.3 Model parameters

The RAFTS model required the inputs described in the following sub-sections.

3.2.3.1 Catchment delineation

Establishment of the respective hydrological model required delineations of the sub-catchments, which were based on:

– Identified flow paths
– Land use types / catchment characteristics
– Key points of interest (as identified in previous reports, ie. Nebo township).

Delineation was undertaken in the GIS software (QGIS) using the DEM as described in Section 2.4.3 in accordance with the methods detailed in QUDM. Characteristics of each sub-catchment were then determined for input to the RAFTS model.

For Nebo, the total catchment area is approximately 345 km^2, with 22 sub-catchments being delineated, as seen in Figure 3.2. The characteristics adopted for each sub-catchment are provided in Appendix B.

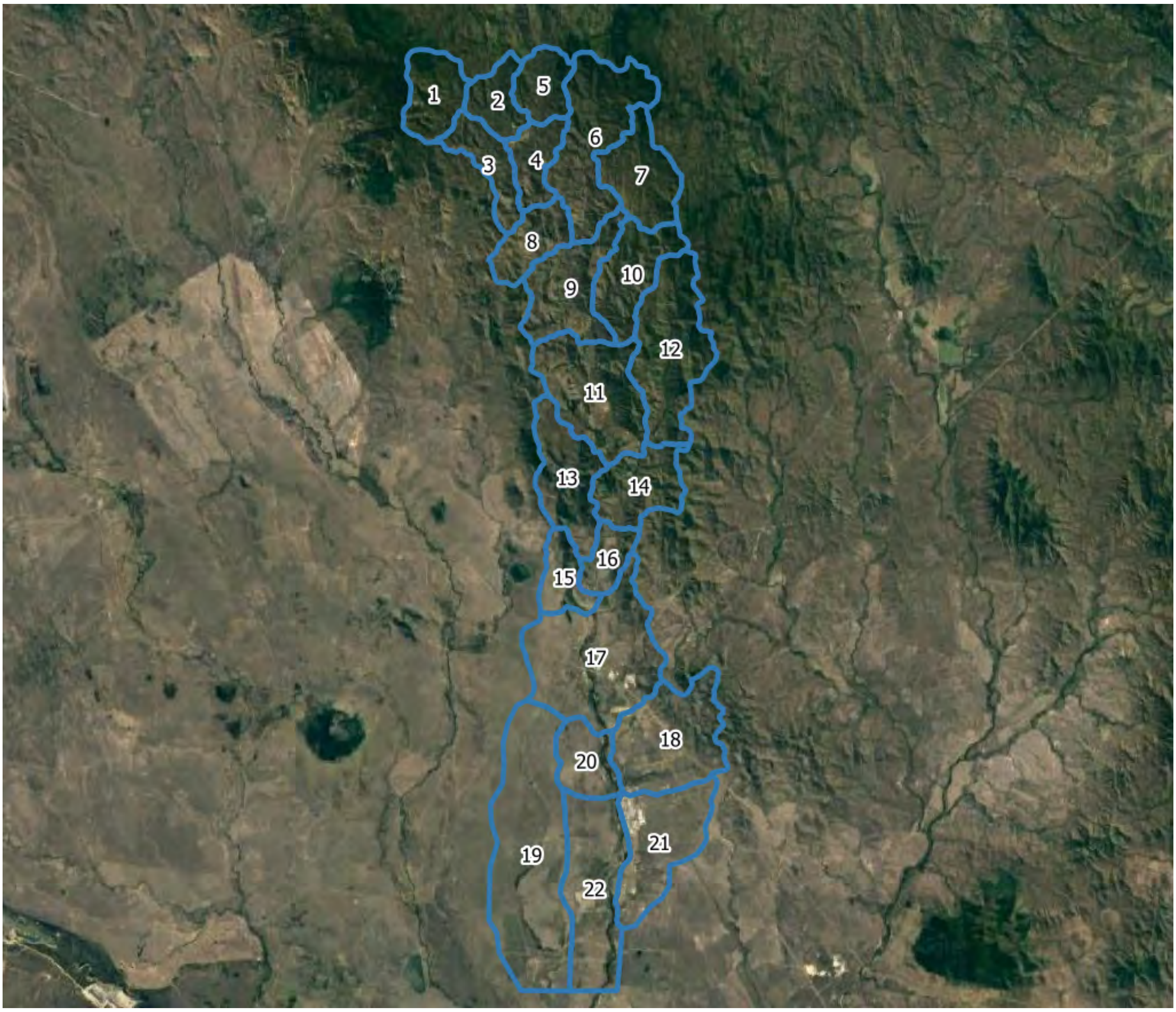


Figure** 3.2* ***Nebo sub-catchment delineation

3.2.3.2 Catchment slope

Equal Area Slope (EAS) utilises the elevation profile of the Longest Flow Path (LFP) to determine the slope where half the points fall above and below the slope line. LFP is the distance from the furthest point of a catchment to the catchment's outlet. The length and respective EAS for each sub-catchment were determined by using the profile tool in the QGIS software to define the terrain profile along the longest flow-path line, the profile was then analysed to calculate the EAS. These results are provided for all sub-catchments in Appendix B.

3.2.3.3 Land use/roughness

PERN 'n' roughness (which is a surface roughness factor applied to the RAFTS model) was determined for each sub-catchment based on an assessment of the existing land use as determined through a review of aerial photography, zoning data and cadastral data. Values adopted for different ground types are provided in Table 3-1, which vary within these classes based on density of the vegetation. For each sub catchment, the pervious Manning's n is provided in Appendix B.

Table 3-1 Adopted hydrologic PERN 'n' roughness

Adopted PERN 'n' Roughness	Ground Type
0.012 – 0.015	Impervious (i.e., roads, buildings etc.)
0.035 – 0.050	Combination of low density to medium density vegetation
0.050 – 0.070	Combination medium density to high density vegetation
0.080 – 0.120	Forested/high density vegetation

3.2.3.4 Rainfall losses

Initial losses for all pervious ground types were adopted based on the ARR Data Hub information from ARR 2019 guidelines. Continuing losses were adopted based on reconciling the RAFTS peak flows against the RFFE derived peak flows for various AEP's. The values from the ARR 2019 guidelines were adopted initially and adjusted until a reasonable fit against the RFFE peak flows was achieved which including varying the continuing loss values for different AEP's. A zero value for initial loss and one for continuing loss was adopted for the Probable Maximum Precipitation (PMP) event per ARR 2019 recommendations, interpolation of the initial and continuing loss values between the 1% AEP and PMP events was completed to derive the loss adopted for the 0.2% AEP event. Table 3-2 summarises the adopted storm loss parameters for a 24-hour storm duration event in Nebo for the various AEP's simulated.

Table 3-2 Nebo loss parameters (24-hour event)

Ground Type	Rainfall Event	Initial Loss (mm)	Median Pre-burst Depth (mm)	Net Initial Losses (mm)	Continuing Loss (mm/hr)
Impervious	All	1.00	-*	0.1	0
Pervious	50 % AEP	38.0	0	34.0	1.5
	20 % AEP	38.0	7.6	26.4	1.5
	5 % AEP	38.0	17.5	16.5	1.5
	2 % AEP	38.0	31.5	2.5	1.5
	1 % AEP	38.0	41.9	0	1.5
	0.2% AEP	38.0	-*	0	1.5
	PMP	0	-*	0	1.0

* - ARR 2019 data hub does not specify a median pre-burst rainfall depth for this event, therefore values for net initial loss have been derived based on ARR 2019 guidance and applied directly.

3.2.3.5 Design storm

The design storm events that were assessed in this study included the 50 %, 20 %, 5 %, 2 %, 1 %, 0.2 % AEP, and the Probable Maximum Flood (PMF) events. To generate design rainfall for various durations, the RAFTS model simulated through Storm Injector used either extracted ARR (2019) Data Hub rainfall and temporal pattern data, or manually input rainfall and temporal pattern data. Rainfall depths were applied based on the datahub rainfall depth value nearest to the sub-catchment centroid. To determine peak discharge rates, design storm events were assessed for a range of design storm durations and methods, as listed in Table 3-3.

Table 3-3 Design storm durations

Rainfall Event	Duration (min)	Source of Rainfall Data and Temporal Patterns
50 – 0.2 % AEP	45, 60, 90, 120, 180, 270, 360, 540, 720, 1080, 1440, 1800, 2160, 2880	ARR Data Hub for each study area

Rainfall Event	Duration (min)	Source of Rainfall Data and Temporal Patterns
PMP	15, 30, 45, 60, 90, 120, 180, 240, 300, 360, 540, 1080, 1440, 2160, 2880, 4320, 5760, 7200	Generalised Short Duration Method (GSDM) and Generalised Tropical Storm Method Revised (GTSMR)

The design rainfall depths are summarized in Appendix A for the frequent, infrequent and rare events.

3.2.3.6 Probable Maximum Precipitation/Flood

As indicated in Table 3-4, PMP rainfall depths were calculated based on GTSMR method by BoM. This design rainfall depth and the temporal patterns were manually input into RAFTS to simulate the PMF hydrograph.

The PMP rainfall depths and parameters applied to determine these are detailed in Table 3-4.

Table 3-4 PMP parameters

Parameter	Duration (min)								
	540	720	1080	1440	2160	2880	4320	5760	7200
Decay Amplitude Factor, DAF	1.0								
Topographical Adjustment Factor, TAF	1.39								
Moisture Adjustment Factor, MAF	0.81								
Initial Depth Rough, Dr	1100	1130	1210	1290	1558	1808	2252	2525	2657
PMP (mm)	1240	1280	1370	1450	1750	2030	2530	2830	2980

Note that PMF uses a different set of temporal patterns to that used in smaller AEP events. For PMF simulations 11 temporal patterns have been considered in order to assess the PMF. Ten temporal patterns from the historical and the Average Variability Method (AVM) temporal pattern as defined in the GTSMR guideline were used to form the set of 11 temporal patterns.

3.2.3.7 Areal reduction factors

Areal reduction factors for the events up to the very-rare rainfall event (0.2% AEP) were applied based on the ARR 2019 areal reduction factor parameters. The coefficients informing these factors are summarised in Table 3-5.

Table 3-5 Areal reduction factor coefficients

Parameter	Value
Zone	Semi-arid Inland Queensland
A	0.159
B	0.283
C	0.250
D	0.308
E	7.3E-07
F	1.000
G	0.039
H	0.000
I	0.000

For the PMP rainfall depths, no areal reduction factors have been applied based on the ARR 2019 recommendations in Book 8 Chapter 3 Section 3.1. These rainfall depths for the PMP event are shown in Figure 3.3.

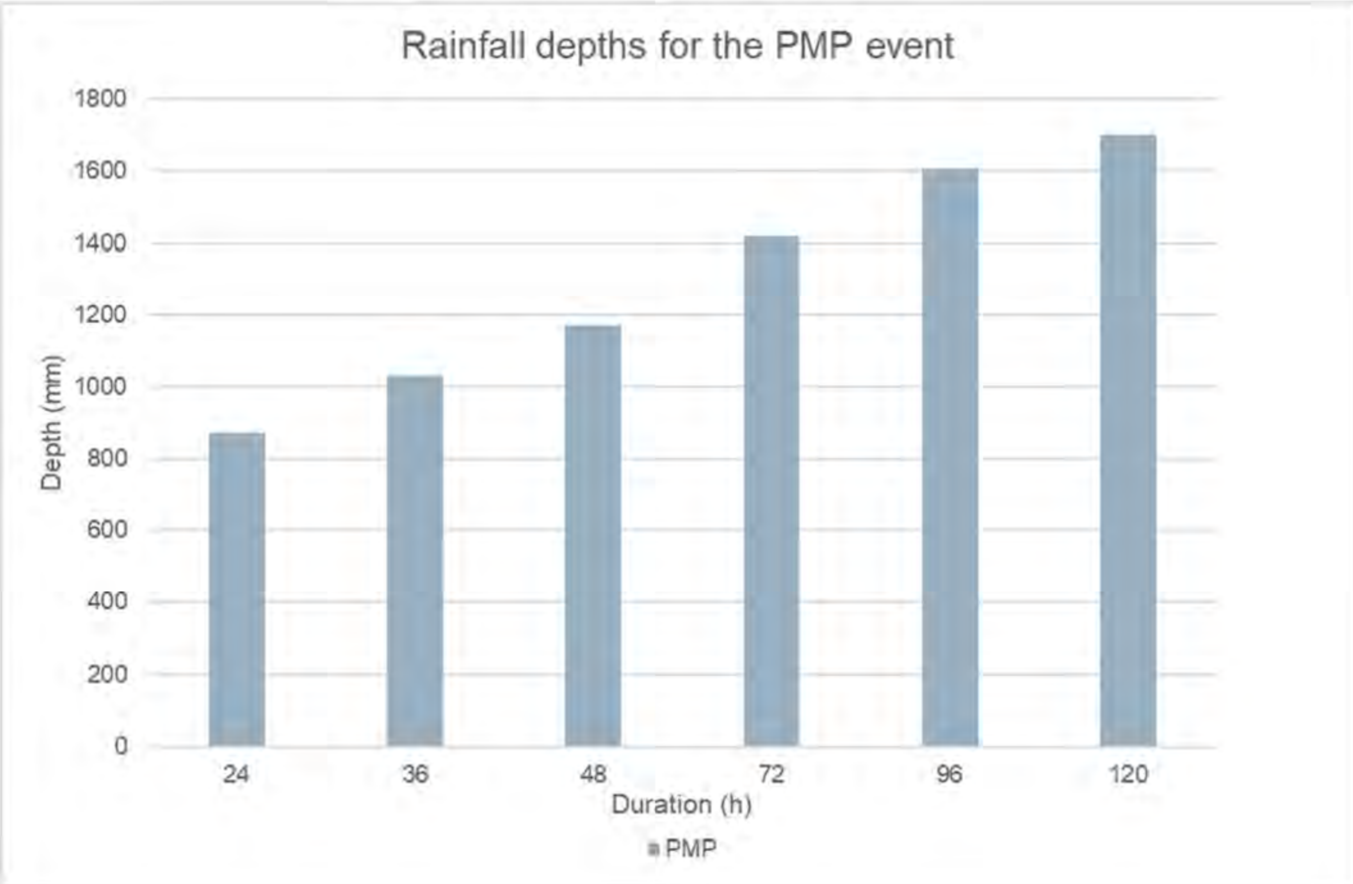


Figure 3.3 *Rare rainfall interpolation*

3.2.3.8 Temporal Patterns

One of the significant differences between the 1987 and 2019 iterations of the ARR guidelines is the change to temporal pattern analyses. ARR 1987 prescribed three temporal patterns: one for event up to an Average Recurrence Interval (ARI) of 30 years, one for all events less frequent than the 30-year ARI and a final temporal pattern for the Probable Maximum Precipitation (PMP) event. In comparison, ARR 2019 applies ten temporal patterns for each duration for each AEP, resulting in a significantly more robust analysis. As this study was conducted using the 2019 guidelines, the ensemble temporal patterns from the ARR datahub for all AEPs less than the PMF have been applied. As the catchment area to the downstream end of the study area is larger 75 km^2, areal temporal patterns have been applied, the 500 km^2 designated areal temporal pattern set have been adopted. The study area exists close to the region boundary between the East Coast North and the Wet Tropics temporal regions and as recommended by ARR 2019 Book 2 Chapter 5 Section 5.9.8, temporal patterns from both temporal regions have been applied. The runoff resulting in the most severe conditions of the two temporal regions is the East Coast North which has been adopted as the temporal region for this study.

3.2.3.9 Climate change

The parameter adjusted to account for climate change impacts in this study have been limited to the rainfall intensity only. Climate change scenarios for 2050 and 2100 time horizons were modelled for the 1% AEP event as the current guidance (noting the guidance regarding PMP is undergoing an update) does not recommend factoring climate change into PMP rainfall depths. The rainfall depth percentage increase for the 2100 time horizon was extrapolated from the time horizons gathered from ARR 2019 data hub data and plotted to derive a line of best fit, the line of best fit was used to undertake the extrapolation. The climate change scenarios considered an increase in the design rainfall as specified in Table 3-6, these consider the Representative Concentration Pathway (RCP) 6 climate change scenario.

Table 3-6 Climate change variables

Year	Rainfall Intensity Increase (%)
2050	6.2
2100	12.67

3.3 Hydrologic model results

Due to the ARR (2019) ensemble method of determining the duration and critical temporal pattern combination from a range of potentially critical storm combinations for each AEP, a wide range of outcomes were possible. An initial assessment of the results indicated that for the PMF event, the 24 hours (1440 minutes) event was critical in 95% of the sub-catchments within the study area. Further analysis indicated that 24hrs (1440 minutes), historical temporal pattern 1963APR16-4 storm produced the highest flow of the events simulated at the critical location within the model for this study (the township of Nebo). As such, the 24 hour historical temporal pattern 1963APR16-4 storm was adopted as the critical storm for the PMF event.

The peak discharge results from the RAFTS model simulations at sub-catchment 20 within the model (corresponding closest to the township of Nebo) are presented in Table 3-7.

Table 3-7 Peak discharge results from the RAFTS model

Storm Events	Peak Flow (m^3/s)	Critical Duration (hours) and Temporal Pattern
50% AEP	304.6	24 hour temporal pattern 1094
20% AEP	579.9	18 hour temporal pattern 1003
5% AEP	938.8	12 hour temporal pattern 921
2% AEP	1,181.9	12 hour temporal pattern 921
1% AEP	1,369.4	12 hour temporal pattern 916
1% AEP 2050 Climate Change	1,462.2	12 hour temporal pattern 912
1% AEP 2100 Climate Change	1,561.4	12 hour temporal pattern 912
0.2% AEP	2,030.4	24 hour temporal pattern 1955FEB25-2
PMF	6,613.0	24 hour temporal pattern 1963APR16-4

4. Hydrologic model validation

4.1 Validation background

To quantify the Nebo Creek flows, a Flood Frequency Analysis (FFA) of the stream gauge (130407A – Nebo Creek at Nebo) recordings was intended to be used as a first priority for validation of the hydrologic model flow used in developing flood inflows into the hydraulic model. The FFA technique was undertaken using recorded data from 1966 to 1987 (when the gauge first ceased recording) then 2007 to 2019 when the gauge began to record and ceased recording again. This data was analysed to find annual maximums for the define water year. This resulted in 32 years of stream flow recordings to analyse. It is noted though that the stream flow recording have been documented to show poor quality data codes across the all annual maximums extracted from stream gauge recordings. A conversation with a Queensland Government Department of Regional Development Manufacturing and Water (RDMW) hydrographer revealed that poor quality reading for flow are likely and water levels are potentially estimated for high flood stages (which would most likely correspond with annual maximums). The RFFE tool was used at this point to further investigate the uncertainty at this gauge and the results showed that the Nebo Creek gauge (13407A) was not used in the RFFE analysis, further confirming our understanding about the unreliability of this gauge. This indicates that there is significant uncertainty in the flow recordings for this gauge. Nonetheless, the analysis was completed with the data through the use of the TUFLOW FLIKE software. The results from the analysis were compared to the RAFTS model results and showed large discrepancies (more than double the flow predicted by the FFA results) compared to the RAFTS model results for the 1% AEP. This trend was consistent for other more frequent AEP events. The RAFTS model was reviewed and parameters including:

– Rainfall losses
– PERN ‘n’ roughness
– Catchment linking

These parameters were adjusted to understand the sensitivity of the results for the system to these parameters and attempt to explore whether a better comparison to the FFA results was possible (noting the concerns regarding the quality of the gauged data informing the FFA). The resulting adjustments showed small increases to slightly better the comparison to the FFA results but were still not considered a reasonable fit. As detailed rainfall data (i.e. sub-daily pluviography data) was not available for a sufficient number of gauges within or nearby to the catchment to appropriately quantify rainfall behaviour, calibration to recorded flood events was not possible.

On the basis that the RAFTS model parameters were explored to the extreme that would be considered acceptable based on industry guidelines as well as the questionable quality of the data informing the FFA, the decision was made to forego the calibration and validation of the RAFTS model to the FFA results. Instead, the RFFE technique was reviewed and adopted to complete the validation of flows from the RAFTS model. The RFFE inputs and results are presented in Section 4.2 and 4.3.

4.2 RFFE inputs

The RFFE technique is a regional flood estimation approach that is detailed and recommended for use in the ARR 2019 guideline. The technique relies upon using nearby stream gauge data to the site being analysed and a weighting approach to estimate peak flow runoff at the location of interest. The following inputs into the tool have been used:

– Catchment outlet (-21.6819, 148.6856)
– Catchment centroid (-21.5106, 148.6732)
– Total catchment area of 259.4 km^2

4.3 RFFE results

The results output from the RFFE are presented in Table 4-1.

Table 4-1 RFFE results

Rain Event	RFFE peak flow (m^3/s)	Lower confidence limit (m^3/s)	Upper confidence limit (m^3/s)
50% or 1 in 2 AEP	236.4	161.3	345.6
20% or 1 in 5 AEP	617.2	441.5	880.4
5% or 1 in 20 AEP	1,313.7	908.1	2,251.0
2% or 1 in 50 AEP	1,835.9	1,178.6	3,888.4
1% or 1 in 100 AEP	2,259.0	1,348.9	5,676.8

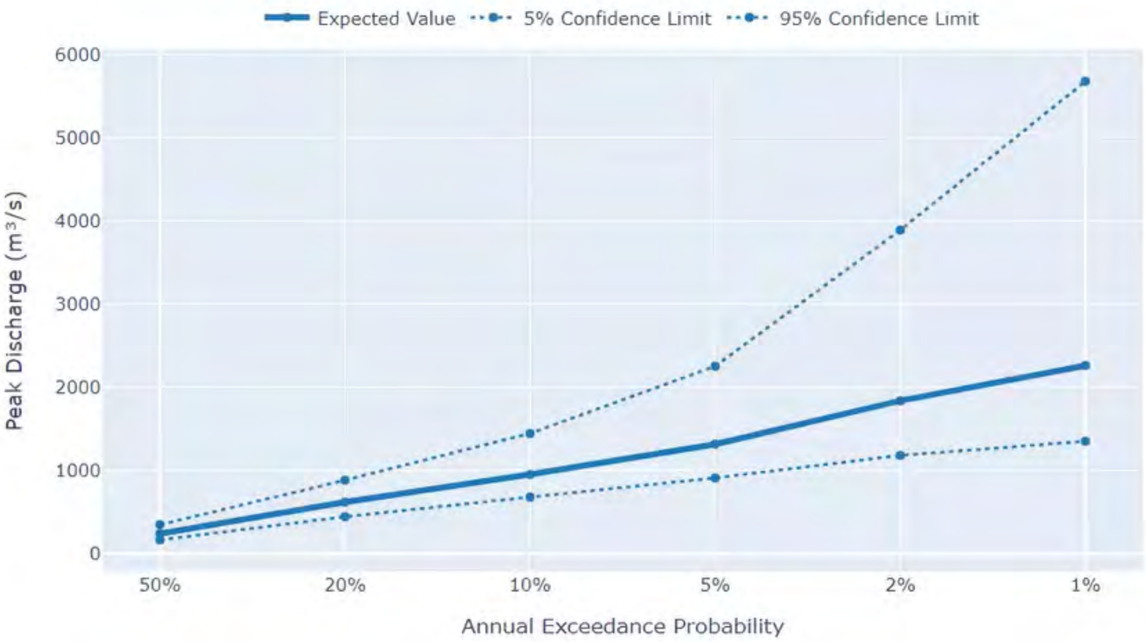


Figure 4.1 RFFE output

The RFFE considered stream gauged results from a range of 15 nearby gauges with varying catchment areas contributing from 22 to 4060 km^2. These gauges range from 14 kilometres away from the Nebo Creek catchment centroid considered for this analysis to 103 kilometres from the Nebo Creek catchment centroid considered for this analysis. For the nearest comparable gauged site by catchment area (125009 with a catchment area of 190 km^2) the 1% AEP peak flow is predicted to be 1,205 m^3/s. This gauge is 61 kilometres from the Nebo Creek centroid considered for this analysis. As the catchment is smaller compared to that considered in the results presented in Table 4-1 it is expected that the peak flow result would be lower. The result does provide an order of magnitude comparison as the two catchment areas are within the same order of magnitude as each other. The locations of nearby gauges and the Nebo site used for the RFFE analysis are shown on Figure 4-2.

Figure 4.2 Locations of nearby gauges

4.3.1 Comparison of results

The results in Table 4-2 show that the hydrologic model results from the RAFTS model are generally fitting between the RFFE output and the 5% confidence limit RFFE output result. This demonstrates the RAFTS results are lower than the expected RFFE result. The model results have also been compared to the Quantile Regression Technique (QRT) to provide further comparison of the hydrologic model results. The QRT is a regression technique that relates catchment area and design rainfall intensity to calculate peak flow estimates. These estimates for a range of AEP's are presented in Table 4-2. They show a reasonable correlation between the RAFTS model and the QRT results, with the RAFTS results generally higher until events less frequent than the 5% AEP. The hydrological model parameters were interrogated and tested to the credible limits. This yielded similar results and didn't improve the comparison to the expected RFFE result. The RFFE results were also interrogated further to understand the location, catchment and rainfall characteristics for the gauges used in the RFFE analysis. These are shown in Figure 4.2 and show that the majority of gauges (11 of the 15) used for the analysis are east of the Great Dividing Range. An investigation of the 1% AEP 24 hour rainfall depths from the design IFD rainfall data across the region was undertaken to understand the rainfall variation between gauge locations. This revealed that in the Pioneer River valley (where the majority of rainfall gauges used in the RFFE analysis are, north of the Nebo Creek catchment), the rainfall depths are around 500-550 mm for the 1% AEP 24 hour event. For the same event at the catchment centroid, this value is 330 mm. This demonstrates a strong rain shadowing effect for the catchment and the use of the gauges in the Pioneer River valley in the RFFE analysis is likely skewing the results higher than what would realistically be expected in the Nebo Creek catchment.

As such the model parameters detailed in this report were adopted for this study and the fit of the hydrologic model peak flows to the RFFE 5% confidence limit results is considered reasonable validation of the RAFTS model along with a reasonable fit to the QRT method. The WT 2014 (Water Technology, 2014) values have been presented to provide another comparison point. The results derived in the previous study (Water Technology, 2014), were based on stream gauge water level results from the Nebo Creek stream gauge (130407A) discussed in Section 4.1 and were identified in that study to 'have a high level of uncertainty'. The previous study accounted for the uncertainty by using a scaling factor applied through judgement to better fit modelled results from a validation event simulation. The approach taken for the previous study to account for the uncertainty has not been adopted for this study because it is too conservative and not representative of the design rainfall (and therefore stream flow) for the area (see Section 4.3.2). On this basis it is expected that results from the previous study will differ to this study.

Table 4-2 Hydrology results comparison (5% confidence limit results in parentheses)

Rain Event	RFFE peak flow (m^3/s)	WT 2014 peak flow (m^3/s)	RAFTS peak flow (m^3/s)	QRT peak flow (m^3/s)
50% or 1 in 2 AEP	236.4 (161)	-	304.6	204
20% or 1 in 5 AEP	617.2 (442)	-	579.9	489
5% or 1 in 20 AEP	1,313.7 (908)	-	938.8	990
2% or 1 in 50 AEP	1,835.9 (1179)	1,700	1,181.9	1,362
1% or 1 in 100 AEP	2,259.0 (1349)	2,100	1,369.4	1,655
0.2% or 1 in 500 AEP	-	3,300	2,030.4	-

To further understand the differences between the RFFE results adopted for the validation and the hydrologic model results (RAFTS) an investigation of the design rainfall depths used in the hydrologic modelling to the rainfall depth derived based on recorded rainfall was completed. The results of this comparison are presented in Section 4.3.2.

4.3.2 Comparison of rainfall depths

This section presents a comparison of rainfall depths from the ARR datahub to recorded daily rainfall from two daily rainfall gauges managed by the Bureau of Meteorology being:

- 033027 (Gargett Post Office), approximately 50 km from the Nebo Creek catchment centroid and near to the catchment headwater, within the Pioneer River valley. The gauge opened in 1914 and records obtained ceased in 2009
- 033054 (Nebo), approximately 14 km from the catchment centroid and within the Nebo Creek catchment. The gauge opened in 1870 and records obtained ceased in 2019.

The recorded rainfall was analysed to extract the Annual Maximum Series (AMS) from the daily rainfall totals for each water year (taken to be from July 1 in a calendar year to June 30 the following calendar year). These AMS values for each gauge are presented in Appendix C.

A rainfall frequency analysis was performed on the AMS daily rainfall data, the Log-Pearson III distribution was used and the results for each gauge are presented in Figure 4.3 and Figure 4.4.

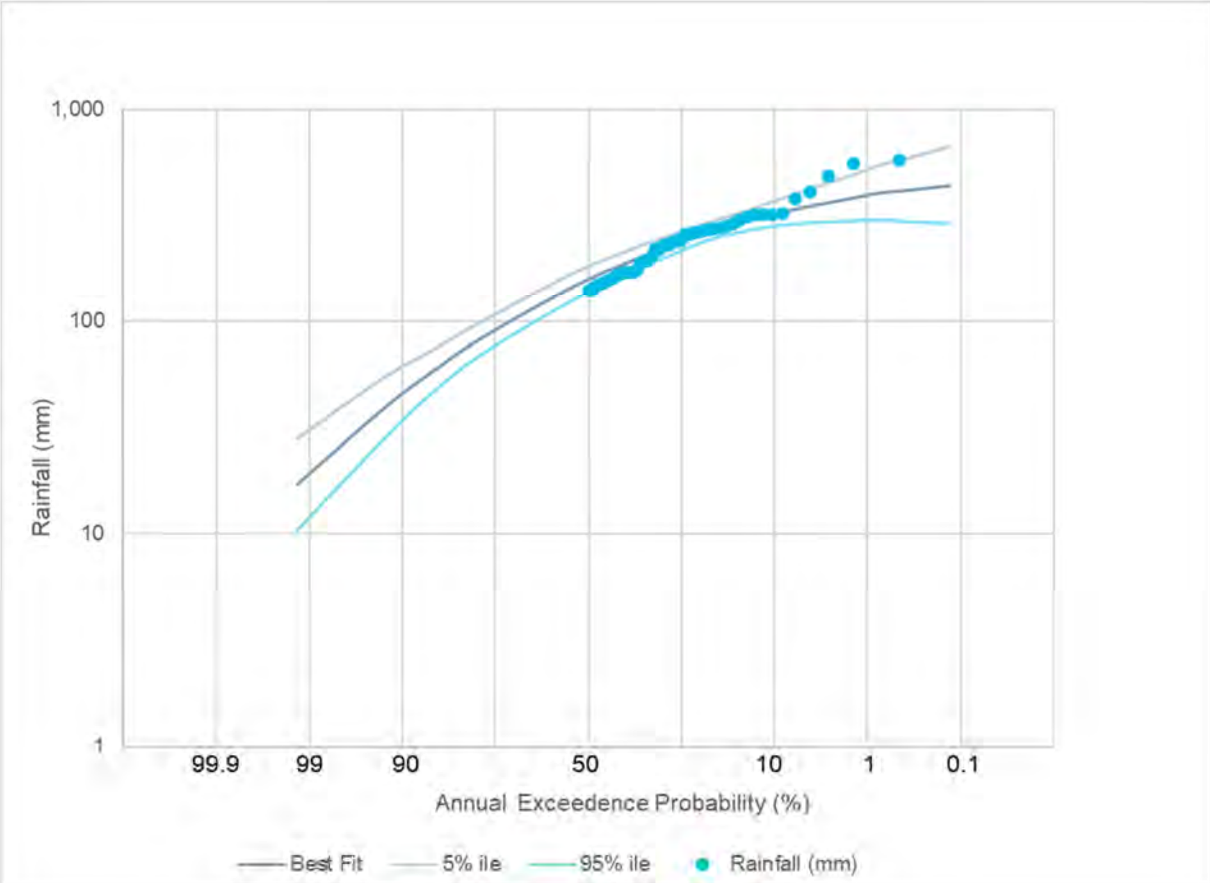


Figure 4.3 ***Rainfall frequency analysis (gauge number 033027)***

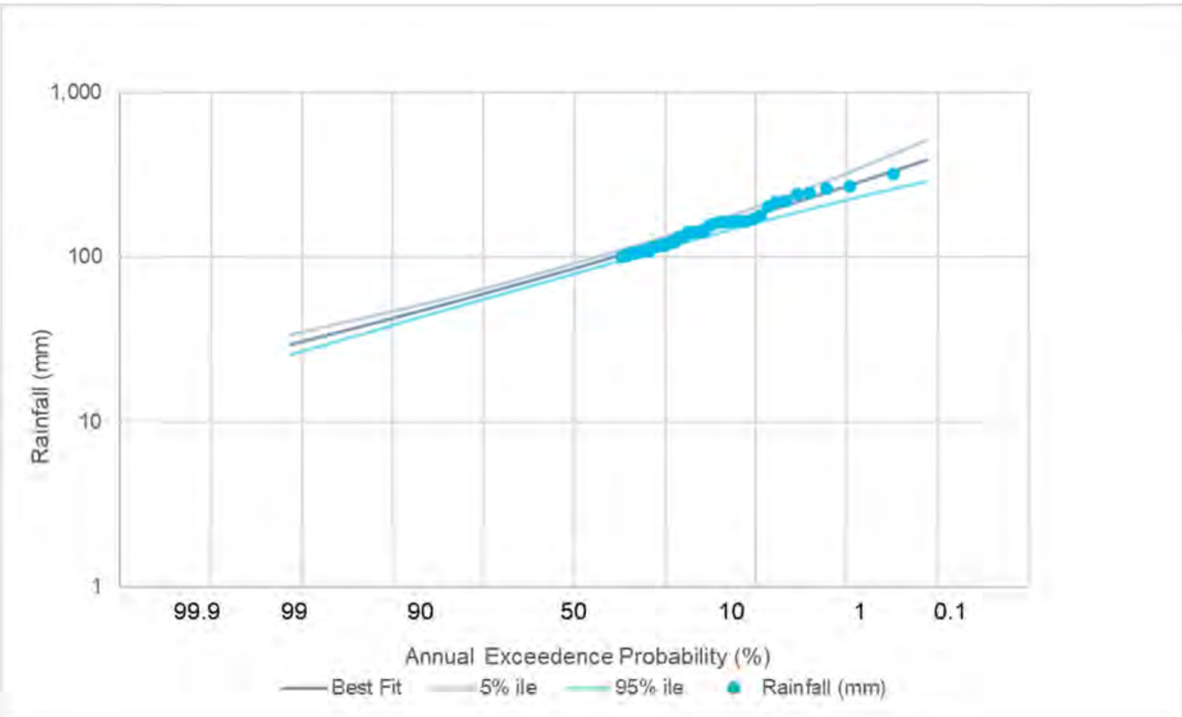


Figure 4.4 ***Rainfall frequency analysis (gauge number 003054)***

The results from the rainfall frequency analysis for different annual exceedance probabilities are presented in Table 4-3 and Table 4-4. The results have been presented along with the design rainfall depth for the 24 hour duration from the ARR datahub for the nearest sub-catchment to the gauge.

Table 4-3 Rainfall depth comparison (24 hour duration) - 033027

AEP (%)	Rainfall depth (mm) (033027)	Design rainfall depth (mm) (ARR datahub)
50	159.4	140
20	251.9	224
5	339.4	357
2	378.3	450
1	406.2	528

Table 4-4 Rainfall depth comparison (24 hour duration) - 033054

AEP (%)	Rainfall depth (mm) (033054)	Design rainfall depth (mm) (ARR datahub)
50	85.5	89.5
20	129.8	139
5	196.7	218
2	244.8	274
1	283.9	321

The results presented in Table 4-3 and Table 4-4 show that the design rainfall values applied in the RAFTS model are generally higher than the rainfall frequency analysis estimates at the relevant gauge. This analysis and comparison show that the values applied in the RAFTS model produce an appropriate representation of rainfall for the catchment at the locations where comparison is possible. On this basis the design rainfall depths adopted are considered appropriate for the hydrologic modelling.

5. Hydraulic analysis

This section summarises the hydraulic investigations undertaken for the study area. Hydraulic modelling was undertaken to estimate design event flood levels, and velocities, and to determine flow patterns across the study area to inform flood hazard predictions. A two-dimensional (2D) flood modelling approach was adopted to simulate the complex nature of flood flows, in conjunction with one-dimensional (1D) hydraulic structures. Hydraulic results were utilised to identify key areas of flood risk and can be used to potentially develop flood mitigation options in the future.

The scope of work involved:

- Data collection and review of available hydraulic information
- Hydraulic model setup (GIS and TUFLOW)
- Estimation of event-based flood inundation.

The TUFLOW model for the study area has been developed considering the previous studies for the area including:

- Nebo Flood Hazard Mapping report (2014) prepared by Water Technology
- Flooding and Drainage Assessment (November 2012) prepared by VDM.

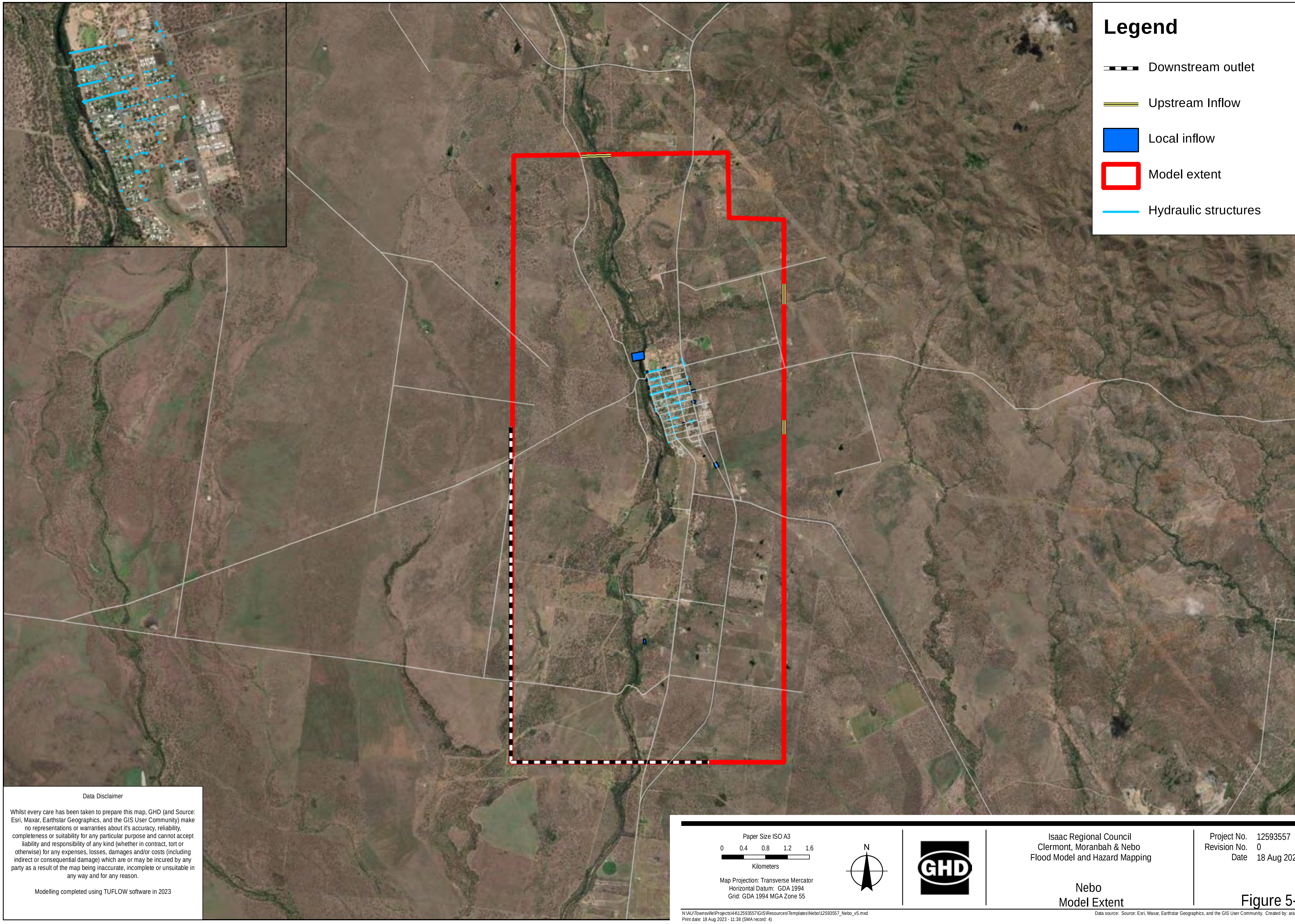
The previous TUFLOW model (Water Technology, 2014) was compared to this study, using the re-validated hydrologic output hydrographs adopted for this study as detailed in Section 3. A plan showing the extent of the hydraulic models is provided in Figure 5.1, highlighting upstream inflow boundaries and downstream outflow boundaries from the hydraulic model.

5.1 Data collection

The following data was used to undertake this assessment:

- 2022 High resolution Aerial Imagery – provided by IRC
- 1 m LiDAR Terrain Data – obtained from ELVIS Spatial
- GIS Land Use Zoning – provided by IRC
- Pit, pipe, and culverts structures – as surveyed by Bennet and Bennett in 2012
- Hydrographs output from the RAFTS model.

Resulting assumptions have been identified throughout the following sections of the report.



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Modelling completed using TUFLOW software in 2023

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping

Nebo
Model Extent

Project No. 12593557
Revision No. 0
Date 18 Aug 2023

Figure 5-1

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5.2 Hydraulic model setup

5.2.1 Model selection

The TUFLOW model provided by IRC from Water Technology (Water Technology, 2014) has been utilised as a comparison in developing the model for this project. The latest hydrologic inflow hydrographs as detailed in Section 3 have been input into the hydraulic model. It should be noted that TUFLOW is a modelling tool developed by BMT-WBM and is recognised as an industry standard 2D hydrodynamic modelling package within Australia. It is well suited to the modelling of the waterways and networks within the study area. In addition, TUFLOW is oriented towards establishing 2D flow and inundation patterns in coastal waters, rivers, and floodplains, as well as urban areas. The data used to undertake this assessment were presented in Section 5.1 of this report.

5.2.2 Software version

The model developed for this assessment has been simulated in the latest version of the TUFLOW software at the time of the assessment. This included utilising some of the new functionality available in the latest version of the software. Key new functionality within the TUFLOW software (since the previous TUFLOW modelling for the study area) includes:

– Adoption of the TUFLOW Graphical Processing Unit (GPU) Heavily Parallelised Compute (HPC) solution scheme, including an explicit solver for the full 2D shallow water equation and sub-grid scale eddy viscosity
– Full release notes detailing changes from previous versions of the software are available on the TUFLOW website.

The hydraulic model was simulated using the 2023-03-AA version of the TUFLOW software.

5.2.3 Cell size convergence

To justify a balance between hydraulic model detail and performance, a grid cell convergence assessment was undertaken to determine the effect of the model cell resolution on the following:

– Model predicted flood levels
– Simulation time
– Data volumes.

The previous model (Water Technology, 2014) provided by IRC utilized a 10 metre grid cell size. In this study, the hydraulic model was tested using a 10, 5, and 3 metre grid cell size for the assessment. The results of the assessment are detailed in Table 5-1.

Table 5-1 Grid cell convergence assessment summary

Grid cell size (m)	Number of cells	Runtime (hours)[1]	Time series output (MB)	Maximum grid output (MB)	Δ1% AEP in peak water level[2] (m)
10	7,650,000	0.2	64	12	0.16
5	15,300,000	0.8	227	48	0.08
3	25,500,000	3.5	610	133	-

Based on the results of the comparison detailed above, the 3 metre grid size was selected for the hydraulic model. The decision was made based on the following key points:

– Maintains a practical runtime to complete hydraulic model simulations within a reasonable timeframe

[1] For 1% AEP 24 hour storm duration temporal pattern 1099 selected as this event is the critical event for the 1% AEP in the vicinity of Nebo.
[2] Relative to 3 m grid cell size

– Maintains a level of model detail appropriate for the assessment

– Provides a reasonable balance between model detail and data volumes.

5.2.4 Model parameters

The TUFLOW model required the following input parameters:

5.2.4.1 Topography

The 1m LiDAR terrain Data obtained from the 2014 Water Technology study and provided by IRC was ingested into TUFLOW using a model grid cell size of 3 m.

5.2.4.2 Design event modelling

Design storm events assessed in this study were the 50%, 20%, 5%, 2%, 1%, 0.2% AEP events, and the PMF. Critical storm durations were used to generate maximum flood results. Critical storm durations were determined by modelling all durations from RAFTS in conjunction with the Storm Injector and selecting the representative critical storm based on the peak flow at the modelled sub-catchment that corresponds closest to the area of interest for the study (Nebo). The critical event from the hydrologic model was confirmed as being the critical event for the hydraulic model by simulating the critical duration event from the hydrologic model in the hydraulic model along with one standard duration above and below for the 1% AEP event. This assessment then confirmed the adoption of the hydrologic model critical duration in the hydraulic model. Any site-specific based assessments within the catchment should complete their own assessment of the critical event to be applied at the subject site.

5.2.4.3 Inflow boundaries

Hydrographs sourced from the RAFTS models were adopted as the upstream inflow boundary conditions (QT or flow vs. time) for the required events and were applied across the model extent at the applicable upstream location (within the model boundary). Local inflow hydrographs were applied as source-area inflow boundary conditions directly to the 2D domain where the sub-catchment is contained within the model extent.

5.2.4.4 Outflow boundaries

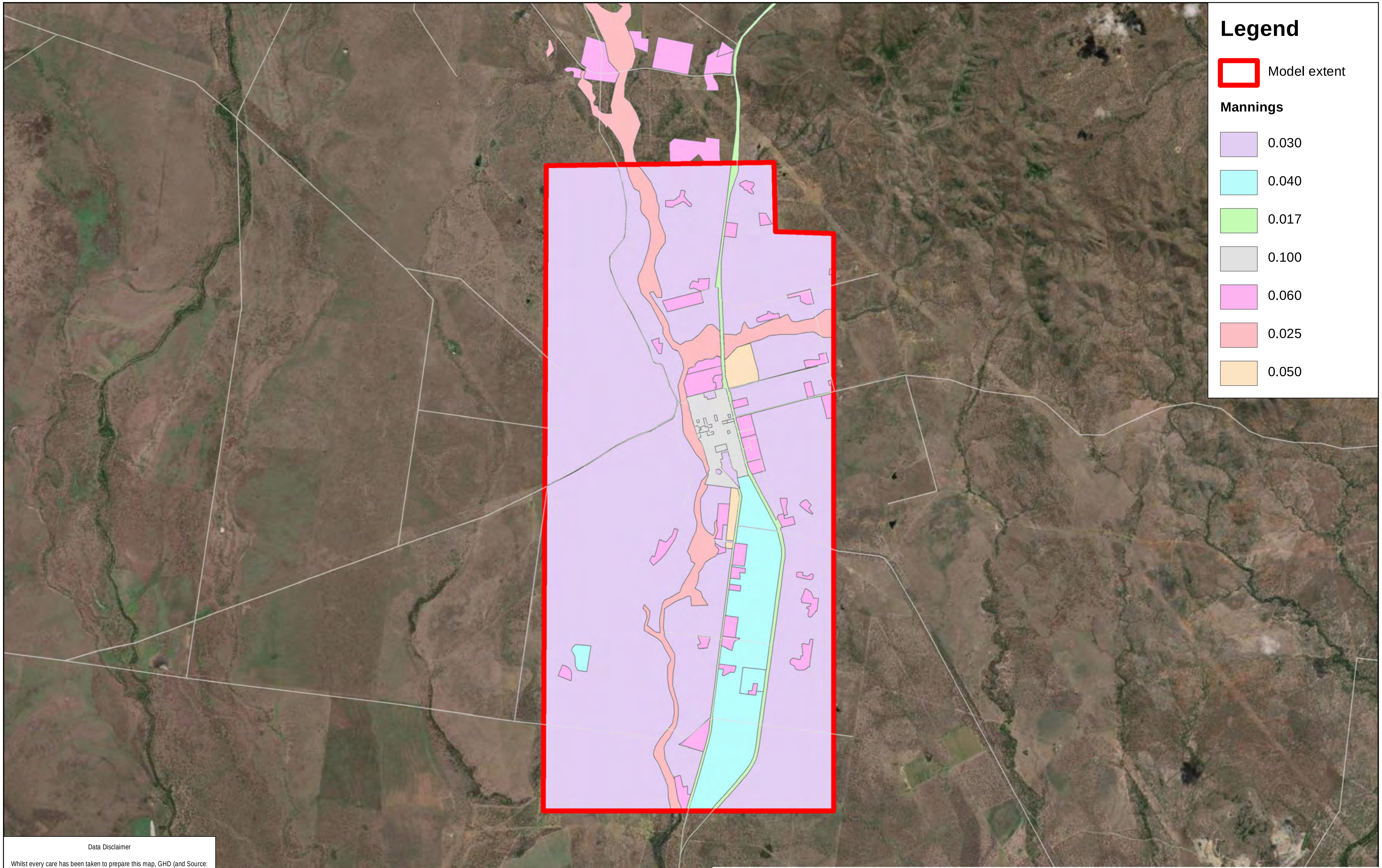
Outflow boundaries were setup as “HQ” boundaries, with slope based on the energy grade line of the waterway conveying the outflow. This boundary condition considered the Nebo Creek outlet from the model only. The outflow boundary condition location within the hydraulic model is shown in Figure 5.1.

5.2.4.5 Hydraulic roughness

Hydraulic roughness values across the study areas were determined based on a combination of the existing land use through review of aerial photography and zoning data as well as comparison to the 2014 study by Water Technology (Water Technology, 2014). The Manning’s ‘n’ roughness values adopted for different land uses are presented in Table 5-2 and a roughness map illustrating the spatial variation is presented in Figure 5.2.

Table 5-2 Manning's 'n' roughness values

Ground Type	Manning’s ‘n’ roughness
Natural channel	0.030
Cultivated Lands	0.040
Road	0.017
Buildings	0.100
Industrial	0.060
Water Body	0.025
Scattered brush, heavy weeds	0.050



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Modelling completed using TUFLOW software in 2023

Paper Size ISO A3

0 0.4 0.8 1.2 1.6

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping

Nebo
TUFLOW Hydraulic Roughness

Project No. 12593557
Revision No. 0
Date 18 Aug 2023

Figure 5-2

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Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: aramos2

5.2.4.6 Hydraulic structures

There is one road crossing of Nebo Creek within the study area, that is at Strathfield Road. This crossing is a low level waterway crossing (I.e. causeway) that is likely overtopped frequently. As such the structure has only been modelled explicitly within the 2D model DEM and no implicit modelling of the weir flow over the road undertaken due to the high submergence of the road in the events simulated for this study (~2.5 m flood depth in a 50% AEP).

Details for the pit, pipe and culvert structures within the urban area of Nebo have been taken from detailed survey data provided by IRC captured by Bennett and Bennett surveyors in 2012. This information contained invert levels, pipe sizes, number of elements, connectivity of the systems and inlet and outlets. Further details of the hydraulic structures have been provided in Appendix D and the spatial location is displayed on Figure 5.1.

5.3 Model results

5.3.1 Flood inundation mapping

As per the agreed scope for the project, 50%, 20%, 5%, 2%, 1% (including current climate, 2050 and 2100 future climate), 0.2% AEP and PMF events were simulated and the results from these simulations were mapped (See Appendix E). Using these simulated results, the following observations were made in Section 5.3.2.

5.3.2 Discussion of existing flood behaviour

The general flood behaviour across the study area as observed from the simulations is characterised in Table 5-3 for the various AEP events simulated for this study. Peak flood depths, velocity and hazard category maps for all the storm events are provided in Appendix E.

Table 5-3 Summary of general flooding concern within the area

Flood Event (AEP)	Flood Behaviour
50%	– Generally the simulated flow is confined within the banks of Nebo Creek – Simulated flow in Nebo Creek does not reach Water Street, the street nearest to the banks of the Nebo Creek – Water Street and the main township simulated to not be inundated – Strathfield Road that connects to Bowen Street and passes through Nebo Creek has flood depths up to 2.3 m at the causeway – The low-lying portions of Leggetts Road, the road that intersects with Strathfield Road to the north, has simulated flood depths up to 0.6 m – Low-lying portions of the Airstrip Road, approximately 3 km from the Nebo township, are submerged by a continuation of the flow path through the town, with simulated depths up to 0.9 m – Approximately 850 m north of the Nebo Township, it is observed that the simulated floodwaters inundate the Peaks Down Highway up to 1 m deep. – Approximately 600 m south of the Anne Street, it is observed that the simulated floodwaters cross Peaks Down Highway and is simulated to be inundated up to 0.7 m deep. The floodwaters extend eastward approximately 700m from the Peaks Down Highway. – Inundation in the flow paths through the town generally confined to within open-spaces. Drainage structures underneath roads etc. are generally adequate, with the exception of Trimmer Street (simulated up to 0.2 m). – Flood extent in tributary of Nebo Creek between the Racecourse and Holcim operations confined to within the channel/watercourse. GHD notes the watercourse through this location looks to be an excavated channel, less than 10 metres wide until it reaches the road crossing of the Peak Downs Highway.
20%	– Most of the simulated flow is still confined within the banks of Nebo Creek – Water Street and the main township simulated to not be inundated

Flood Event (AEP)	Flood Behaviour
	– Strathfield Road that connects to Bowen Street and passes through Nebo Creek has flood depths up to 3.4 m at the causeway – It is observed that the simulated floodwaters along Leggetts Road have increased and is simulated to be inundated up to 1.4 m deep – Low-lying portions of the Airstrip Road, approximately 3 km from the Nebo township, are submerged by a continuation of the flow path through the town, simulated depths up to 1.1 m – Approximately 850m north of the Nebo Township, it is observed that the simulated floodwaters cross Peaks Down Highway and is simulated to be inundated up to 2 m deep. The floodwaters extend eastward approximately 2km from the Peaks Down Highway. – Approximately 600m south of the Anne Street, it is observed that the simulated floodwaters cross Peaks Down Highway and is simulated to be inundated up to 1.2 m deep. The floodwaters extend eastward approximately 770m from the Peaks Down Highway. – Inundation of the flow paths through the town generally confined to within open-spaces. Drainage structures underneath roads etc. are generally adequate, with the exception of Trimmer Street (simulated up to 0.3 m), Saint Lawrence Street (simulated up to 0.2 m) and Cemetery Road (simulated up to 0.1 m). – Flood extent in tributary of Nebo Creek between the Racecourse and Holcim operations confined to within the channel/watercourse. GHD notes the watercourse through this location looks to be an excavated channel, less than 10 metres wide until it reaches the road crossing of the Peak Downs Highway.
5%	– Simulated flood depths along Leggetts Road and Strathfield Road range from 2.5 m up to 4.5 m respectively – Water Street and the main township simulated to not be inundated by Nebo Creek flooding – Backwater flows in Nebo Creek extending towards Peak Downs Highway between Bowen Road and Walshs Road, were not simulated to overtop the road – Low-lying portions of the Airstrip Road, approximately 3 km from the Nebo township, are submerged by a continuation of the flow path through the town, with simulated depths up to 2.3 m – Approximately 850m north of the Nebo Township, it is observed that the simulated floodwaters cross Peaks Down Highway and is simulated to be inundated up to 1.6 m deep. The floodwaters extend eastward approximately 2km from the Peaks Down Highway. – Approximately 600m south of the Anne Street, it is observed that the simulated floodwaters cross Peaks Down Highway and is simulated to be inundated up to 1 m deep. The floodwaters extend eastward approximately 800m from the Peaks Down Highway. – Inundation of the flow paths through the town generally confined to within open-spaces. Drainage structures underneath roads etc. are generally adequate, with the exception of Trimmer Street (simulated up to 0.3 m), Saint Lawrence Street (simulated up to 0.2 m) and Cemetery Road (simulated up to 0.1 m). – Flood extent in tributary of Nebo Creek between the Racecourse and Holcim operations showing some out of bank flow, low hazard. GHD notes the watercourse through this location looks to be an excavated channel, less than 10 metres wide until it reaches the road crossing of the Peak Downs Highway.
2%	– Simulated flood depths along Leggetts Road and Strathfield Road range from 3.1 m up to 5.1 m respectively – Backwater flows in Nebo Creek extending towards Peak Downs Highway between Bowen Road and Walshs Road, were not simulated to overtop the road – Simulated flows along Nebo Creek adjacent to the Water Street are still confined to within the banks.

Flood Event (AEP)	Flood Behaviour
	– Large inundation of the Airstrip Road, approximately 3 km from the Nebo township, submerged by a continuation of the flow path through the town, with simulated depths up to 2.9 m – Approximately 850m north of the Nebo Township, it is observed that the simulated floodwaters cross Peaks Down Highway and is simulated to be inundated up to 2.5 m deep. The floodwaters extend eastward approximately 2km from the Peaks Down Highway. – Approximately 600m south of the Anne Street, it is observed that the simulated floodwaters cross Peaks Down Highway and is simulated to be inundated up to 1.7 m deep. The floodwaters extend eastward approximately 800m from the Peaks Down Highway. – Inundation of the flow paths through the town generally confined to within open-spaces. Drainage structures underneath roads etc. generally adequate, with the exception of Trimmer Street (simulated up to 0.3 m), Saint Lawrence Street (simulated up to 0.3 m), Cemetery Road (simulated up to 0.2 m) and Waverley Road/Peak Downs Highway (simulated less than 0.05 m). – Flood extent in tributary of Nebo Creek between the Racecourse and Holcim operations showing some out of bank flow, low hazard. GHD notes the watercourse through this location looks to be an excavated channel, less than 10 metres wide until it reaches the road crossing of the Peak Downs Highway.
1%	– Simulated flood depths along Leggetts Road and Strathfield Road range from 3.6 m up to 5.6 m respectively – Backwater flows in Nebo Creek extending towards Peak Downs Highway between Bowen Road and Walshs Road, not simulated to overtop the road – Simulated flows along Nebo Creek adjacent to the Water Street are still confined to within the banks. – Large inundation of the Airstrip Road, approximately 3 km from the Nebo township, submerged by a continuation of the flow path through the town, with simulated depths up to 3.3 m – Approximately 850m north of the Nebo Township, it is observed that the simulated floodwaters cross Peaks Down Highway and is simulated to be inundated up to 3 m deep. The floodwaters extend eastward approximately 2km from the Peaks Down Highway. – Approximately 600m south of the Anne Street, it is observed that the simulated floodwaters cross Peaks Down Highway and is simulated to be inundated up to 1.7 m deep. The floodwaters extend northward to Johnson Road, and eastward approximately 860m from the Peaks Down Highway. – Inundation of the flow paths through the town generally confined to within open-spaces. Drainage structures underneath roads etc. generally adequate, with the exception of Trimmer Street (simulated up to 0.4 m), Saint Lawrence Street (simulated up to 0.3 m), Cemetery Road (simulated up to 0.15 m) and Waverley Road/Peak Downs Highway (simulated up to 0.07 m). – Flood extent in tributary of Nebo Creek between the Racecourse and Holcim operations showing some out of bank flow, low hazard. GHD notes the watercourse through this location looks to be an excavated channel, less than 10 metres wide until it reaches the road crossing of the Peak Downs Highway.
1% plus Climate Change 2050	– Simulated flood depths along Leggetts Road and Strathfield Road range from 3.8 m up to 5.8 m – Backwater flows in Nebo Creek extending towards Peak Downs Highway between Bowen Road and Walshs Road, not simulated to overtop the road – Simulated flows along Nebo Creek adjacent to the Water Street are still confined to within the banks. – Large inundation of the Airstrip Road, approximately 3 km from the Nebo township, submerged by a continuation of the flow path through the town, with simulated depths up to 3.5 m

Flood Event (AEP)	Flood Behaviour
	– Approximately 850m north of the Nebo Township, it is observed that the simulated floodwaters cross Peaks Down Highway and is simulated to be inundated up to 3 m deep. The floodwaters extend northward to Johnson Road, and eastward approximately 2km from the Peaks Down Highway. – Approximately 600m south of the Anne Street, it is observed that the simulated floodwaters cross Peaks Down Highway and is simulated to be inundated up to 1.7 m deep. The floodwaters extend eastward approximately 860m from the Peaks Down Highway. – Inundation of the flow paths through the town generally confined to within open-spaces. Drainage structures underneath roads etc. generally adequate, with the exception of Trimmer Street (simulated up to 0.4 m), Saint Lawrence Street (simulated up to 0.3 m), Cemetery Road (simulated up to 0.2 m) and Waverley Road/Peak Downs Highway (simulated up to 0.1 m). – Flood extent in tributary of Nebo Creek between the Racecourse and Holcim operations showing some out of bank flow, low hazard. GHD notes the watercourse through this location looks to be an excavated channel, less than 10 metres wide until it reaches the road crossing of the Peak Downs Highway.
1% plus Climate Change 2100	– Simulated flood depths along Strathfield Road and on to Leggetts Road range from 4.0 m up to 6.1 m – Backwater flows in Nebo Creek extending towards Peak Downs Highway between Bowen Road and Walshs Road, not simulated to overtop the road – Simulated flows along Nebo Creek adjacent to the Water Street are still confined to within the banks – Large inundation of the Airstrip Road, approximately 3 km from the Nebo township, submerged by continuation of flow path through the town, simulated depths up to 3.7 m – Approximately 850m north of the Nebo Township, it is observed that the simulated floodwaters cross Peaks Down Highway and is simulated to be inundated up to 3 m deep. The floodwaters extend eastward approximately 2km from the Peaks Down Highway. – Approximately 600m south of the Anne Street, it is observed that the simulated floodwaters cross Peaks Down Highway and is simulated to be inundated up to 1.7 m deep. The floodwaters extend northward to Johnson Road, and eastward approximately 860m from the Peaks Down Highway. – Inundation of the flow path through the town generally confined to within open-spaces. Drainage structures underneath roads etc. generally adequate, with the exception of Trimmer Street (simulated up to 0.4 m), Saint Lawrence Street (simulated over 0.3 m), Cemetery Road (simulated up to 0.2 m) and Waverley Road/Peak Downs Highway (simulated above 0.1 m). – Flood extent in tributary of Nebo Creek between the Racecourse and Holcim operations showing some out of bank flow, low hazard. GHD notes the watercourse through this location looks to be an excavated channel, less than 10 metres wide until it reaches the road crossing of the Peak Downs Highway.
0.2%	– Simulated flood depths along Strathfield Road and on to Leggetts Road range from 5.2 m up to 7.2 m – Backwater flows in Nebo Creek extending over Peak Downs Highway between Bowen Road and Walshs Road, simulated to overtop the road by up to 0.7 m – Simulated flows along Nebo Creek adjacent to the Water Street are still confined to within the banks – Large inundation of the Airstrip Road, approximately 3 km from the Nebo township, submerged by a continuation of the flow path through the town, with simulated depths up to 4.5 m – Approximately 850m north of the Nebo Township, it is observed that the simulated floodwaters cross Peaks Down Highway and is simulated to be inundated up to

Flood Event (AEP)	Flood Behaviour
	3.5 m deep. The floodwaters extend northward to Johnson Road, and eastward approximately 2km from the Peaks Down Highway. – Approximately 600m south of the Anne Street, it is observed that the simulated floodwaters cross Peaks Down Highway and is simulated to be inundated up to 1.8 m deep. The floodwaters extend eastward approximately 870m from the Peaks Down Highway. – Inundation of the flow paths through the town generally confined to within open-spaces. Drainage structures underneath roads etc. generally adequate, with the exception of Trimmer Street (simulated up to 0.4 m), Saint Lawrence Street (simulated up to 0.3 m), Cemetery Road (simulated up to 0.2 m) and Waverley Road/Peak Downs Highway (simulated above 0.1 m). – Flood extent in tributary of Nebo Creek between the Racecourse and Holcim operations showing some out of bank flow, low hazard. GHD notes the watercourse through this location looks to be an excavated channel, less than 10 metres wide until it reaches the road crossing of the Peak Downs Highway.
PMF	– Simulated flood depths along Strathfield Road and on to Leggetts Road range from 10.9 m up to 12.7 m – Widespread flows simulated over Peak Downs Highway north of the Nebo township – Approximately 850m north of the Nebo Township, it is observed that the simulated floodwaters cross Peaks Down Highway and is simulated to be inundated up to 7.8 m deep. The floodwaters extend northward to Johnson Road, and eastward approximately 2km from the Peaks Down Highway. – Approximately 600m south of the Anne Street, it is observed that the simulated floodwaters cross Peaks Down Highway and is simulated to be inundated up to 3 m deep. The floodwaters extend eastward approximately 900m from the Peaks Down Highway. – Breakout flows from Nebo Creek north of the township, simulated to flow through Nebo township via an overland flow drainage path. Depths through the township simulated to be above 1 m generally, and more than 2 m in the overland flow drainage path – Airstrip Road is submerged in a number of locations, simulated depths more than 8 m. – Large out of bank flows in tributary of Nebo Creek between the Racecourse and Holcim operations. GHD notes the watercourse through this location looks to be an excavated channel, less than 10 metres wide until it reaches the road crossing of the Peak Downs Highway.

5.4 Model validation

The hydrology model was validated to the RFFE method as described in Section 4. As detailed calibration information was not made available for the hydraulic model, reasonableness checks were undertaken to confirm that the model was providing outputs consistent with the inputs and the surrounding hydraulic conditions. Also, the hydraulic model results were compared to the flood mapping provided as part of the Water Technology study (Water Technology, 2014). Though the maps presented in that study only show flood extents around the township of Nebo and not further upstream or downstream of the township, they do help provide comparison. The following was noted:

– The 1% AEP event shows generally the same depths and extent through Nebo Creek, though the Water Technology study (Water Technology, 2014) did not consider any local runoff through the township
– No breakouts are predicted in events up to the 0.2% AEP (the largest flood event simulated) in the Water Technology study (Water Technology, 2014) from Nebo Creek around the township of Nebo. This is consistent with the outcomes of this study
– The hazard extents presented across all events comparable (2%, 1% and 0.2% AEP), are consistent between the Water Technology study (Water Technology, 2014) and this study

– The velocity results through Nebo Creek are consistent with the maps presented in Appendix E.

5.5 Sensitivity assessment

Sensitivity testing was conducted for the Manning's 'n' parameter where the hydraulic roughness was adjusted by 10% (higher and lower). The +/- 10% value represents bands of Manning's n value that fall within industry accepted-values. The results were compared against the adopted Manning's n and a histogram chart of water level difference within the model domain is presented in Figure 5.3 and Figure 5.4. These plots show that majority of the differences in results are in the 100-250 mm band for both the increased and decreased Manning's 'n' value scenarios. As such, it is considered that the model is sensitive to changes in roughness. Generally, the changes to flood extent are minor relative to the township of Nebo and in line with what would be expected within a hydraulic model, where increasing the Manning's 'n' roughness value results in an increase in flood level and slight increase in flood extent due to the slowing down or retarding of flow. The increases are confined to the main waterway and do not create large increases in flood extent. Road infrastructure immunity outcomes are consistent for both the sensitivity assessment and the base line event across the study extent.

For the decreased Manning's 'n' roughness scenario, the decrease results in reduction in flood level and very slight reduction in flood extent due to the speeding up of flow. The values are adopted according to the industry standard range.

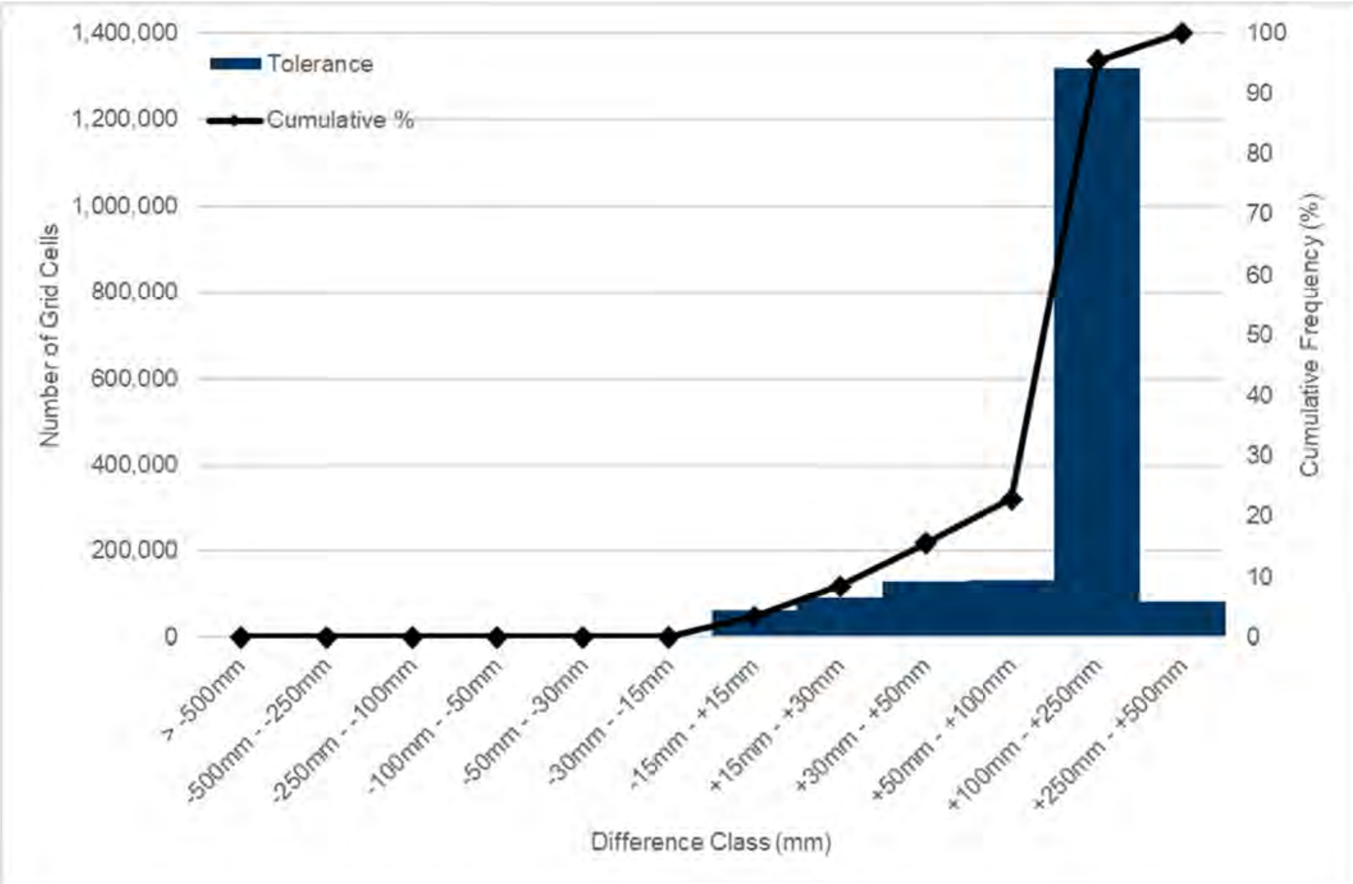

Figure 5.3 Water level difference histogram considering adopted Manning's n and 10% reduced Manning's n

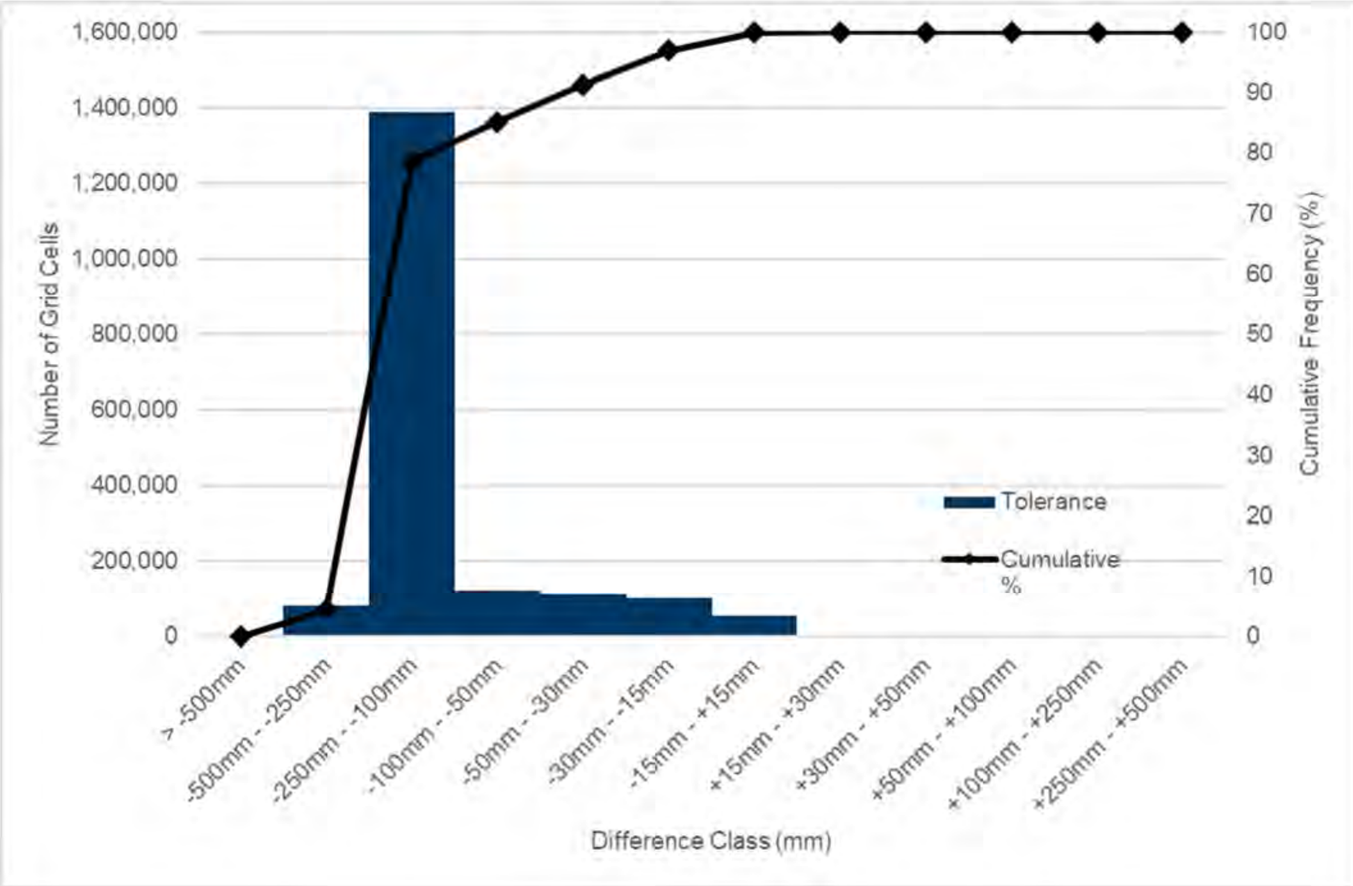

Figure 5.4 ***Water level difference histogram considering adopted Manning's n and 10% increased Manning's n***

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6. Summary

GHD have been engaged by IRC to undertake the flood modelling and hazard mapping for the township of Nebo. This report documents the analyses undertaken, which involved:

– Review of available data and historic flood information
– Hydrologic and hydraulic modelling of developed flood conditions for a range of AEP events
– Development of flood maps (including hazard maps) for each of the design events

To develop an understanding of existing flooding and drainage issues, detailed hydrologic and hydraulic modelling and flood inundation mapping of the Nebo township has been undertaken in accordance with the best practice approaches. Flood maps are provided in Appendix E.

Table 6-1 Summary of general flooding issues

Flood Event (AEP)	Flood Behaviour
50%	– Generally the simulated flow is confined within the banks of Nebo Creek – Simulated flow in Nebo Creek does not reach Water Street, the street nearest to the banks of the Nebo Creek – Water Street and the main township simulated to not be inundated – Strathfield Road that connects to Bowen Street and passes through Nebo Creek has flood depths up to 2.3 m at the causeway – The low-lying portions of Leggetts Road, the road that intersects with Strathfield Road to the north, has simulated flood depths up to 0.6 m – Low-lying portions of the Airstrip Road, approximately 3 km from the Nebo township, are submerged by a continuation of the flow path through the town, with simulated depths up to 0.9 m – Approximately 850 m north of the Nebo Township, it is observed that the simulated floodwaters inundate the Peaks Down Highway up to 1 m deep. – Approximately 600 m south of the Anne Street, it is observed that the simulated floodwaters cross Peaks Down Highway and is simulated to be inundated up to 0.7 m deep. The floodwaters extend eastward approximately 700m from the Peaks Down Highway. – Inundation in the flow paths through the town generally confined to within open-spaces. Drainage structures underneath roads etc. are generally adequate, with the exception of Trimmer Street (simulated up to 0.2 m). – Flood extent in tributary of Nebo Creek between the Racecourse and Holcim operations confined to within the channel/watercourse. GHD notes the watercourse through this location looks to be an excavated channel, less than 10 metres wide until it reaches the road crossing of the Peak Downs Highway.
20%	– Most of the simulated flow is still confined within the banks of Nebo Creek – Water Street and the main township simulated to not be inundated – Strathfield Road that connects to Bowen Street and passes through Nebo Creek has flood depths up to 3.4 m at the causeway – It is observed that the simulated floodwaters along Leggetts Road have increased and is simulated to be inundated up to 1.4 m deep – Low-lying portions of the Airstrip Road, approximately 3 km from the Nebo township, are submerged by a continuation of the flow path through the town, simulated depths up to 1.1 m – Approximately 850m north of the Nebo Township, it is observed that the simulated floodwaters cross Peaks Down Highway and is simulated to be inundated up to

Flood Event (AEP)	Flood Behaviour
	2 m deep. The floodwaters extend eastward approximately 2km from the Peaks Down Highway. – Approximately 600m south of the Anne Street, it is observed that the simulated floodwaters cross Peaks Down Highway and is simulated to be inundated up to 1.2 m deep. The floodwaters extend eastward approximately 770m from the Peaks Down Highway. – Inundation of the flow paths through the town generally confined to within open-spaces. Drainage structures underneath roads etc. are generally adequate, with the exception of Trimmer Street (simulated up to 0.3 m), Saint Lawrence Street (simulated up to 0.2 m) and Cemetery Road (simulated up to 0.1 m). – Flood extent in tributary of Nebo Creek between the Racecourse and Holcim operations confined to within the channel/watercourse. GHD notes the watercourse through this location looks to be an excavated channel, less than 10 metres wide until it reaches the road crossing of the Peak Downs Highway.
5%	– Simulated flood depths along Leggetts Road and Strathfield Road range from 2.5 m up to 4.5 m respectively – Water Street and the main township simulated to not be inundated by Nebo Creek flooding – Backwater flows in Nebo Creek extending towards Peak Downs Highway between Bowen Road and Walshs Road, were not simulated to overtop the road – Low-lying portions of the Airstrip Road, approximately 3 km from the Nebo township, are submerged by a continuation of the flow path through the town, with simulated depths up to 2.3 m – Approximately 850m north of the Nebo Township, it is observed that the simulated floodwaters cross Peaks Down Highway and is simulated to be inundated up to 1.6 m deep. The floodwaters extend eastward approximately 2km from the Peaks Down Highway. – Approximately 600m south of the Anne Street, it is observed that the simulated floodwaters cross Peaks Down Highway and is simulated to be inundated up to 1 m deep. The floodwaters extend eastward approximately 800m from the Peaks Down Highway. – Inundation of the flow paths through the town generally confined to within open-spaces. Drainage structures underneath roads etc. are generally adequate, with the exception of Trimmer Street (simulated up to 0.3 m), Saint Lawrence Street (simulated up to 0.2 m) and Cemetery Road (simulated up to 0.1 m). – Flood extent in tributary of Nebo Creek between the Racecourse and Holcim operations showing some out of bank flow, low hazard. GHD notes the watercourse through this location looks to be an excavated channel, less than 10 metres wide until it reaches the road crossing of the Peak Downs Highway.
2%	– Simulated flood depths along Leggetts Road and Strathfield Road range from 3.1 m up to 5.1 m respectively – Backwater flows in Nebo Creek extending towards Peak Downs Highway between Bowen Road and Walshs Road, were not simulated to overtop the road – Simulated flows along Nebo Creek adjacent to the Water Street are still confined to within the banks. – Large inundation of the Airstrip Road, approximately 3 km from the Nebo township, submerged by a continuation of the flow path through the town, with simulated depths up to 2.9 m – Approximately 850m north of the Nebo Township, it is observed that the simulated floodwaters cross Peaks Down Highway and is simulated to be inundated up to 2.5 m deep. The floodwaters extend eastward approximately 2km from the Peaks Down Highway. – Approximately 600m south of the Anne Street, it is observed that the simulated floodwaters cross Peaks Down Highway and is simulated to be inundated up to

Flood Event (AEP)	Flood Behaviour
	1.7 m deep. The floodwaters extend eastward approximately 800m from the Peaks Down Highway. – Inundation of the flow paths through the town generally confined to within open-spaces. Drainage structures underneath roads etc. generally adequate, with the exception of Trimmer Street (simulated up to 0.3 m), Saint Lawrence Street (simulated up to 0.3 m), Cemetery Road (simulated up to 0.2 m) and Waverley Road/Peak Downs Highway (simulated less than 0.05 m). – Flood extent in tributary of Nebo Creek between the Racecourse and Holcim operations showing some out of bank flow, low hazard. GHD notes the watercourse through this location looks to be an excavated channel, less than 10 metres wide until it reaches the road crossing of the Peak Downs Highway.
1%	– Simulated flood depths along Leggetts Road and Strathfield Road range from 3.6 m up to 5.6 m respectively – Backwater flows in Nebo Creek extending towards Peak Downs Highway between Bowen Road and Walshs Road, not simulated to overtop the road – Simulated flows along Nebo Creek adjacent to the Water Street are still confined to within the banks. – Large inundation of the Airstrip Road, approximately 3 km from the Nebo township, submerged by a continuation of the flow path through the town, with simulated depths up to 3.3 m – Approximately 850m north of the Nebo Township, it is observed that the simulated floodwaters cross Peaks Down Highway and is simulated to be inundated up to 3 m deep. The floodwaters extend eastward approximately 2km from the Peaks Down Highway. – Approximately 600m south of the Anne Street, it is observed that the simulated floodwaters cross Peaks Down Highway and is simulated to be inundated up to 1.7 m deep. The floodwaters extend northward to Johnson Road, and eastward approximately 860m from the Peaks Down Highway. – Inundation of the flow paths through the town generally confined to within open-spaces. Drainage structures underneath roads etc. generally adequate, with the exception of Trimmer Street (simulated up to 0.4 m), Saint Lawrence Street (simulated up to 0.3 m), Cemetery Road (simulated up to 0.15 m) and Waverley Road/Peak Downs Highway (simulated up to 0.07 m). – Flood extent in tributary of Nebo Creek between the Racecourse and Holcim operations showing some out of bank flow, low hazard. GHD notes the watercourse through this location looks to be an excavated channel, less than 10 metres wide until it reaches the road crossing of the Peak Downs Highway.
1% plus Climate Change 2050	– Simulated flood depths along Leggetts Road and Strathfield Road range from 3.8 m up to 5.8 m – Backwater flows in Nebo Creek extending towards Peak Downs Highway between Bowen Road and Walshs Road, not simulated to overtop the road – Simulated flows along Nebo Creek adjacent to the Water Street are still confined to within the banks. – Large inundation of the Airstrip Road, approximately 3 km from the Nebo township, submerged by a continuation of the flow path through the town, with simulated depths up to 3.5 m – Approximately 850m north of the Nebo Township, it is observed that the simulated floodwaters cross Peaks Down Highway and is simulated to be inundated up to 3 m deep. The floodwaters extend northward to Johnson Road, and eastward approximately 2km from the Peaks Down Highway. – Approximately 600m south of the Anne Street, it is observed that the simulated floodwaters cross Peaks Down Highway and is simulated to be inundated up to 1.7 m deep. The floodwaters extend eastward approximately 860m from the Peaks Down Highway.

Flood Event (AEP)	Flood Behaviour
	– Inundation of the flow paths through the town generally confined to within open-spaces. Drainage structures underneath roads etc. generally adequate, with the exception of Trimmer Street (simulated up to 0.4 m), Saint Lawrence Street (simulated up to 0.3 m), Cemetery Road (simulated up to 0.2 m) and Waverley Road/Peak Downs Highway (simulated up to 0.1 m). – Flood extent in tributary of Nebo Creek between the Racecourse and Holcim operations showing some out of bank flow, low hazard. GHD notes the watercourse through this location looks to be an excavated channel, less than 10 metres wide until it reaches the road crossing of the Peak Downs Highway.
1% plus Climate Change 2100	– Simulated flood depths along Strathfield Road and on to Leggetts Road range from 4.0 m up to 6.1 m – Backwater flows in Nebo Creek extending towards Peak Downs Highway between Bowen Road and Walshs Road, not simulated to overtop the road – Simulated flows along Nebo Creek adjacent to the Water Street are still confined to within the banks – Large inundation of the Airstrip Road, approximately 3 km from the Nebo township, submerged by continuation of flow path through the town, simulated depths up to 3.7 m – Approximately 850m north of the Nebo Township, it is observed that the simulated floodwaters cross Peaks Down Highway and is simulated to be inundated up to 3 m deep. The floodwaters extend eastward approximately 2km from the Peaks Down Highway. – Approximately 600m south of the Anne Street, it is observed that the simulated floodwaters cross Peaks Down Highway and is simulated to be inundated up to 1.7 m deep. The floodwaters extend northward to Johnson Road, and eastward approximately 860m from the Peaks Down Highway. – Inundation of the flow path through the town generally confined to within open-spaces. Drainage structures underneath roads etc. generally adequate, with the exception of Trimmer Street (simulated up to 0.4 m), Saint Lawrence Street (simulated over 0.3 m), Cemetery Road (simulated up to 0.2 m) and Waverley Road/Peak Downs Highway (simulated above 0.1 m). – Flood extent in tributary of Nebo Creek between the Racecourse and Holcim operations showing some out of bank flow, low hazard. GHD notes the watercourse through this location looks to be an excavated channel, less than 10 metres wide until it reaches the road crossing of the Peak Downs Highway.
0.2%	– Simulated flood depths along Strathfield Road and on to Leggetts Road range from 5.2 m up to 7.2 m – Backwater flows in Nebo Creek extending over Peak Downs Highway between Bowen Road and Walshs Road, simulated to overtop the road by up to 0.7 m – Simulated flows along Nebo Creek adjacent to the Water Street are still confined to within the banks – Large inundation of the Airstrip Road, approximately 3 km from the Nebo township, submerged by a continuation of the flow path through the town, with simulated depths up to 4.5 m – Approximately 850m north of the Nebo Township, it is observed that the simulated floodwaters cross Peaks Down Highway and is simulated to be inundated up to 3.5 m deep. The floodwaters extend northward to Johnson Road, and eastward approximately 2km from the Peaks Down Highway. – Approximately 600m south of the Anne Street, it is observed that the simulated floodwaters cross Peaks Down Highway and is simulated to be inundated up to 1.8 m deep. The floodwaters extend eastward approximately 870m from the Peaks Down Highway. – Inundation of the flow paths through the town generally confined to within open-spaces. Drainage structures underneath roads etc. generally adequate, with the exception of Trimmer Street (simulated up to 0.4 m), Saint Lawrence Street

Flood Event (AEP)	Flood Behaviour
	(simulated up to 0.3 m), Cemetery Road (simulated up to 0.2 m) and Waverley Road/Peak Downs Highway (simulated above 0.1 m). – Flood extent in tributary of Nebo Creek between the Racecourse and Holcim operations showing some out of bank flow, low hazard. GHD notes the watercourse through this location looks to be an excavated channel, less than 10 metres wide until it reaches the road crossing of the Peak Downs Highway.
PMF	– Simulated flood depths along Strathfield Road and on to Leggetts Road range from 10.9 m up to 12.7 m – Widespread flows simulated over Peak Downs Highway north of the Nebo township – Approximately 850m north of the Nebo Township, it is observed that the simulated floodwaters cross Peaks Down Highway and is simulated to be inundated up to 7.8 m deep. The floodwaters extend northward to Johnson Road, and eastward approximately 2km from the Peaks Down Highway. – Approximately 600m south of the Anne Street, it is observed that the simulated floodwaters cross Peaks Down Highway and is simulated to be inundated up to 3 m deep. The floodwaters extend eastward approximately 900m from the Peaks Down Highway. – Breakout flows from Nebo Creek north of the township, simulated to flow through Nebo township via an overland flow drainage path. Depths through the township simulated to be above 1 m generally, and more than 2 m in the overland flow drainage path – Airstrip Road is submerged in a number of locations, simulated depths more than 8 m. – Large out of bank flows in tributary of Nebo Creek between the Racecourse and Holcim operations. GHD notes the watercourse through this location looks to be an excavated channel, less than 10 metres wide until it reaches the road crossing of the Peak Downs Highway.

Appendices

Appendix A

BoM design rainfall IFDs (Frequent, infrequent and rare)

Duration	Annual Exceedance Probability (AEP)								
	50%	20%	5%	2%	1%	0.5% (1 in 200)	0.2% (1 in 500)	0.1% (1 in 1000)	0.05% (1 in 2000)
1 min	2.55	3.41	4.47	5.1	5.55	6.39	7.66	8.73	9.91
2 min	4.26	5.71	7.45	8.48	9.22	10.7	13	14.9	17
3 min	6.03	8.1	10.6	12.1	13.1	15.2	18.4	21.1	24
4 min	7.73	10.4	13.6	15.5	16.9	19.5	23.5	26.9	30.5
5 min	9.31	12.5	16.4	18.7	20.3	23.5	28.2	32.2	36.6
10 min	15.7	21	27.5	31.4	34.1	39.2	47	53.4	60.6
15 min	20.3	27.1	35.4	40.4	43.9	50.4	60.4	68.8	77.9
20 min	23.8	31.8	41.5	47.3	51.4	59.1	70.8	80.7	91.5
25 min	26.6	35.5	46.4	52.8	57.5	66.1	79.3	90.4	103
30 min	28.9	38.6	50.5	57.5	62.6	72.1	86.5	98.6	112
45 min	34.1	45.7	59.9	68.4	74.6	86	103	118	134
1 hour	37.7	50.8	67	76.7	83.8	96.7	116	133	151
1.5 hour	42.8	58.4	77.7	89.6	98.3	113	136	156	177
2 hours	46.5	64.1	86.2	100	110	127	153	174	198
3 hours	52.1	72.9	100	117	130	150	180	205	233
4.5 hours	58.2	83.3	117	139	156	179	214	244	276
6 hours	63.2	91.8	131	158	178	204	244	277	314
9 hours	71.3	106	156	190	217	248	297	337	381
12 hours	78	118	177	218	251	287	343	389	441
18 hours	89.2	138	212	265	308	354	424	481	546
24 hours	98.4	154	241	304	356	410	492	561	636
30 hours	106	167	266	337	397	458	552	631	719
36 hours	113	179	288	366	432	499	604	693	792
48 hours	125	199	324	413	489	569	692	796	913
72 hours	142	228	375	479	568	666	813	939	1080
96 hours	154	248	410	523	618	727	886	1020	1170
120 hours	162	262	434	552	652	764	928	1070	1220
144 hours	168	273	451	573	674	786	948	1090	1250
168 hours	173	281	464	587	689	796	954	1090	1250

Appendix B

Catchment Characteristics

Catchment ID	Area (ha)	Pervious Manning's value	Fraction Impervious (%)	EA Slope %
1	980.5	0.06	0	3.73
2	702.4	0.06	0	3.35
3	836.7	0.06	0	2.72
4	742.3	0.06	0	2.67
5	746.4	0.06	0	2.58
6	2297.6	0.06	0	2.35
7	1310.9	0.06	0	2.90
8	848.0	0.06	0	4.09
9	1596.9	0.06	0	2.58
10	1292.7	0.06	0	4.78
11	2164.6	0.06	0	1.98
12	2284.7	0.06	0	2.05
13	1467.5	0.06	0	3.41
14	1217.1	0.06	0	1.33
15	674.4	0.06	0	1.51
16	569.4	0.06	0	0.59
17	3157.1	0.04	0	1.06
18	2191.3	0.06	0	1.89
19	4086.2	0.04	0	0.19
20	867.5	0.04	0	0.56
21	1840.3	0.04	0	0.47
21_A1	1647.2	0.04	0	1.66
21_A2	9.2	0.03	100	0.96
21_A3	46.5	0.03	100	0.56
21_A4	43.1	0.03	100	0.40
21_B1	3.8	0.04	0	0.31
21_B2	3.2	0.03	100	6.22
21_B3	5.9	0.03	100	0.79
21_C1	50.2	0.04	0	1.95
21_C2	10.8	0.03	100	2.49
22	2282.7	0.04	0	0.20

Appendix C

Annual maximum series

Table C-1 033027 Annual maximum series

Year	Daily rainfall (mm)
1913	119.1
1914	66
1915	50.8
1916	162.6
1917	298.5
1918	140.5
1919	68.8
1920	110.2
1921	123.2
1922	151.6
1923	160
1924	108.5
1925	54.6
1926	103.6
1927	94
1928	121.9
1929	275.6
1930	104.1
1931	256.8
1932	88.9
1933	120.7
1934	20.1
1935	121.9
1936	0
1937	139.2
1938	83.1
1939	271.5
1940	171.5
1941	259.8
1942	238.3
1943	171.5
1944	94.5
1945	317.5
1946	409.7
1947	121.4
1948	145.5
1949	318.8

Year	Daily rainfall (mm)
1950	311.2
1951	71.6
1952	134.1
1953	274.3
1954	259.1
1955	485.1
1956	156.2
1957	576.6
1958	218.4
1959	149.9
1960	90.9
1961	153.9
1962	138.4
1963	86.9
1964	61
1965	71.1
1966	112.3
1967	194.1
1968	84.6
1969	556.5
1970	0
1971	5.8
1972	58.4
1973	188.2
1974	116.4
1975	169.6
1976	0
1977	289.1
1978	379.2
1979	324.6
1980	117.2
1981	110.5
1982	114
1983	114
1984	228
1985	86
1986	79
1987	232

Year	Daily rainfall (mm)
1988	221
1989	239
1990	317
1991	74
1992	168
1993	96.5
1994	71
1995	103
1996	193
1997	95
1998	176
1999	266
2000	141
2001	282
2002	86
2003	81
2004	171
2005	52
2006	235
2007	267
2008	204

Table C-2 033054 Annual maximum series

Year	Daily rainfall (mm)
1886	96
1887	130.8
1888	50.8
1889	142.2
1890	96
1891	37.3
1892	65.5
1893	106.7
1894	62.2
1895	142.2
1896	63
1897	216.7
1898	115.6
1899	72.4

Year	Daily rainfall (mm)
1900	35.6
1901	39.9
1902	203.2
1903	76.2
1904	81.3
1905	78.7
1906	63.2
1907	97.8
1908	86.4
1909	160
1910	88.9
1911	77
1912	78.7
1913	89.2
1914	85.1
1915	59.2
1916	86.6
1917	118.1
1918	28.2
1919	40.6
1920	82
1921	63.5
1922	80.8
1923	52.1
1924	132.8
1925	71.9
1926	71.4
1927	85.6
1928	63
1929	142.7
1930	41.4
1931	67.6
1932	75.4
1933	72.6
1934	99.3
1935	102.9
1936	61.7
1937	57.9

Year	Daily rainfall (mm)
1938	41.9
1939	165.9
1940	84.6
1941	66
1942	109
1943	66.3
1944	35.8
1945	81.3
1946	162.6
1947	45.7
1948	42.2
1949	157.5
1950	86.1
1951	80.3
1952	78.5
1953	123.7
1954	165.1
1955	85.3
1956	69.1
1957	244.1
1958	141.2
1959	67.3
1960	82.6
1961	58.4
1962	98.3
1963	67.3
1964	42.7
1965	89.4
1966	52.6
1967	105.4
1968	69.1
1969	259.6
1970	69.3
1971	52.3
1972	36.8
1973	124
1974	97.6
1975	88

Year	Daily rainfall (mm)
1976	88.6
1977	86
1978	179.8
1979	116.4
1980	101.6
1981	71
1982	166
1983	44.6
1984	109.2
1985	142
1986	150
1987	317.8
1988	163.6
1989	240
1990	267.2
1991	33
1992	35.6
1993	82.6
1994	37.8
1995	72.5
1996	105
1997	106.5
1998	122
1999	71
2000	109.2
2001	106
2002	76.2
2003	117
2004	49.8
2005	52
2006	81.8
2007	170
2008	81.4
2009	117.2
2010	164
2011	100.6
2012	133.2
2013	90

Year	Daily rainfall (mm)
2014	95
2015	73
2016	220
2017	98.7
2018	113.4
2019	41

Appendix D

Hydraulic structures

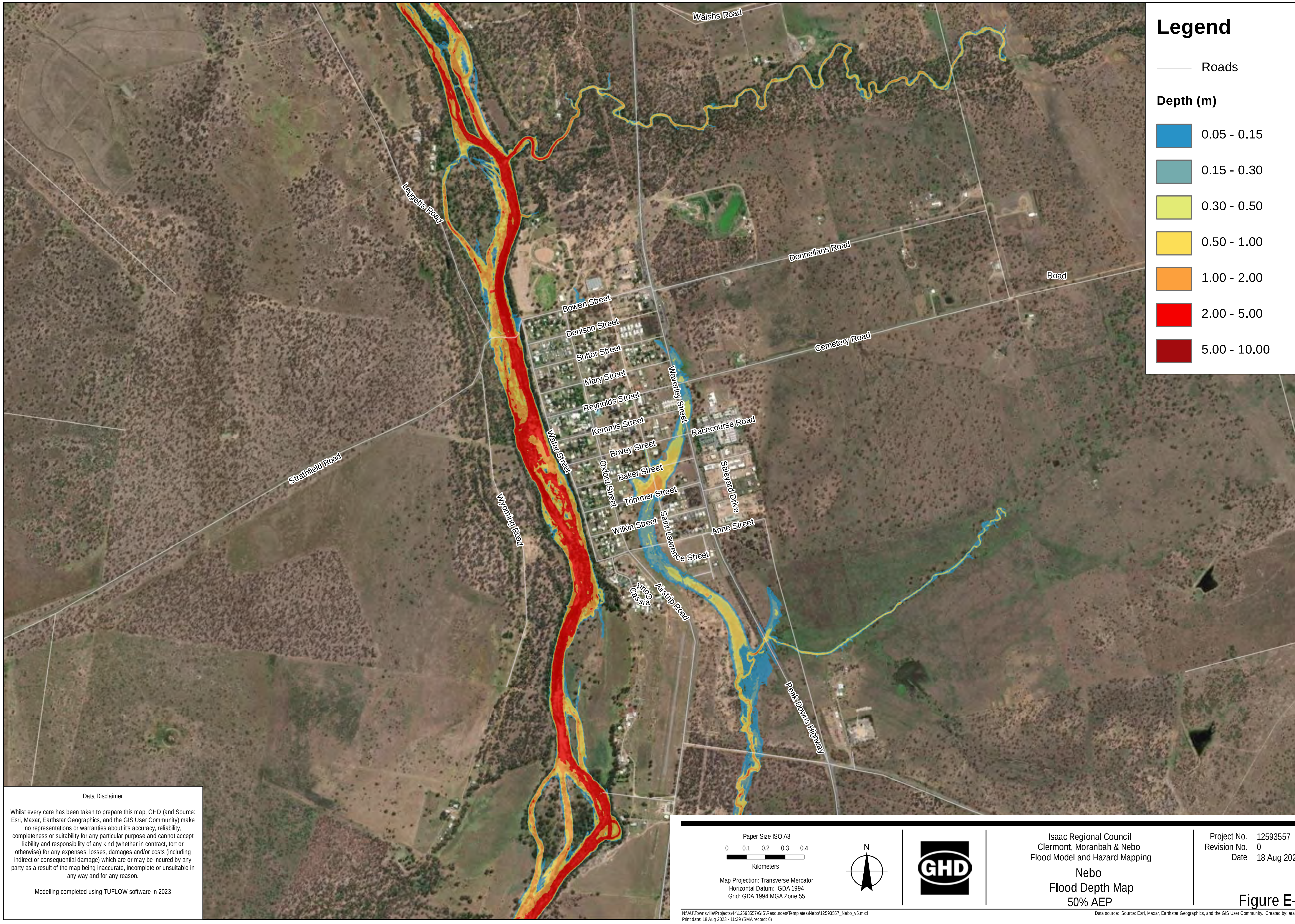
Structure ID	Length (m)	Upstream invert level (m AHD)	Downstream invert level (m AHD)	Structure configuration/size
28D32	284	200.25	198.29	1/1200
28D41	10	200.58	200.54	3/1200x300
28DEA	7	201.35	201	1/375
28DE2	22	203.12	202.98	1/525
28DE3	31	204.85	204.53	1/375
28DDF	10	202.36	202.33	2/375
28D25	219	197.645	196	1/600
28D26	206	199.19	197.645	1/600
28D24	19	199.77	199.2	1/375
2.80E+04	203	199.79	197.645	1/375
28D27	5	200.53	200.52	1/375
28D28	5	200.7	200.7	1/375
28D2D	12	200.46	200.45	1/450
28D2F	11	200.76	200.74	1/1210x450
28D50	168	198.47	197	1/750
28D47	3	200.19	200.19	1/900x450
28D5D	13	200.05	199.93	1/750x450
28D59	13	200.16	200.11	1/1200x300
28D60	4	200.15	200.15	1/1200x450
28D67	4	200.11	200.06	1/1200x450
28D6D	4	200.25	200.25	1/900x600
28D74	4	200.25	200.23	1/900x600
28D76	4	200.21	200.18	1/200
28D78	4	200.05	200.03	1/375
28DDD	20	199.63	199.44	1/375
28CD0	7	200.95	200.75	1/300
28CD5	235	198.01	197	1/600
28E02	3	200.42	200.42	1/450
28CED	214	198.93	198.01	1/600
28CE1	5	199.71	199.67	1/1210x450
28CEC	18	199.18	198.93	1/600
28CDC	11	198.78	198.73	2/1210x450
28CF2	4	199.6	199.59	1/900x600
28CF6	4	199.55	199.52	1/900
28CFA	5	199.45	199.43	1/1200x450
28D00	1	199.39	199.38	1/1200x450
28D02	5	199.35	199.35	1/1210x700
28D08	4	199.36	199.35	1/1210x700
28D0B	4	199.3	199.31	1/1210x600
28D0F	5	199.25	199.24	1/1210x700

Structure ID	Length (m)	Upstream invert level (m AHD)	Downstream invert level (m AHD)	Structure configuration/size
28DD9	13	198.84	198.75	6/1210x470
28C75	2	200.51	200.45	1/300
28C7E	14	199.38	199.3	1/1210x390
28D7B	24	199.52	199.44	1/450
28CA1	4	199.23	199.22	1/1210x450
28CB0	4	199.13	199.13	1/1210x450
28CA6	6	199.2	199.18	1/1210x450
28CAA	7	199.17	199.15	1/1210x450
28CAC	4	199.18	199.13	1/1210x450
28CB6	4	199.14	199.13	1/1210x370
28CBA	4	199.06	199.06	1/1210x600
28CCD	16	199.23	198.89	2/1210x450
28DB1	7	198.51	198.43	3/1210x600
28C58	17	199.11	199	2/750x380
28C5F	8	198.9	198.86	1/520
28C5E	5	198.87	198.84	1/520
28C5B	5	198.86	198.85	1/520
28C69	3	199.25	199.24	1/300
28D92	4	198.2	198.2	2/1210x900
28C65	19	199.1	199.06	1/900x450
28C61	12	198.89	198.85	1/450
28C71	4	198.82	198.8	1/450
28C74	5	198.77	198.75	1/520
28C26	13	198.7	198.64	2/900x450
28D81	4	198.58	198.56	1/900x450
28C44	12	198.53	198.5	2/1210x750
28C47	12	197.75	197.56	1/375
28D8B	4	197.4	197.4	1/1200x900
28C0E	5	198.68	198.58	1/375
28C15	14	198.27	198.23	4/900x380
28C1D	7	198.1	198.06	1/375
28DFB	5	198.18	198.12	1/375
28C1E	6	198.01	197.92	1/375
28C20	12	197.81	197.8	1/375
28C1F	8	197.78	197.72	1/300
28BE7	14	198.61	197.8	2/1200x610
28BEC	17	197.831	197.81	1/375
28BF0	3	198.32	197.63	1/900x450
28BF7	11	197.73	196.52	5/1210x460
28DFF	5	199.07	198.97	1/375

Structure ID	Length (m)	Upstream invert level (m AHD)	Downstream invert level (m AHD)	Structure configuration/size
28DE8	2	198.79	198.78	1/300
28BD7	11	199.22	199.13	1/610x450
28BDE	11	197.46	197.4	2/1210x600
28DA7	13	197.91	197.84	5/1210x770
28D19	11	200.62	200.43	1/1200x300
28D52	3	198.47	198.47	1/375
28D77	4	200.18	200.18	1/375
28D79	1	199.91	199.89	1/375
28D14	4	199.22	199.19	1/900x450
28C9D	6	199.27	199.25	1/1210x450
28CBE	1	198.99	198.99	1/1210x600
28DFC	8	197.48	197.42	1/375
28C0D	5	198.9	198.83	1/375
28C08	5	198.7	198.67	1/375
28BE2	11	199.65	199.46	1/1200x600
28C21	5	199.84	199.72	1/300
28DE9	7	200.52	200.33	1/375
28C48	2	200.59	200.56	1/1210x380

Appendix E

Flood mapping



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Paper Size ISO A3

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping

Nebo
Flood Depth Map
50% AEP

Project No. 12593557
Revision No. 0
Date 18 Aug 2023

Figure E-1

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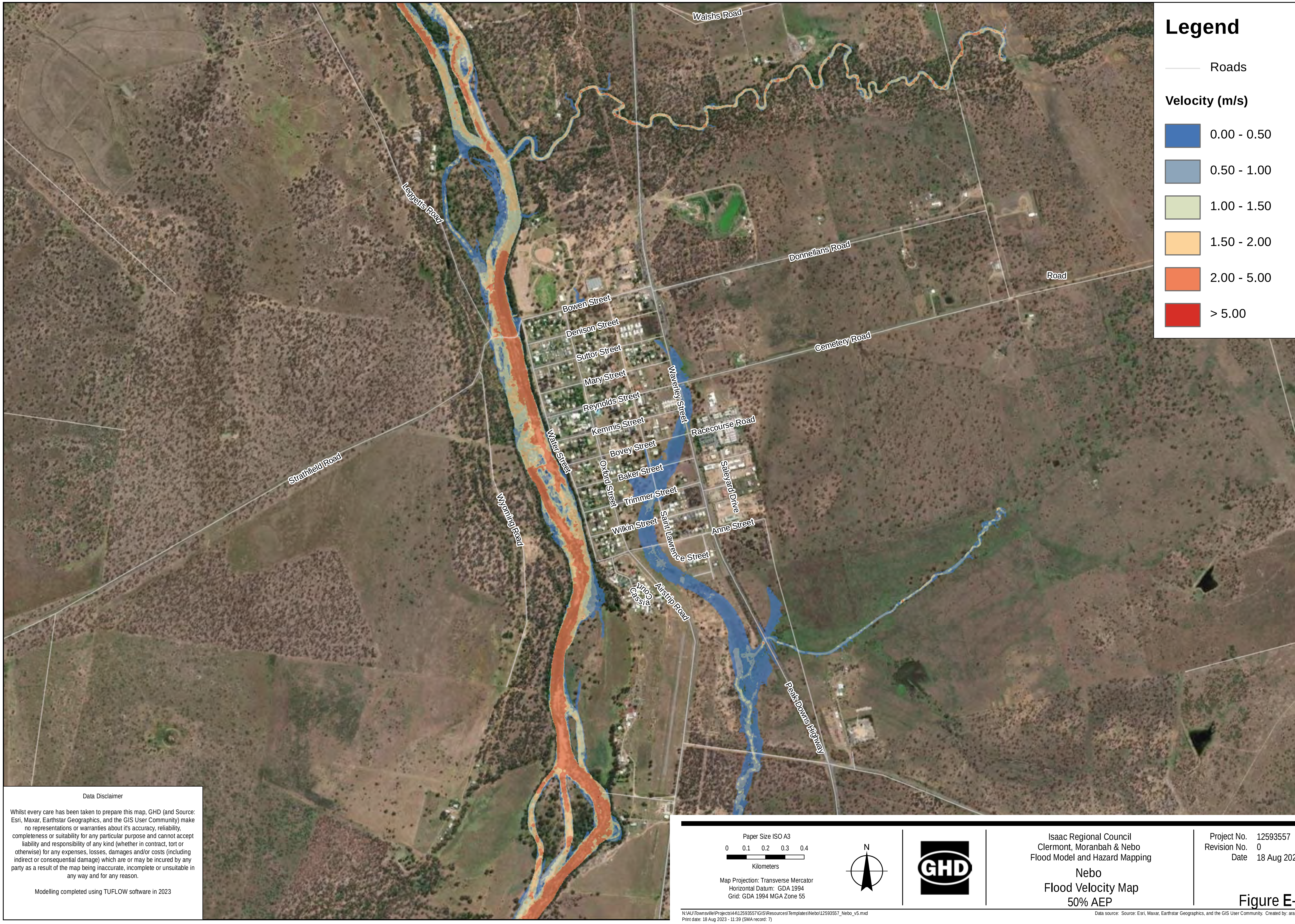

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Modelling completed using TUFLOW software in 2023

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping

Nebo
Flood Velocity Map
50% AEP

Project No. 12593557
Revision No. 0
Date 18 Aug 2023

Figure E-2

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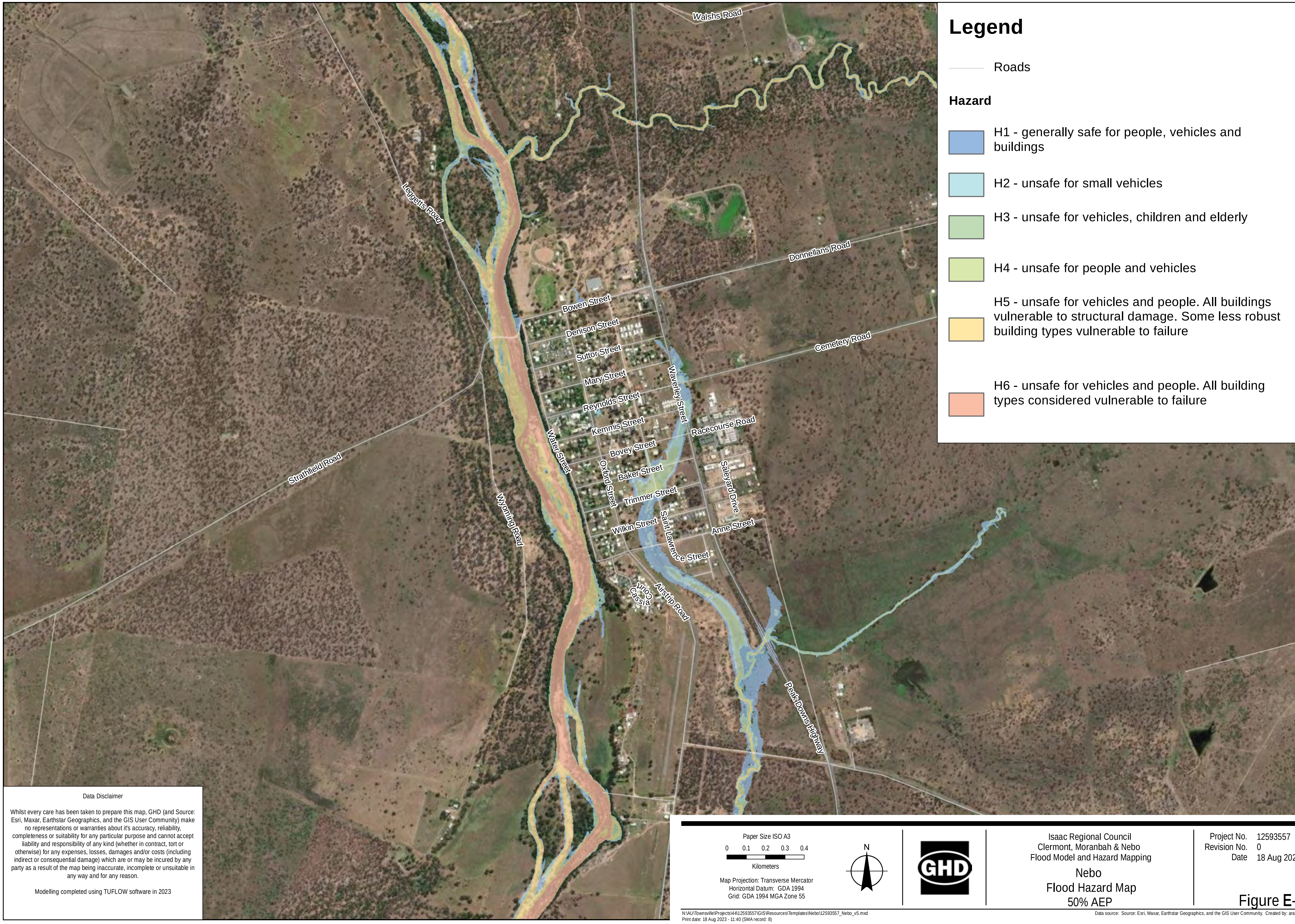

Legend

Roads

Hazard

- H1 - generally safe for people, vehicles and buildings
- H2 - unsafe for small vehicles
- H3 - unsafe for vehicles, children and elderly
- H4 - unsafe for people and vehicles
- H5 - unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust building types vulnerable to failure
- H6 - unsafe for vehicles and people. All building types considered vulnerable to failure

Modelling completed using TUFLOW software in 2023

Paper Size ISO A3

0 0.1 0.2 0.3 0.4
Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping

Nebo
Flood Hazard Map
50% AEP

Project No. 12593557
Revision No. 0
Date 18 Aug 2023

Figure E-3

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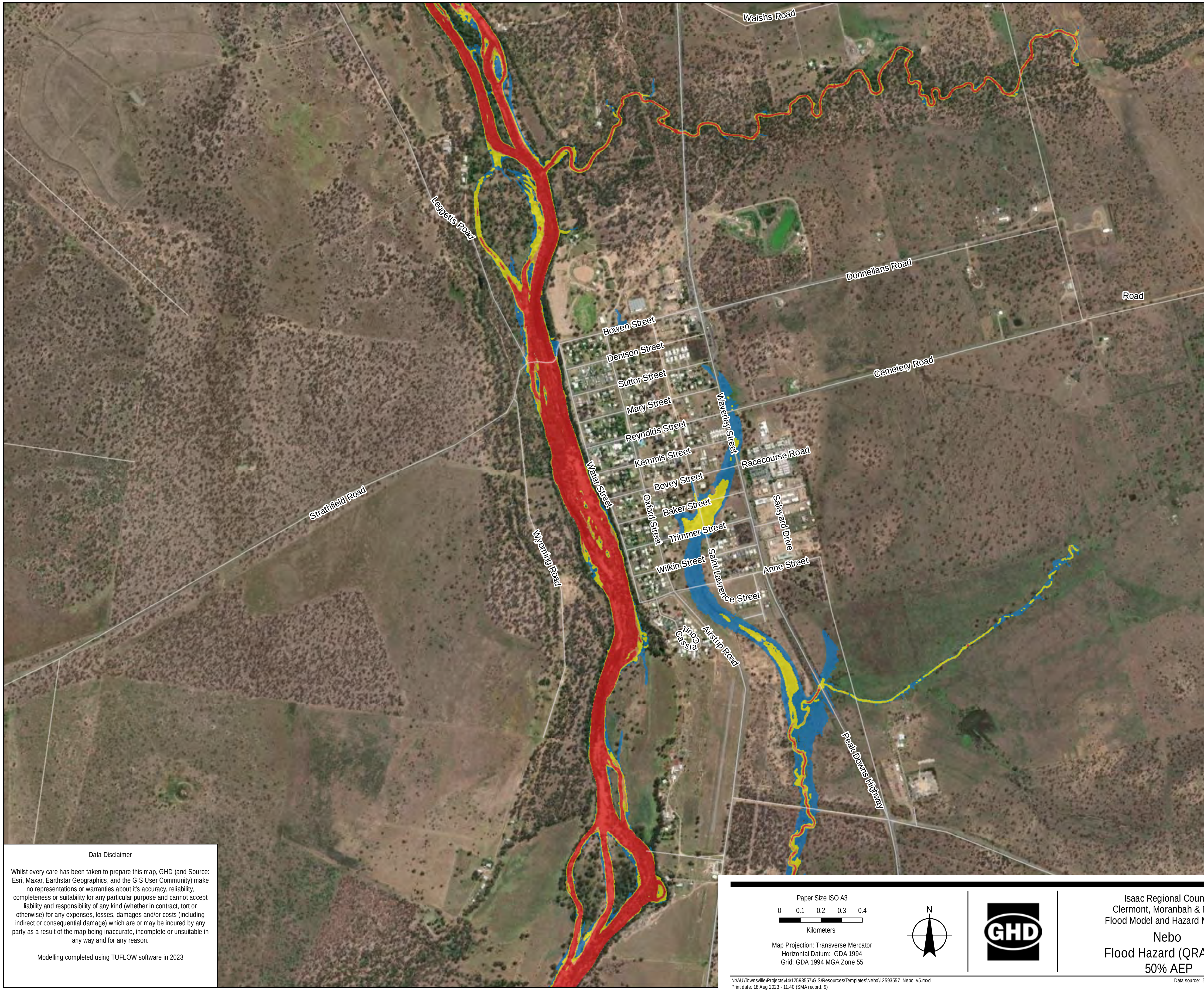

Legend

Roads

Flood Hazard (QRA)

- Low Hazard
- Significant Hazard
- High Hazard
- Extreme Hazard

Data Disclaimer

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Paper Size ISO A3

0 0.1 0.2 0.3 0.4

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping

Nebo
Flood Hazard (QRA) Map
50% AEP

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Revision No. 0
Date 18 Aug 2023

Figure E-4

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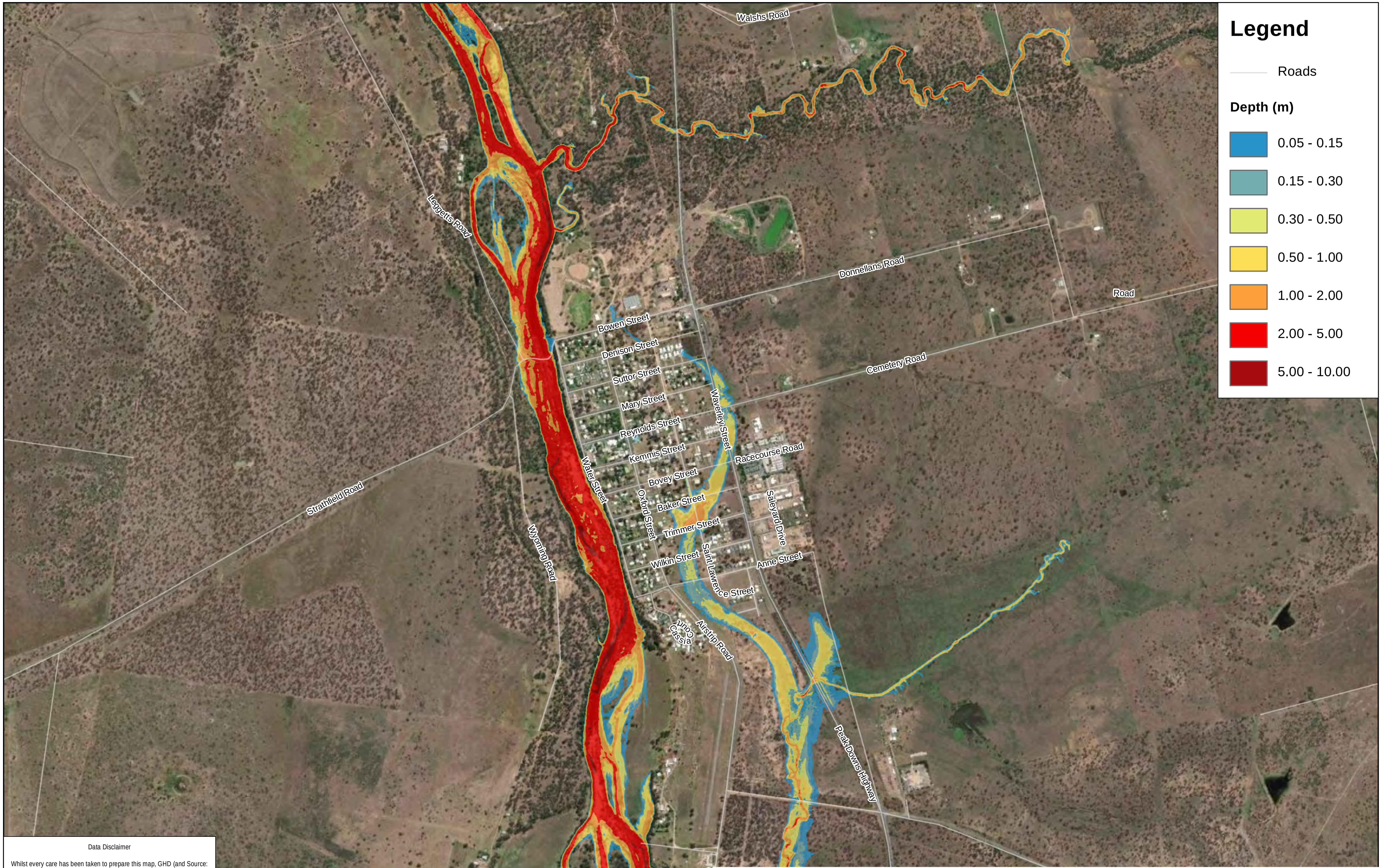

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Paper Size ISO A3

0 0.1 0.2 0.3 0.4

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

GHD

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping

Nebo
Flood Depth Map
20% AEP

Project No. 12593557
Revision No. 0
Date 18 Aug 2023

Figure E-5

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Modelling completed using TUFLOW software in 2023

Paper Size ISO A3

0 0.1 0.2 0.3 0.4

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

GHD

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping

Nebo
Flood Velocity Map
20% AEP

Project No. 12593557
Revision No. 0
Date 18 Aug 2023

Figure E-6

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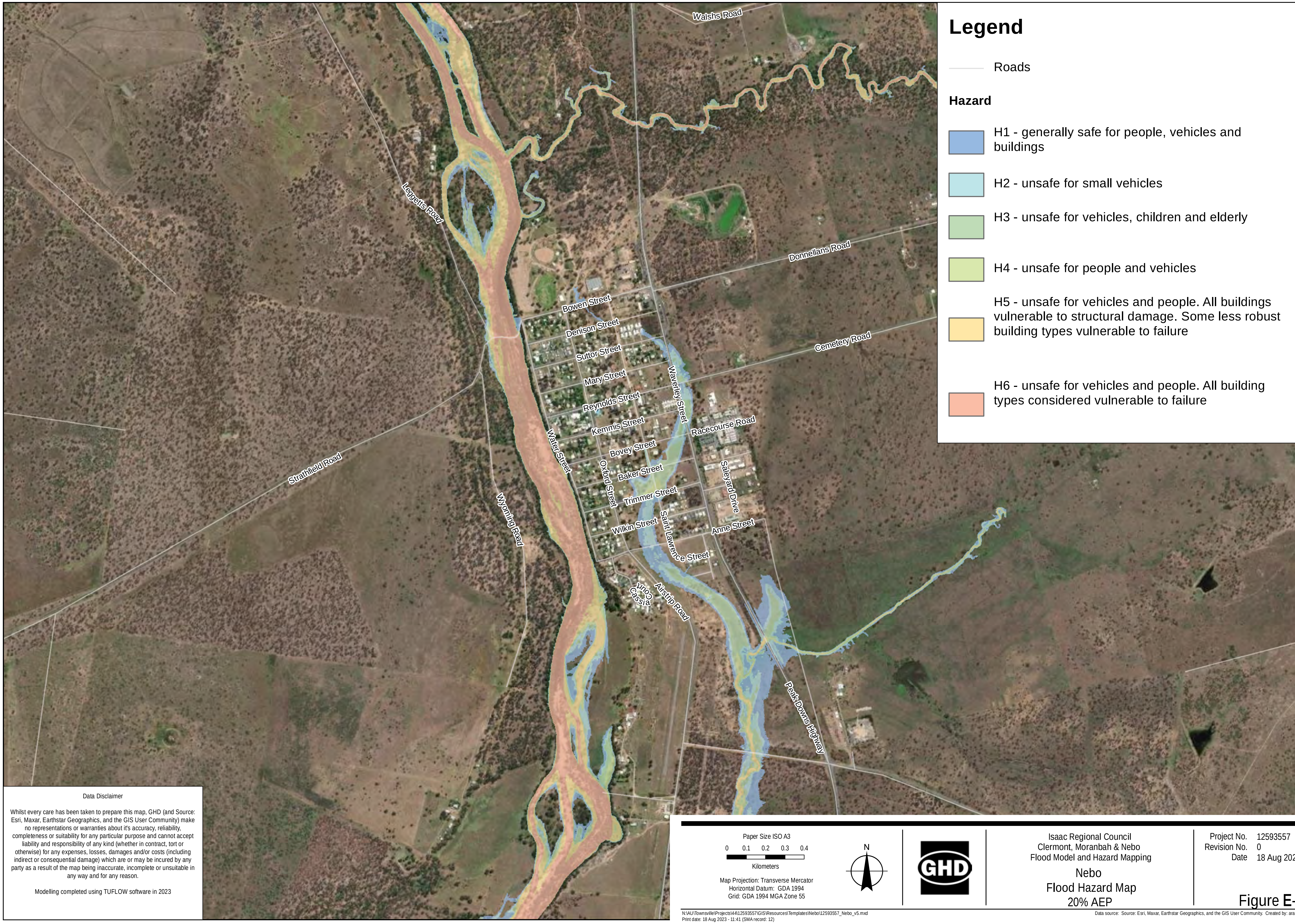

Legend

Roads

Hazard

- H1 - generally safe for people, vehicles and buildings
- H2 - unsafe for small vehicles
- H3 - unsafe for vehicles, children and elderly
- H4 - unsafe for people and vehicles
- H5 - unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust building types vulnerable to failure
- H6 - unsafe for vehicles and people. All building types considered vulnerable to failure

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Modelling completed using TUFLOW software in 2023

Paper Size ISO A3

0 0.1 0.2 0.3 0.4

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping

Nebo
Flood Hazard Map
20% AEP

Project No. 12593557
Revision No. 0
Date 18 Aug 2023

Figure E-7

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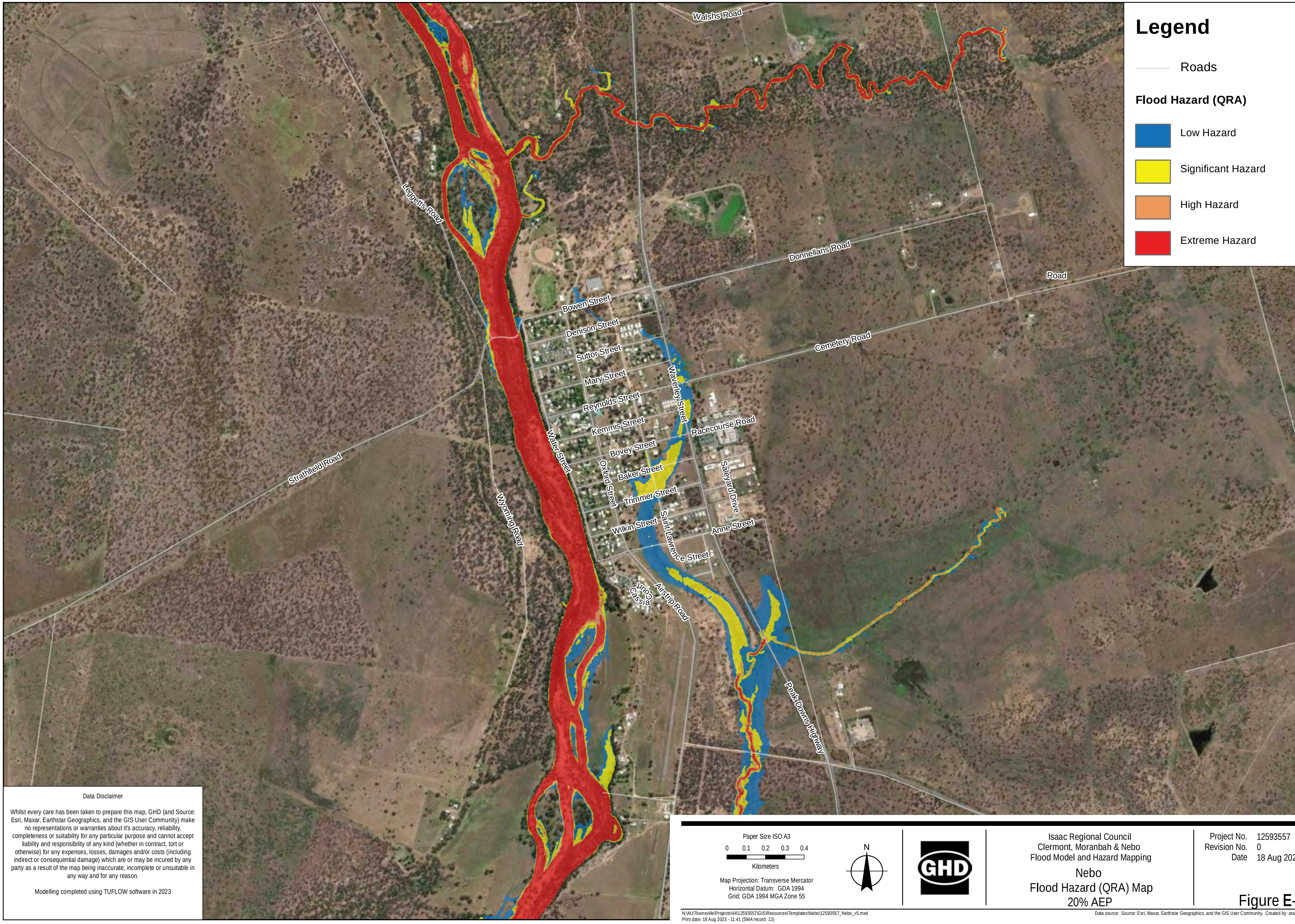

Legend

Roads

Flood Hazard (QRA)

- Low Hazard
- Significant Hazard
- High Hazard
- Extreme Hazard

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Modelling completed using TUFLOW software in 2023

Paper Size ISO A3

0 0.1 0.2 0.3 0.4

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

GHD

Isaac Regional Council
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Flood Model and Hazard Mapping

Nebo
Flood Hazard (QRA) Map
20% AEP

Project No. 12593557
Revision No. 0
Date 18 Aug 2023

Figure E-8

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Document Set ID: 5109910
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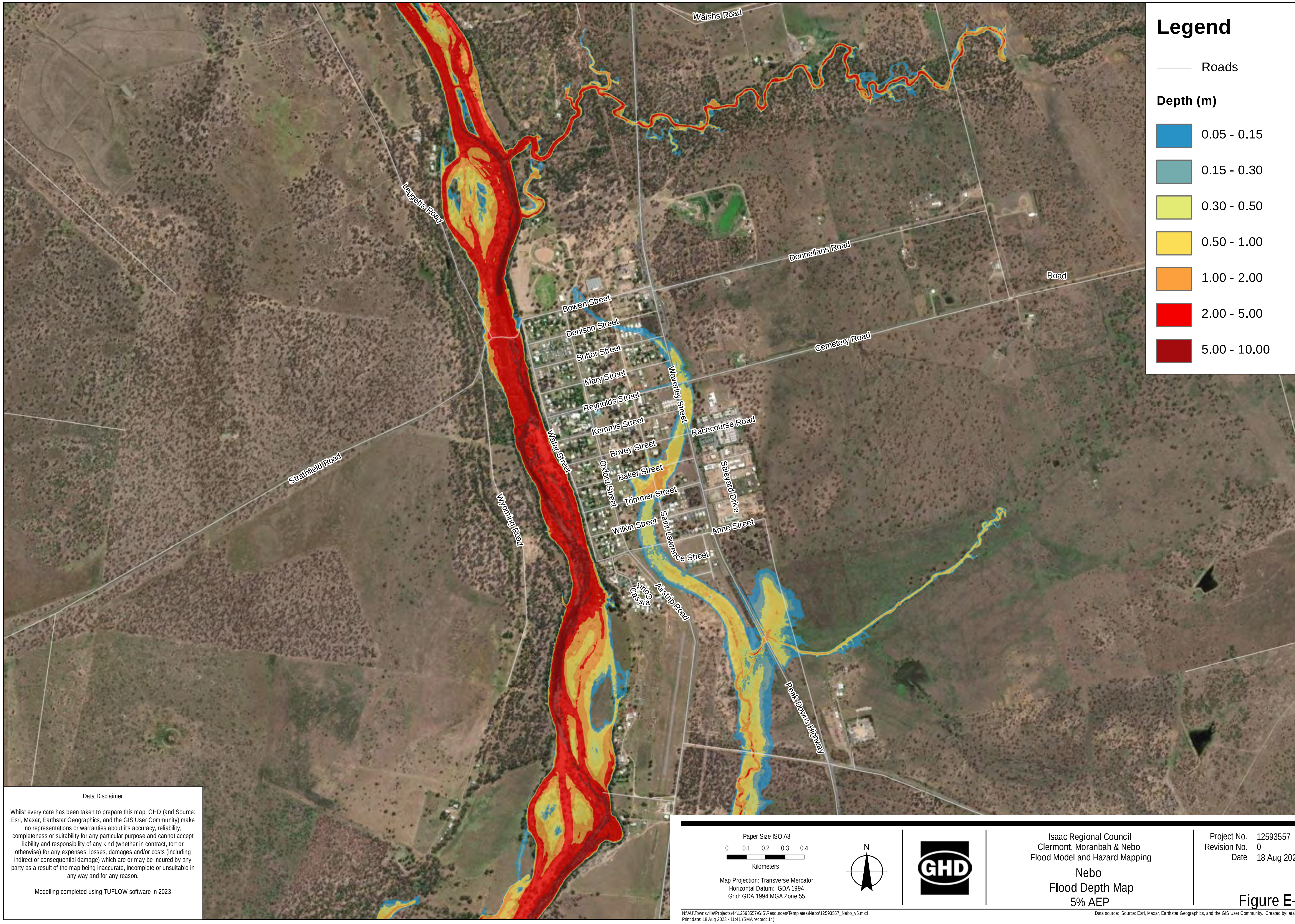

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Modelling completed using TUFLOW software in 2023

Paper Size ISO A3

0 0.1 0.2 0.3 0.4

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping

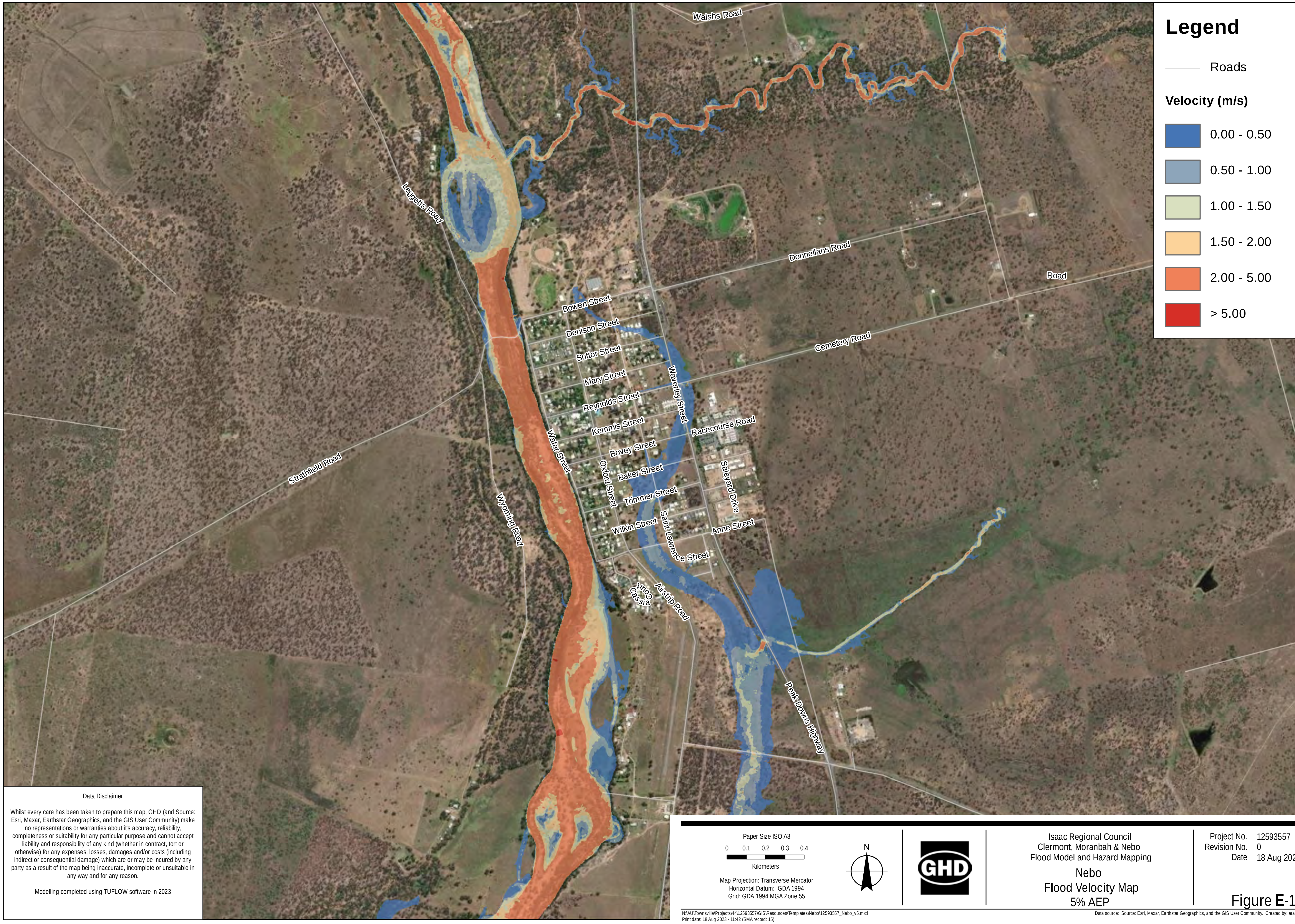
Nebo
Flood Depth Map
5% AEP

Project No. 12593557
Revision No. 0
Date 18 Aug 2023

Figure E-9

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Nebo\12593557_Nebo_v5.mxd
Print date: 18 Aug 2023 - 11:41 (SMA record: 14)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: aramos2



Legend

Roads

Velocity (m/s)

- 0.00 - 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 5.00
- > 5.00

Data Disclaimer

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Modelling completed using TUFLOW software in 2023

Paper Size ISO A3

0 0.1 0.2 0.3 0.4

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping

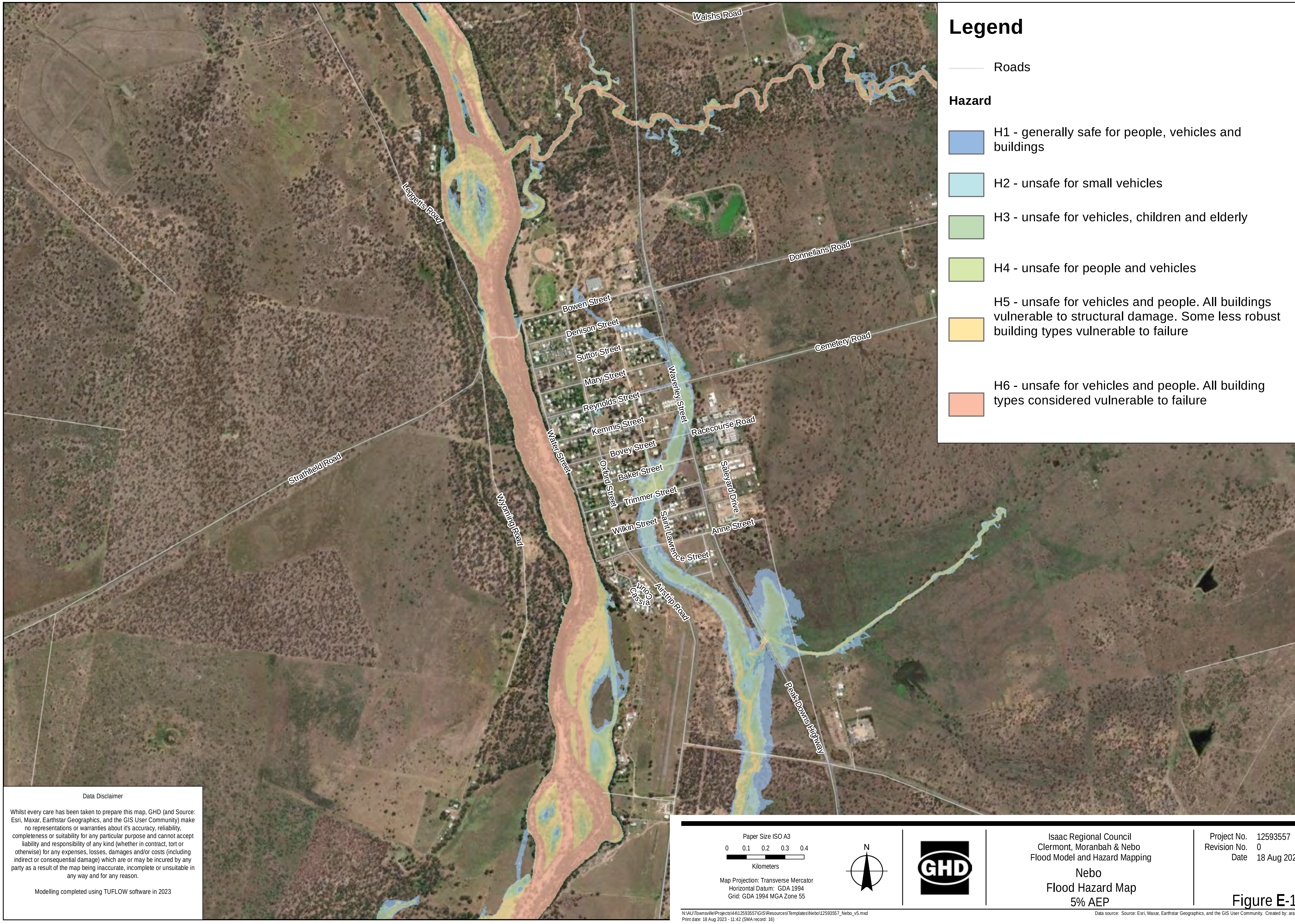
Nebo
Flood Velocity Map
5% AEP

Project No. 12593557
Revision No. 0
Date 18 Aug 2023

Figure **E**-10

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Nebo\12593557_Nebo_v5.mxd
Print date: 18 Aug 2023 - 11:42 (SMA record: 15)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: aramos2



Legend

Roads

Hazard

H1 - generally safe for people, vehicles and buildings

H2 - unsafe for small vehicles

H3 - unsafe for vehicles, children and elderly

H4 - unsafe for people and vehicles

H5 - unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust building types vulnerable to failure

H6 - unsafe for vehicles and people. All building types considered vulnerable to failure

Data Disclaimer

Modelling completed using TUFLOW software in 2023

Paper Size ISO A3

0 0.1 0.2 0.3 0.4

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping

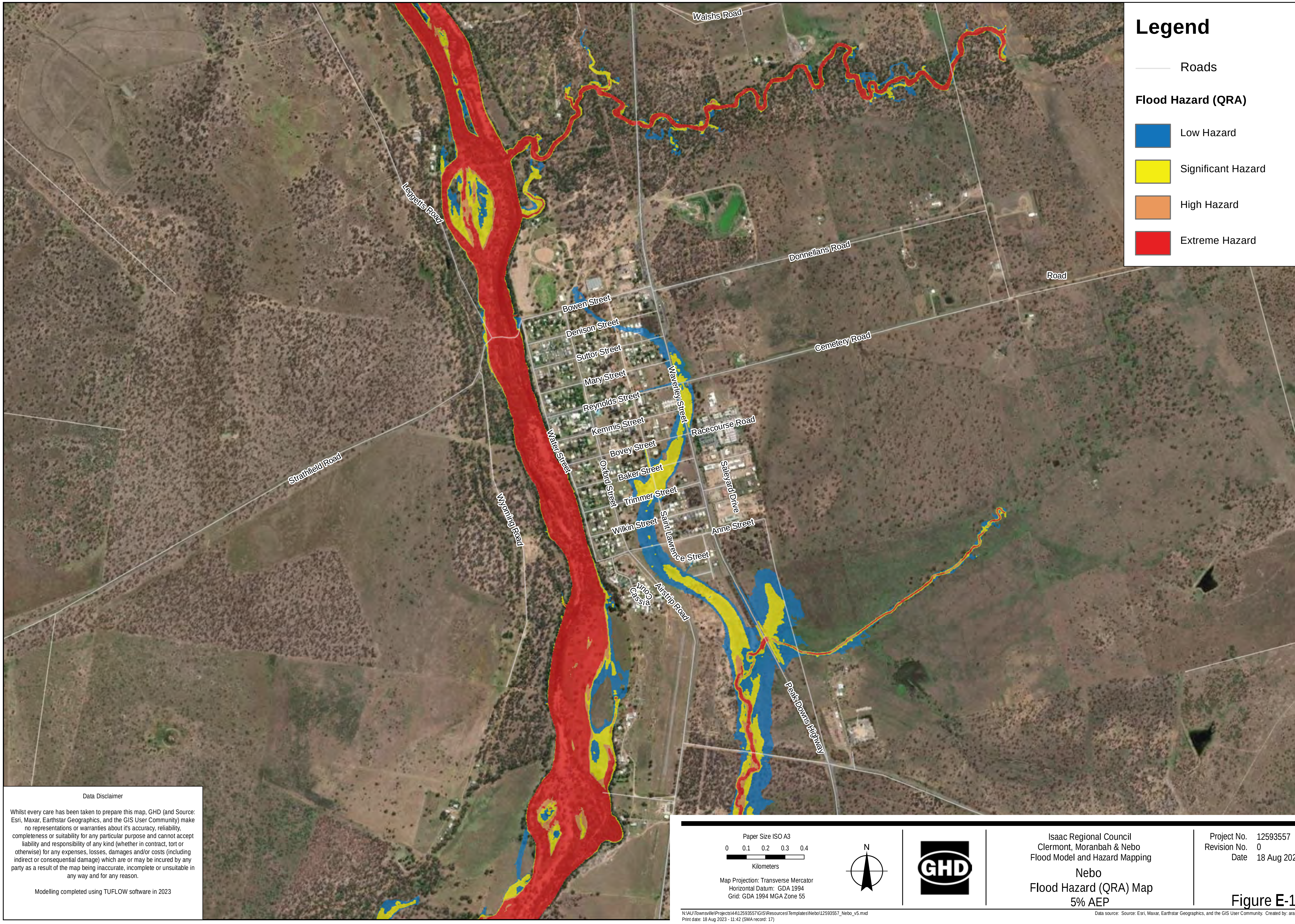
Nebo
Flood Hazard Map
5% AEP

Project No. 12593557
Revision No. 0
Date 18 Aug 2023

Figure E-11

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Nebo\12593557_Nebo_v5.mxd
Print date: 18 Aug 2023 - 11:42 (SMA record: 16)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: aramos2



Data Disclaimer

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Modelling completed using TUFLOW software in 2023

Paper Size ISO A3
0 0.1 0.2 0.3 0.4
Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping

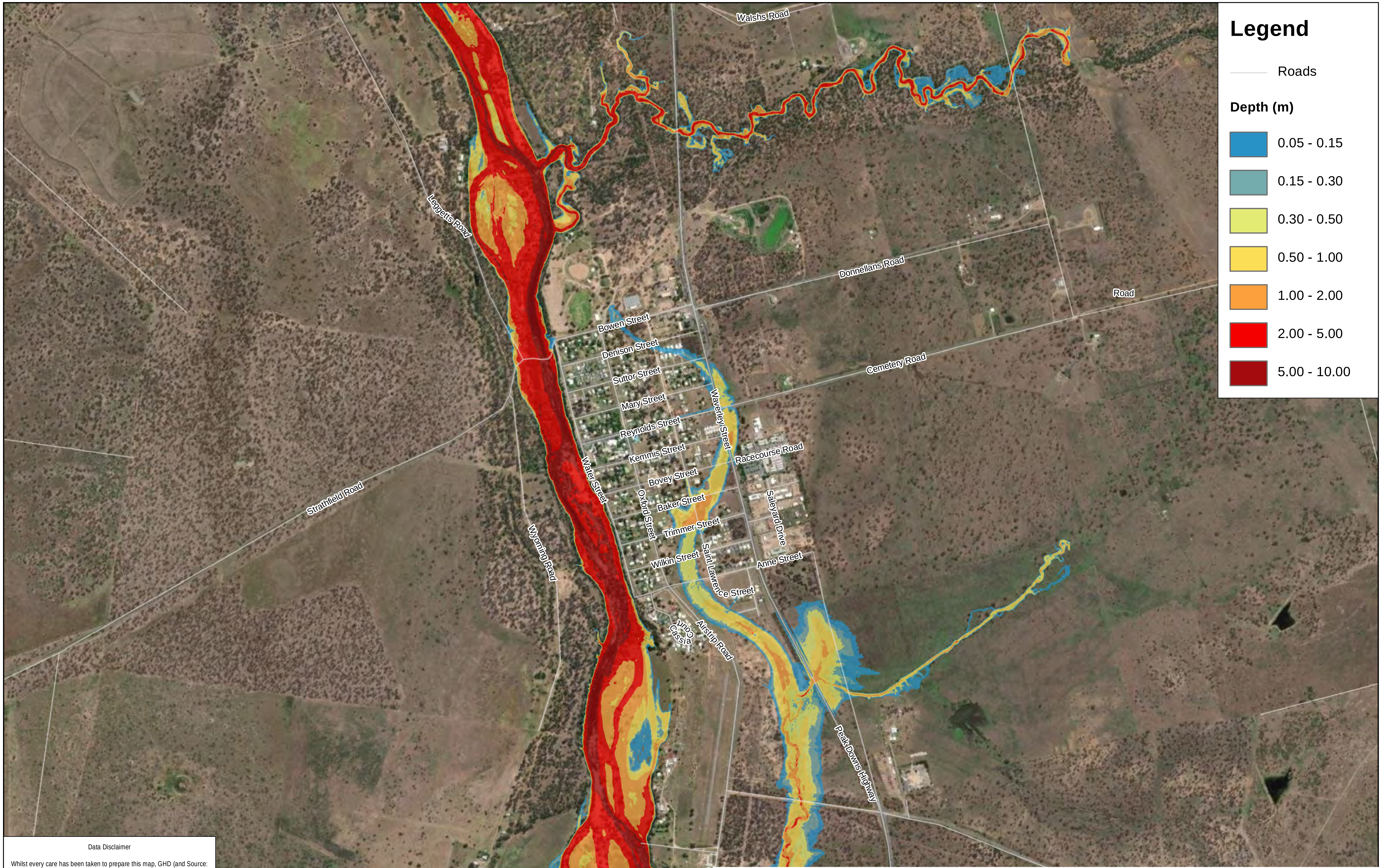
Nebo
Flood Hazard (QRA) Map
5% AEP

Project No. 12593557
Revision No. 0
Date 18 Aug 2023

Figure E-12

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Nebo\12593557_Nebo_v5.mxd
Print date: 18 Aug 2023 - 11:42 (SMA record: 17)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: aramos2



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Modelling completed using TUFLOW software in 2023

Paper Size ISO A3

0 0.1 0.2 0.3 0.4

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

GHD

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping

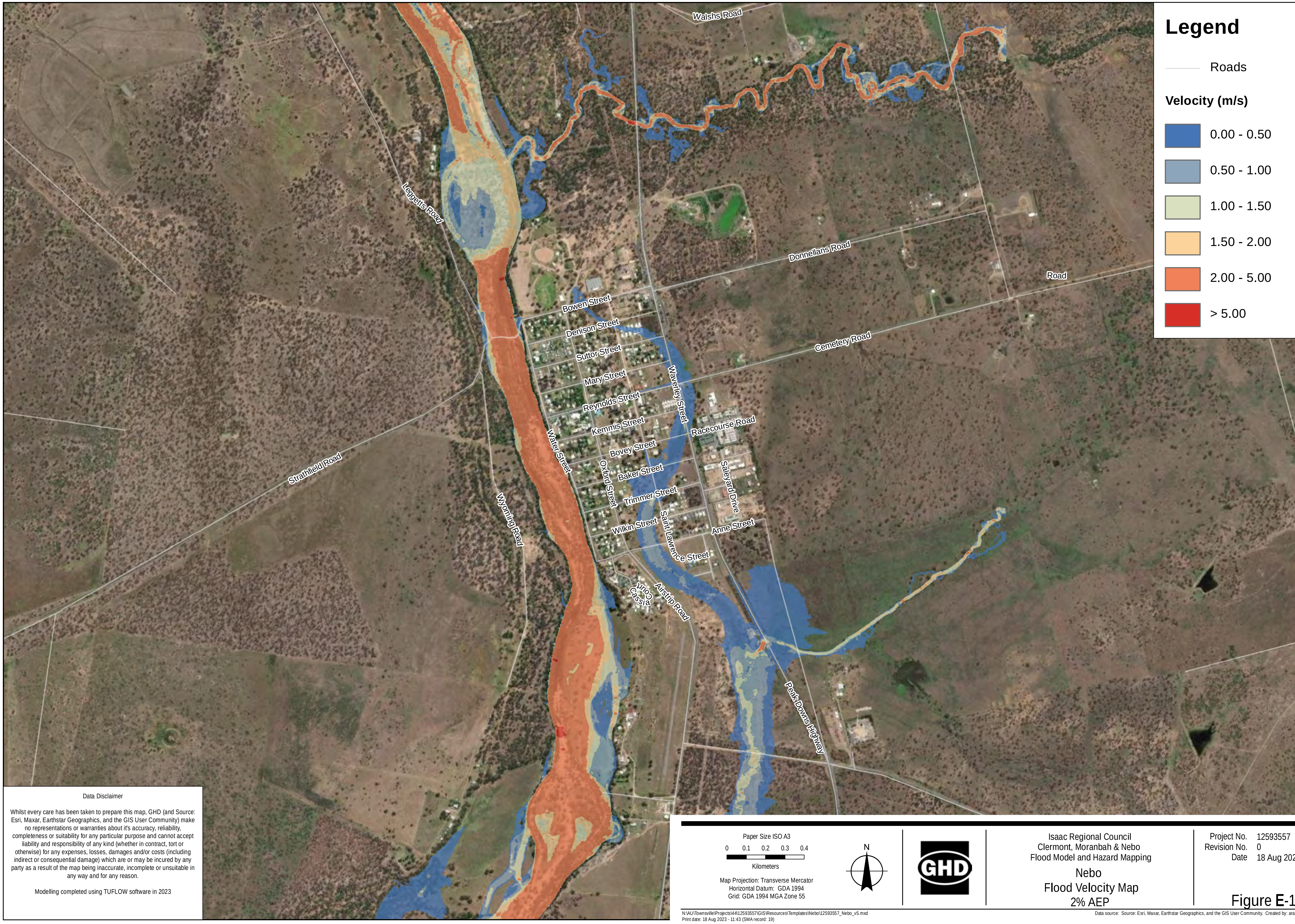
Nebo
Flood Depth Map
2% AEP

Project No. 12593557
Revision No. 0
Date 18 Aug 2023

Figure E-13

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Nebo\12593557_Nebo_v5.mxd
Print date: 18 Aug 2023 - 11:42 (SMA record: 18)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: aramos2



Legend

Roads

Velocity (m/s)

- 0.00 - 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 5.00
- > 5.00

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Modelling completed using TUFLOW software in 2023

Paper Size ISO A3

0 0.1 0.2 0.3 0.4

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping

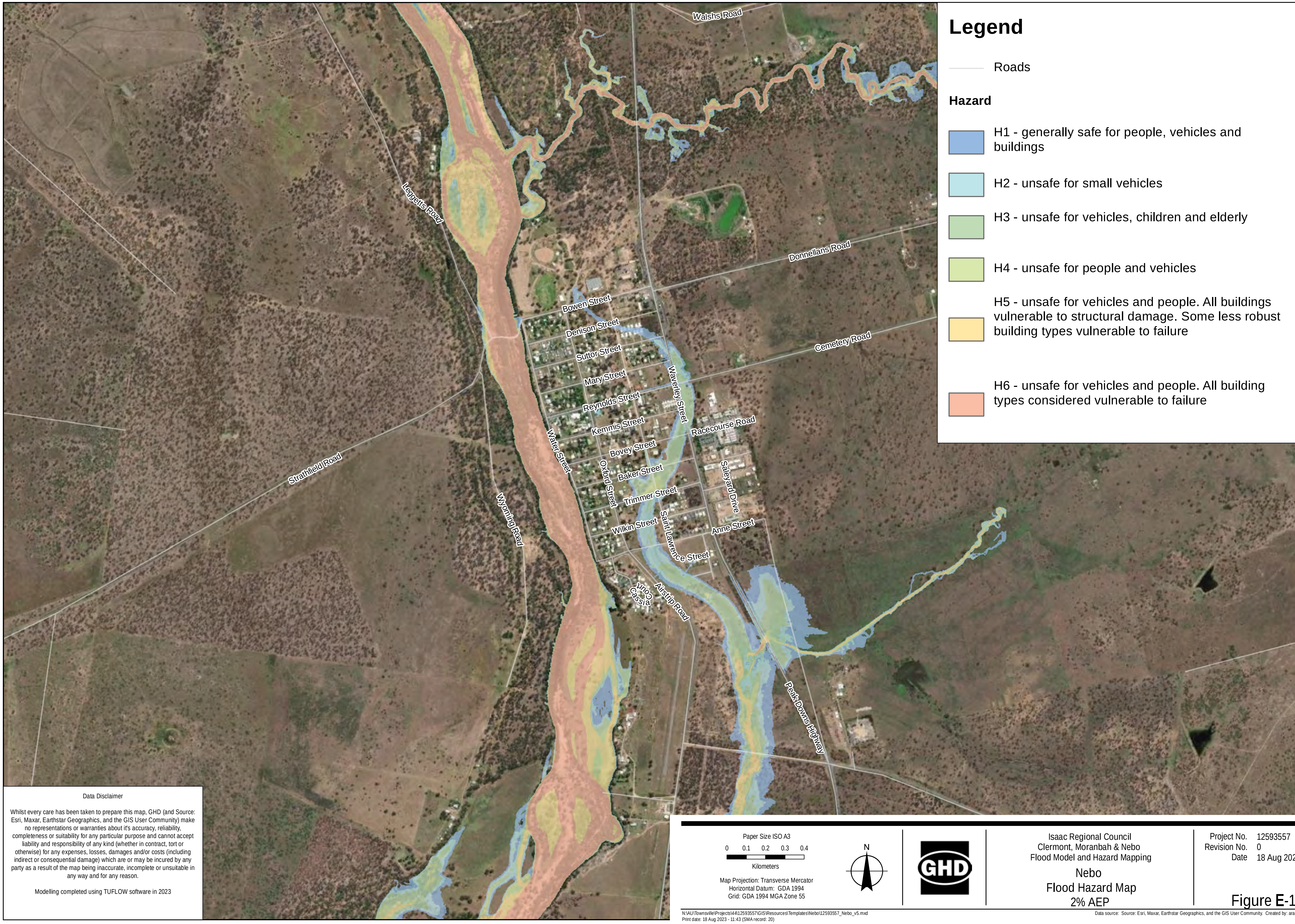
Nebo
Flood Velocity Map
2% AEP

Project No. 12593557
Revision No. 0
Date 18 Aug 2023

Figure E-14

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Nebo\12593557_Nebo_v5.mxd
Print date: 18 Aug 2023 - 11:43 (SMA record: 19)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: aramos2



Legend

Roads

Hazard

- H1 - generally safe for people, vehicles and buildings
- H2 - unsafe for small vehicles
- H3 - unsafe for vehicles, children and elderly
- H4 - unsafe for people and vehicles
- H5 - unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust building types vulnerable to failure
- H6 - unsafe for vehicles and people. All building types considered vulnerable to failure

Data Disclaimer

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Modelling completed using TUFLOW software in 2023

Paper Size ISO A3

0 0.1 0.2 0.3 0.4

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping

Nebo
Flood Hazard Map
2% AEP

Project No. 12593557
Revision No. 0
Date 18 Aug 2023

Figure **E**-15

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Nebo\12593557_Nebo_v5.mxd
Print date: 18 Aug 2023 - 11:43 (SMA record: 20)

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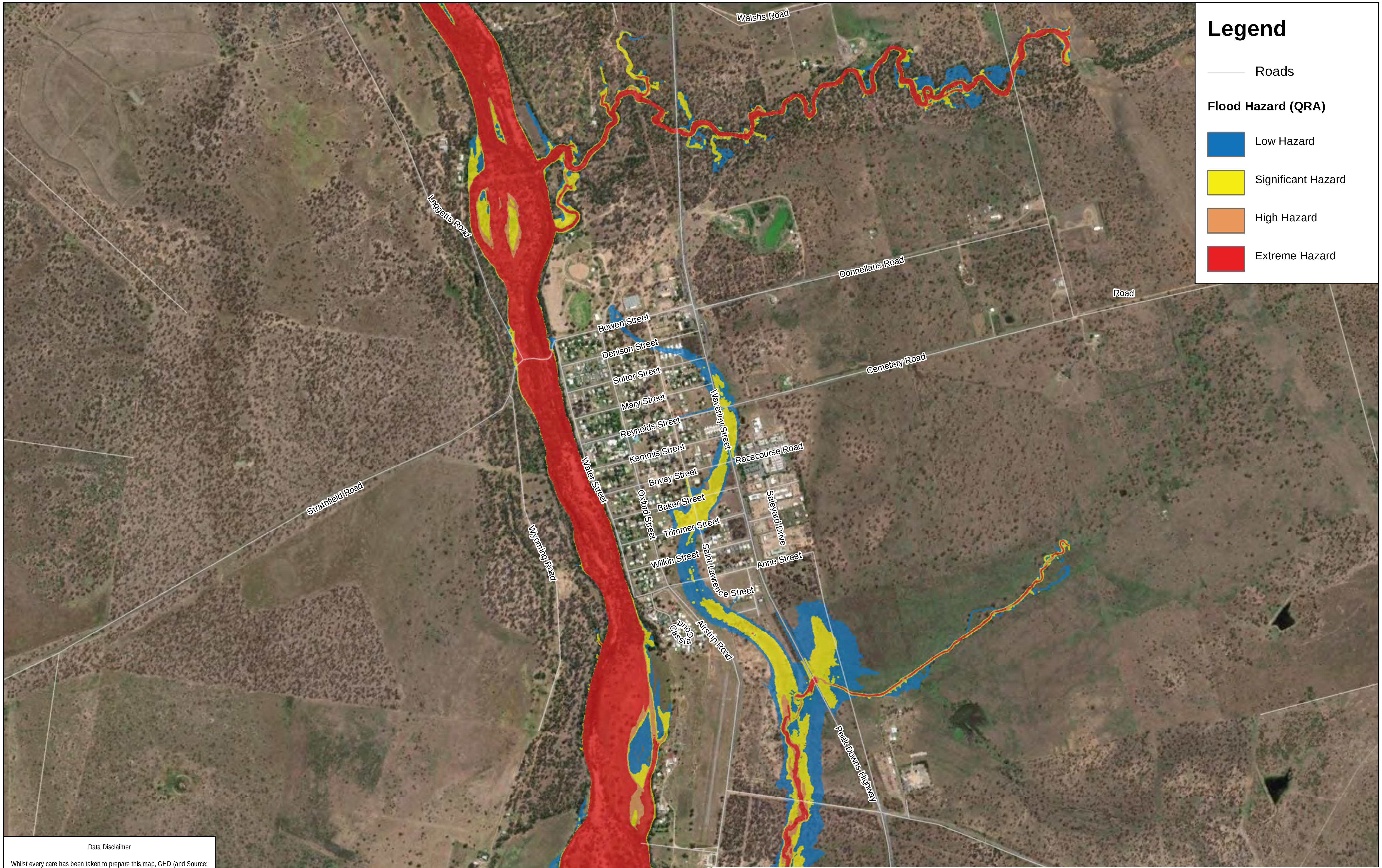

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Modelling completed using TUFLOW software in 2023

Paper Size ISO A3

0 0.1 0.2 0.3 0.4

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

GHD

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping

Nebo
Flood Hazard (QRA) Map
2% AEP

Project No. 12593557
Revision No. 0
Date 18 Aug 2023

Figure E-16

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Nebo\12593557_Nebo_v5.mxd
Print date: 18 Aug 2023 - 11:43 (SMA record: 21)

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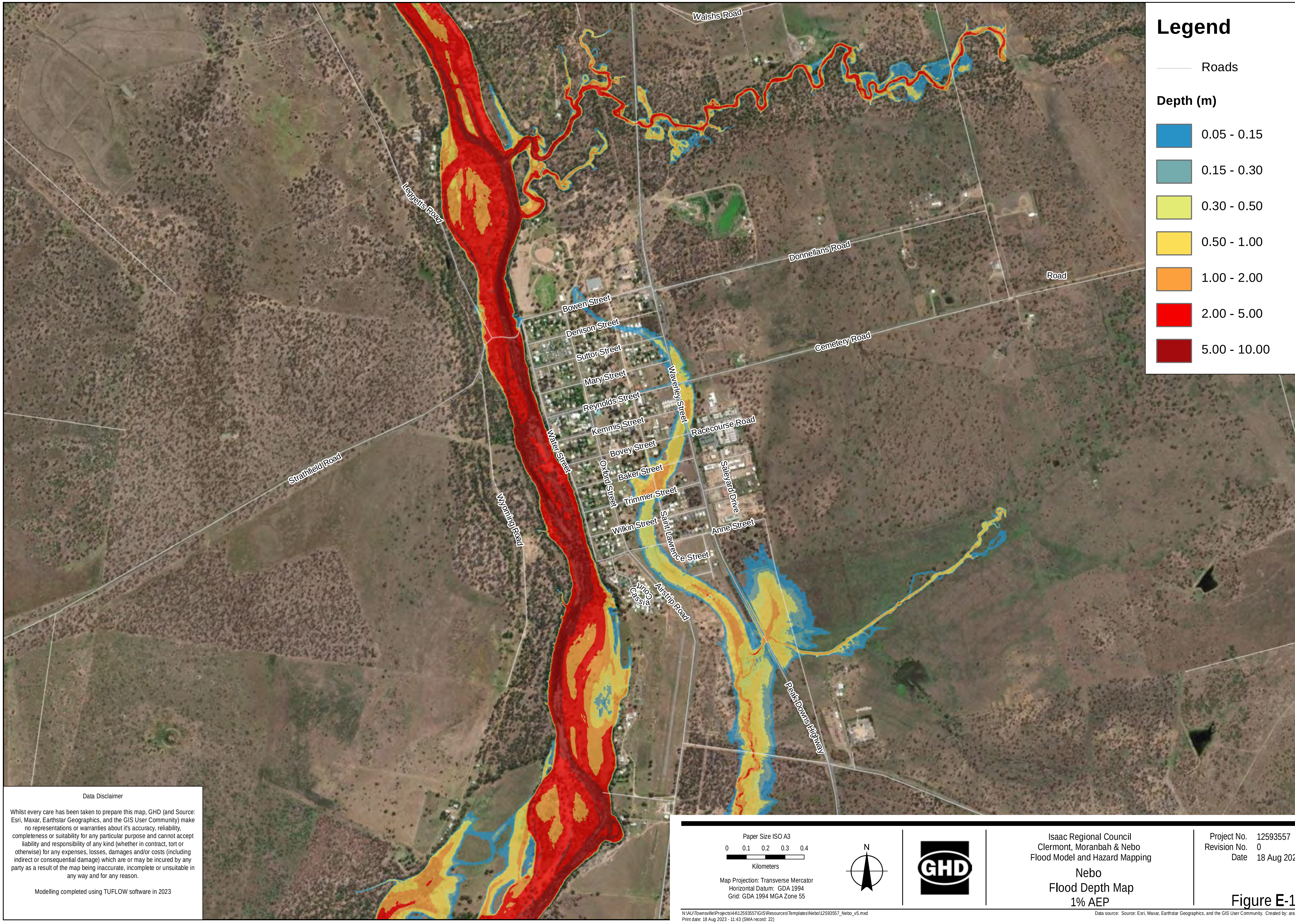

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Modelling completed using TUFLOW software in 2023

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping

Nebo
Flood Depth Map
1% AEP

Project No. 12593557
Revision No. 0
Date 18 Aug 2023

Figure E-17

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Nebo\12593557_Nebo_v5.mxd
Print date: 18 Aug 2023 - 11:43 (SMA record: 22)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: aramos2

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Modelling completed using TUFLOW software in 2023

Paper Size ISO A3
0 0.1 0.2 0.3 0.4
Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping

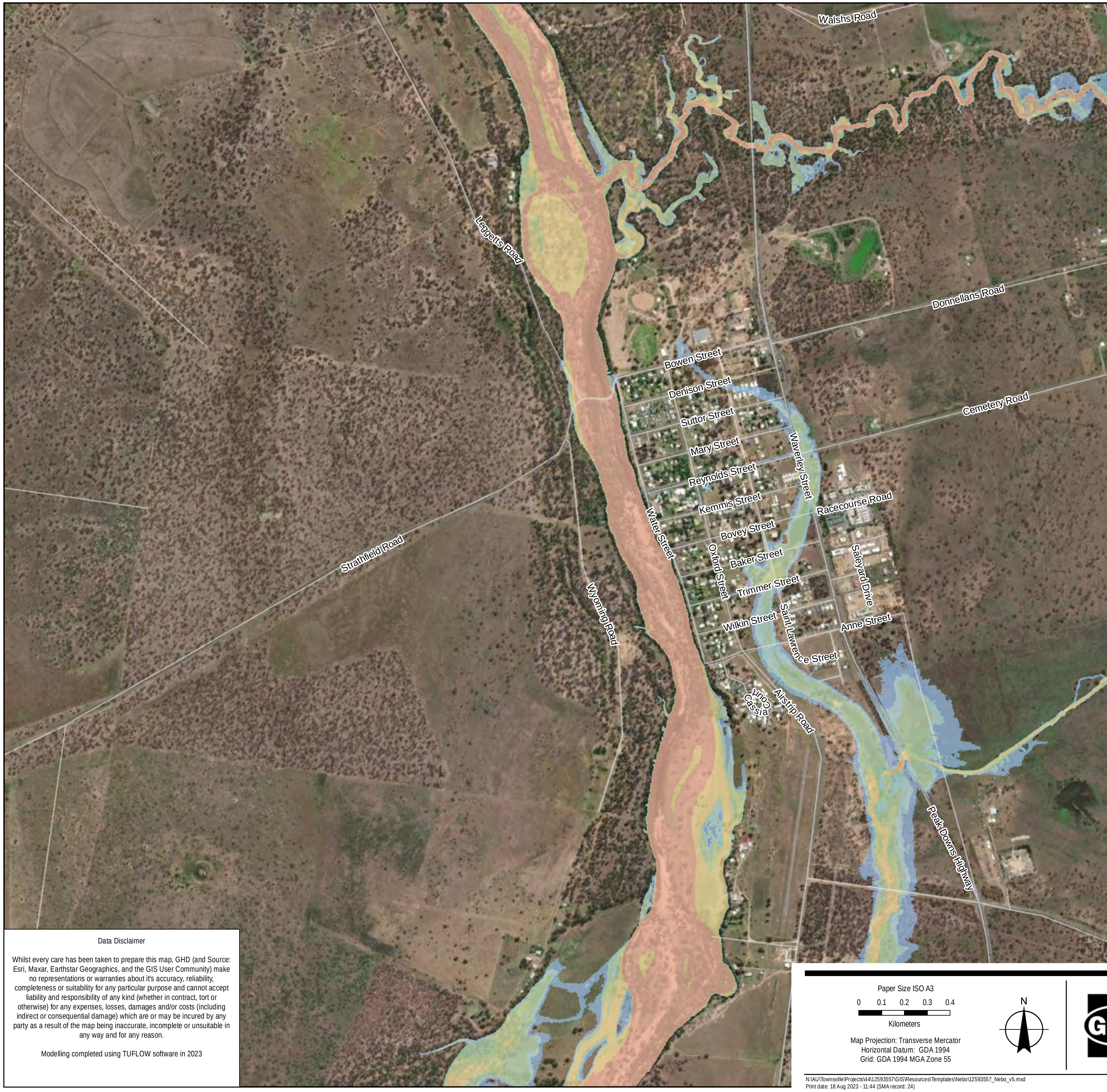
Nebo
Flood Velocity Map
1% AEP

Project No. 12593557
Revision No. 0
Date 18 Aug 2023

Figure E-18

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Nebo\12593557_Nebo_v5.mxd
Print date: 18 Aug 2023 - 11:44 (SMA record: 23)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: aramos2



Legend

Roads

Hazard

- H1 - generally safe for people, vehicles and buildings
- H2 - unsafe for small vehicles
- H3 - unsafe for vehicles, children and elderly
- H4 - unsafe for people and vehicles
- H5 - unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust building types vulnerable to failure
- H6 - unsafe for vehicles and people. All building types considered vulnerable to failure

Modelling completed using TUFLOW software in 2023

Paper Size ISO A3
0 0.1 0.2 0.3 0.4
Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping

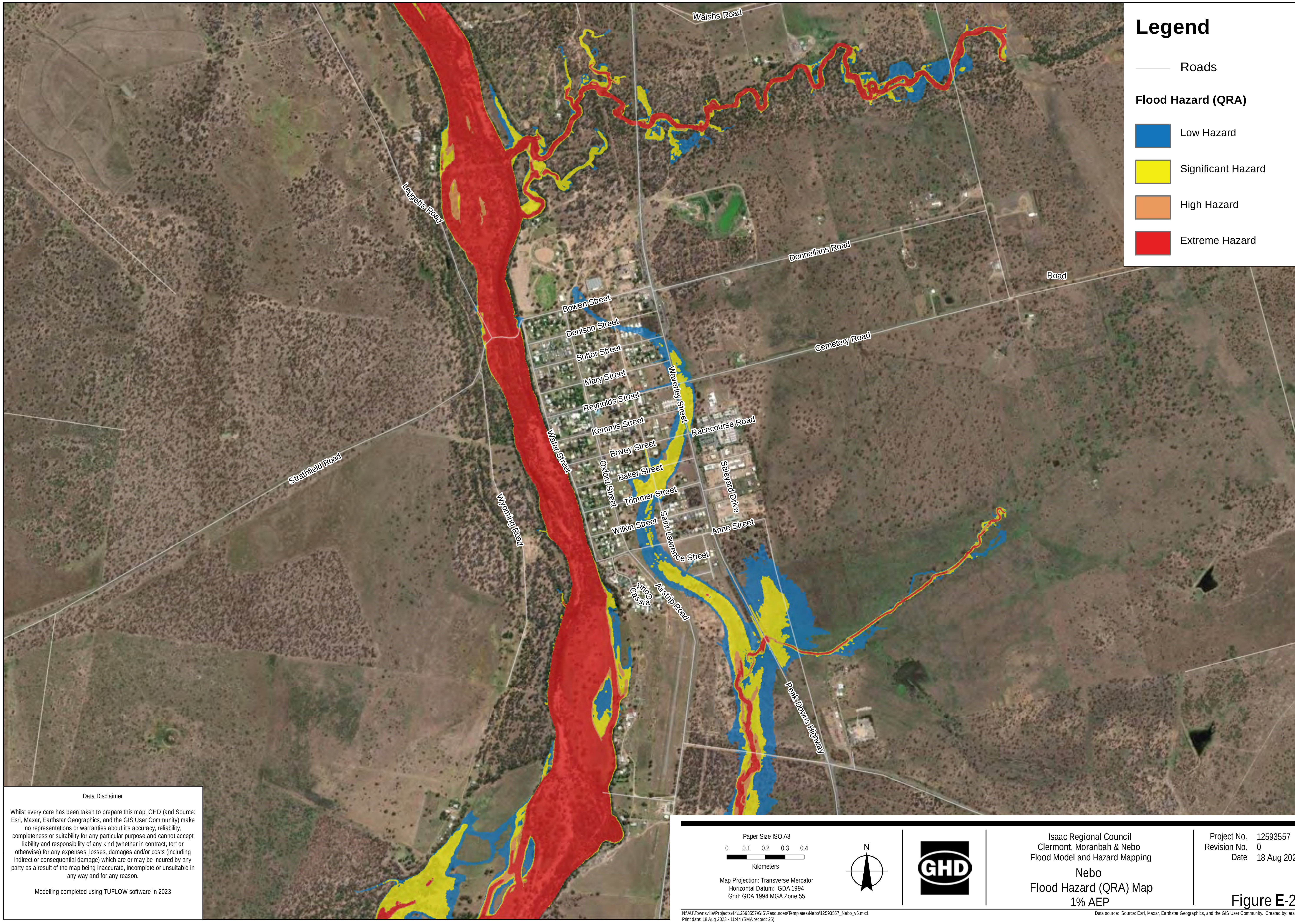
Nebo
Flood Hazard Map
1% AEP

Project No. 12593557
Revision No. 0
Date 18 Aug 2023

Figure E-19

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Nebo\12593557_Nebo_v5.mxd
Print date: 18 Aug 2023 - 11:44 (SMA record: 24)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: aramos2



Legend

Roads

Flood Hazard (QRA)

- Low Hazard
- Significant Hazard
- High Hazard
- Extreme Hazard

Data Disclaimer

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Modelling completed using TUFLOW software in 2023

Paper Size ISO A3

0 0.1 0.2 0.3 0.4

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping

Nebo
Flood Hazard (QRA) Map
1% AEP

Project No. 12593557
Revision No. 0
Date 18 Aug 2023

Figure E-20

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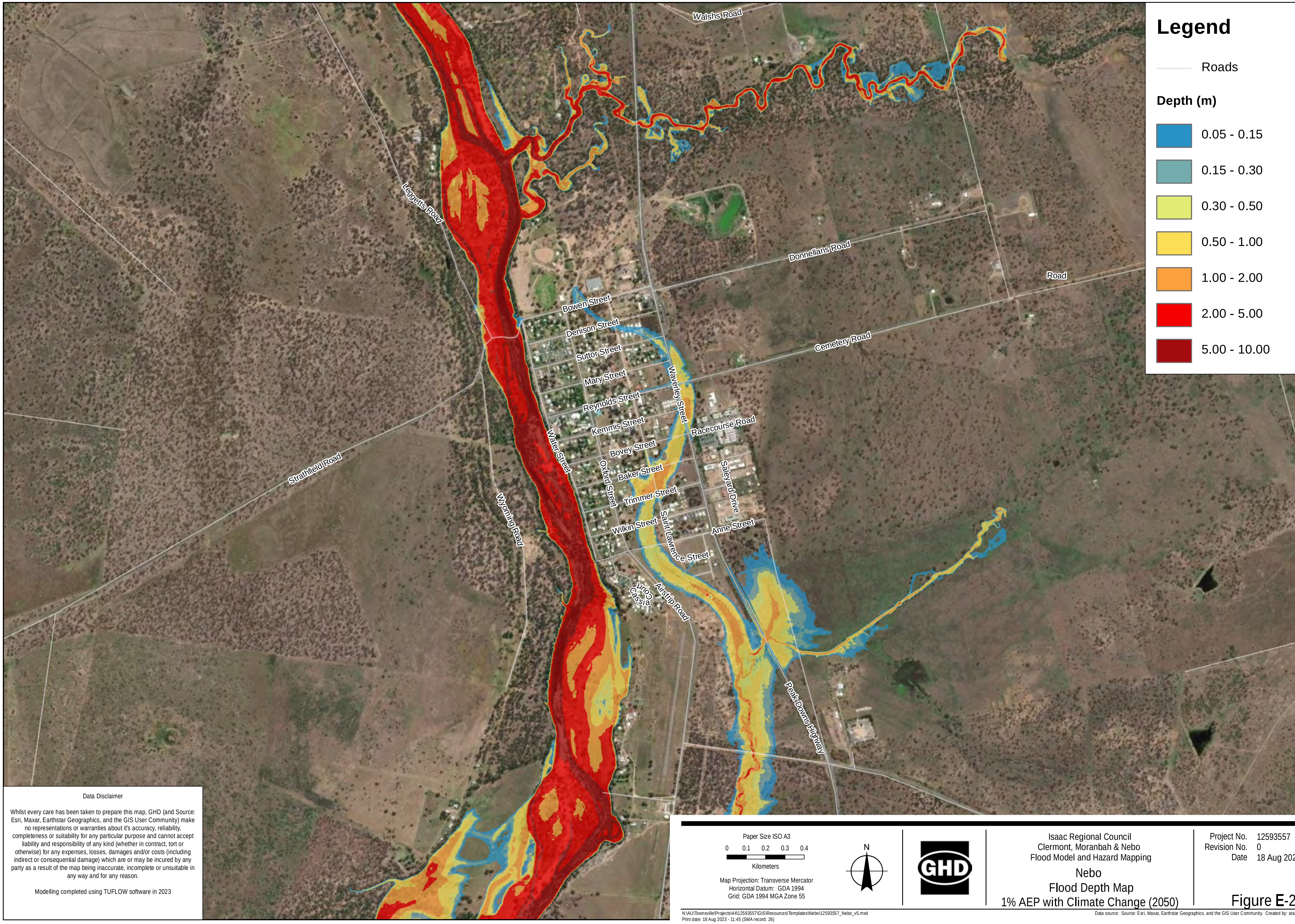
Print date: 18 Aug 2023 - 11:44 (SMA record: 25)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: aramos2



Legend

Roads

Depth (m)

- 0.05 - 0.15
- 0.15 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00
- 2.00 - 5.00
- 5.00 - 10.00

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Modelling completed using TUFLOW software in 2023

Paper Size ISO A3

0 0.1 0.2 0.3 0.4

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

GHD

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping

Nebo
Flood Depth Map
1% AEP with Climate Change (2050)

Project No. 12593557
Revision No. 0
Date 18 Aug 2023

Figure E-21

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Nebo\12593557_Nebo_v5.mxd
Print date: 18 Aug 2023 - 11:45 (SMA record: 26)

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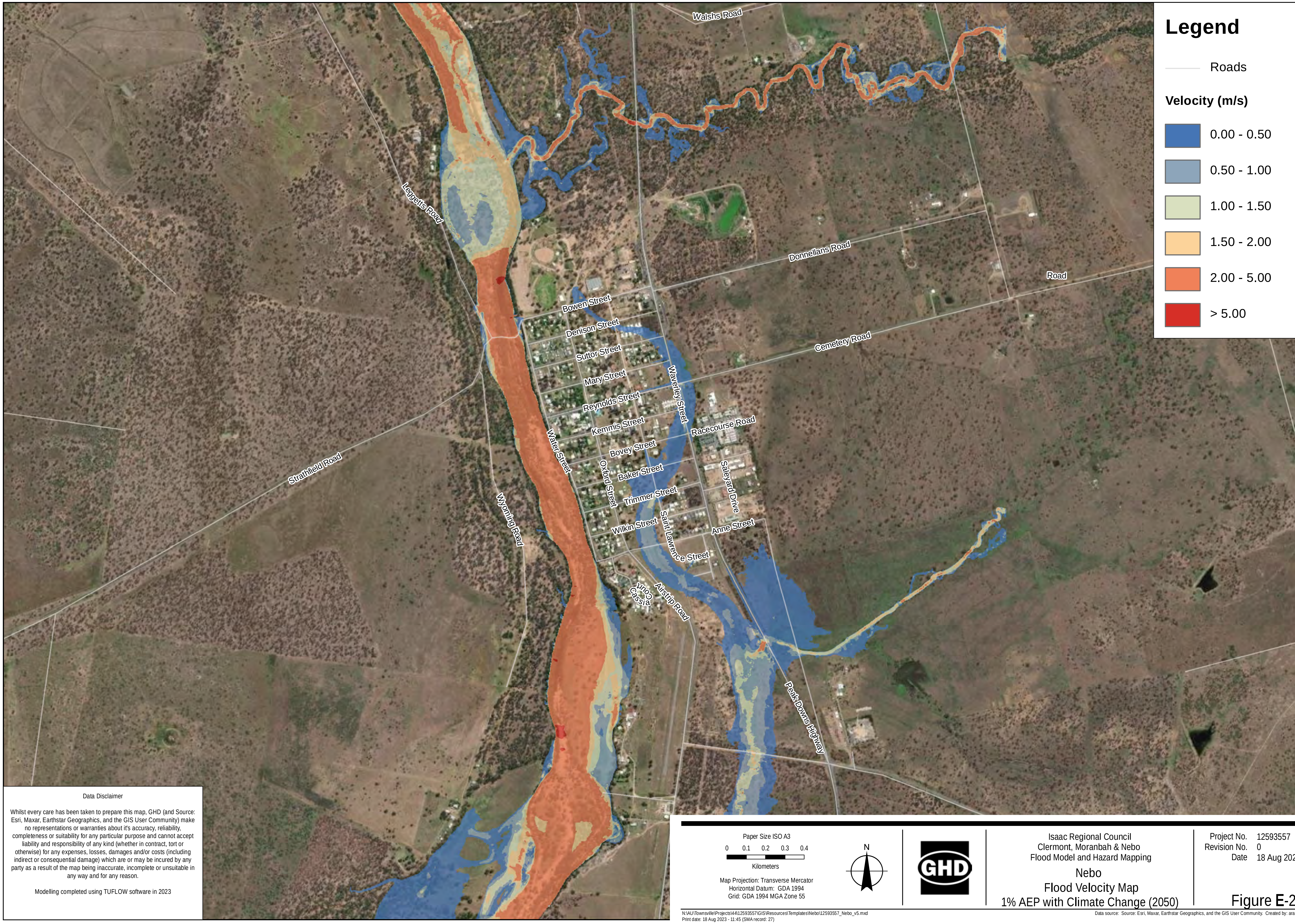

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Modelling completed using TUFLOW software in 2023

Paper Size ISO A3
0 0.1 0.2 0.3 0.4
Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping

Nebo
Flood Velocity Map
1% AEP with Climate Change (2050)

Project No. 12593557
Revision No. 0
Date 18 Aug 2023

Figure E-22

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Print date: 18 Aug 2023 - 11:45 (SMA record: 27)

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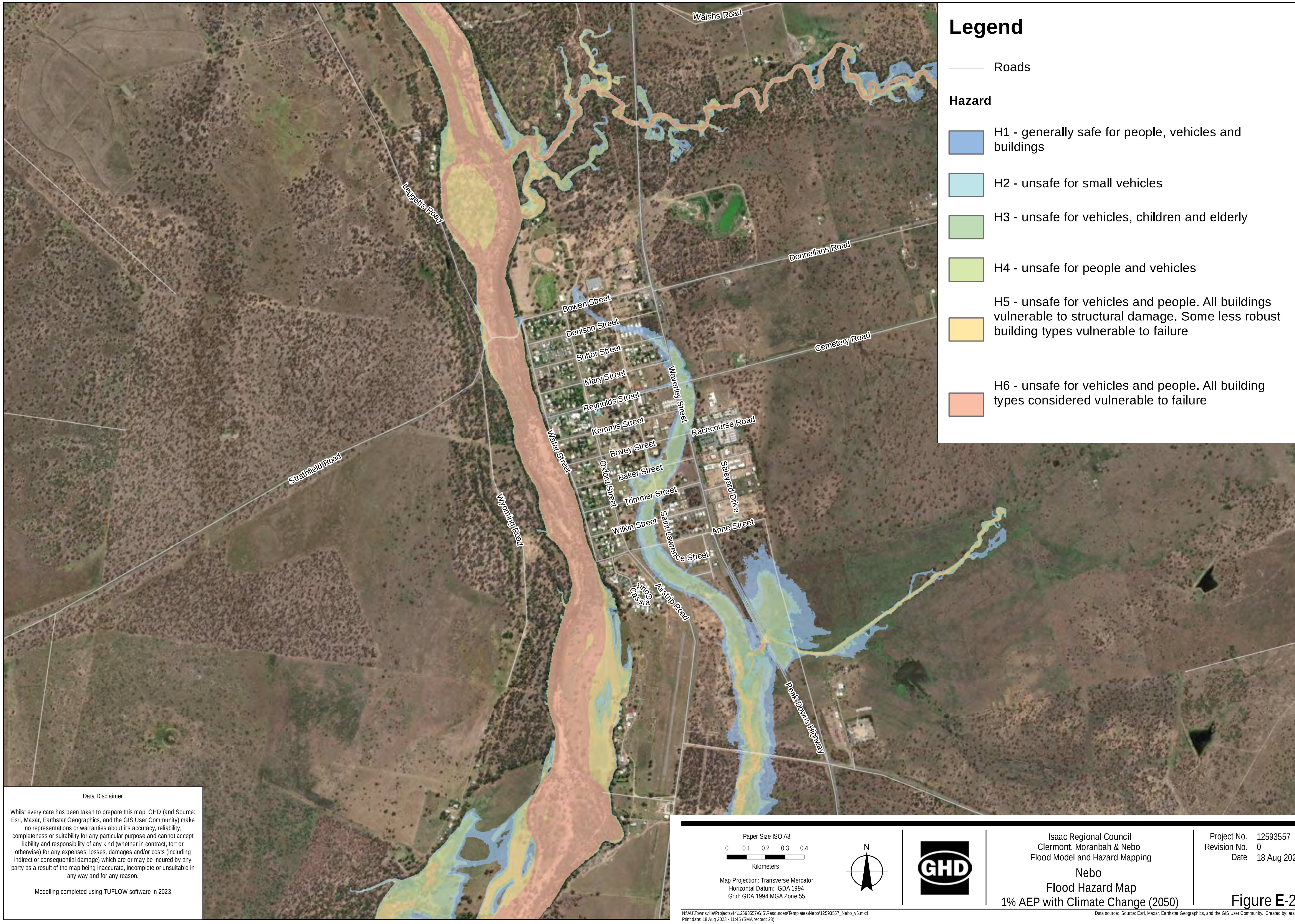
Document Set ID: 5109910
Version: 1, Version Date: 25/08/2023



Legend

Roads

Hazard

- H1 - generally safe for people, vehicles and buildings
- H2 - unsafe for small vehicles
- H3 - unsafe for vehicles, children and elderly
- H4 - unsafe for people and vehicles
- H5 - unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust building types vulnerable to failure
- H6 - unsafe for vehicles and people. All building types considered vulnerable to failure

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Modelling completed using TUFLOW software in 2023

Paper Size ISO A3

0 0.1 0.2 0.3 0.4

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping

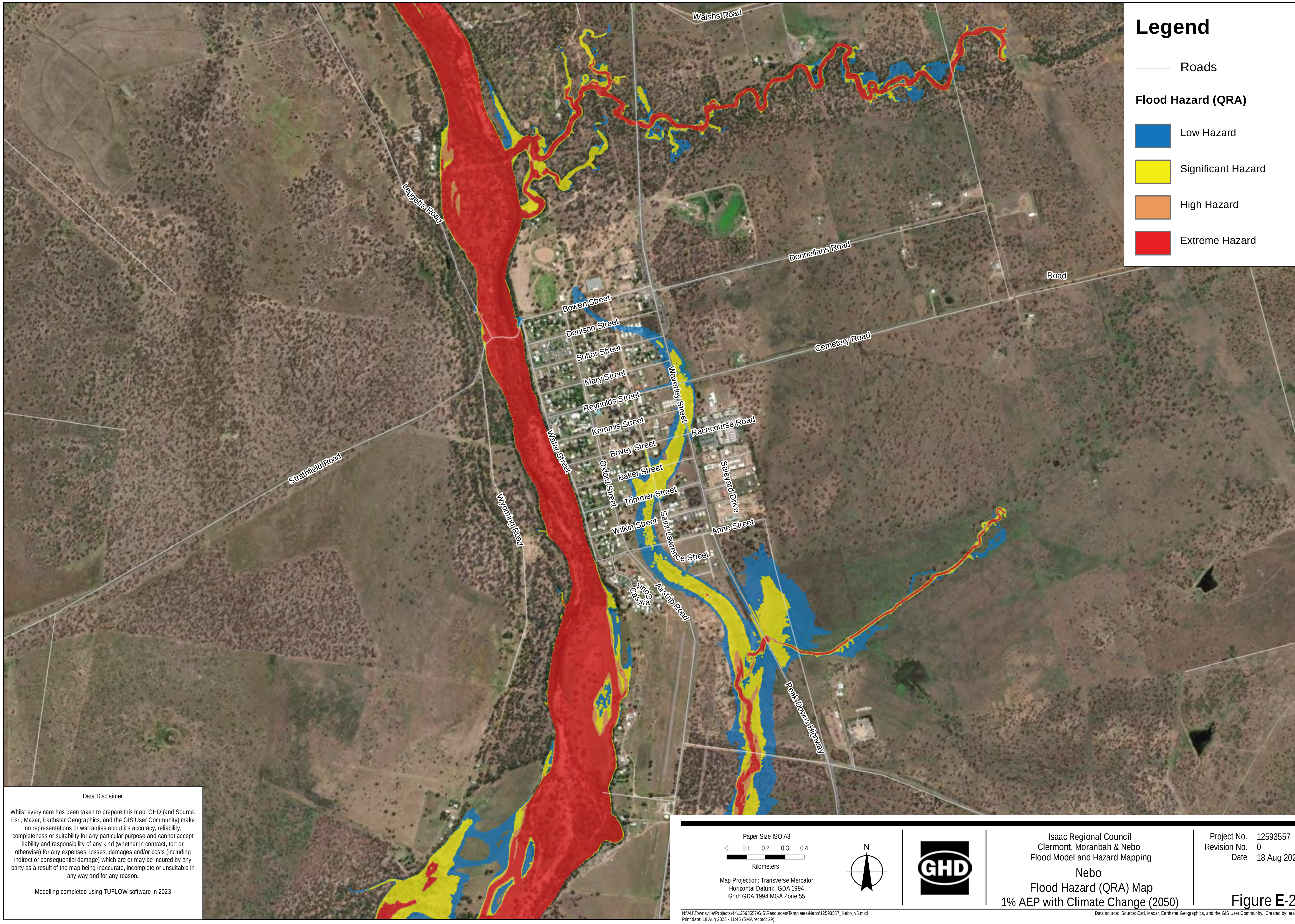
Nebo
Flood Hazard Map
1% AEP with Climate Change (2050)

Project No. 12593557
Revision No. 0
Date 18 Aug 2023

Figure E-23

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Nebo\12593557_Nebo_v5.mxd
Print date: 18 Aug 2023 - 11:45 (SMA record: 28)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: aramos2



Legend

Roads

Flood Hazard (QRA)

- Low Hazard
- Significant Hazard
- High Hazard
- Extreme Hazard

Data Disclaimer

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Modelling completed using TUFLOW software in 2023

Paper Size ISO A3

0 0.1 0.2 0.3 0.4

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

GHD

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping

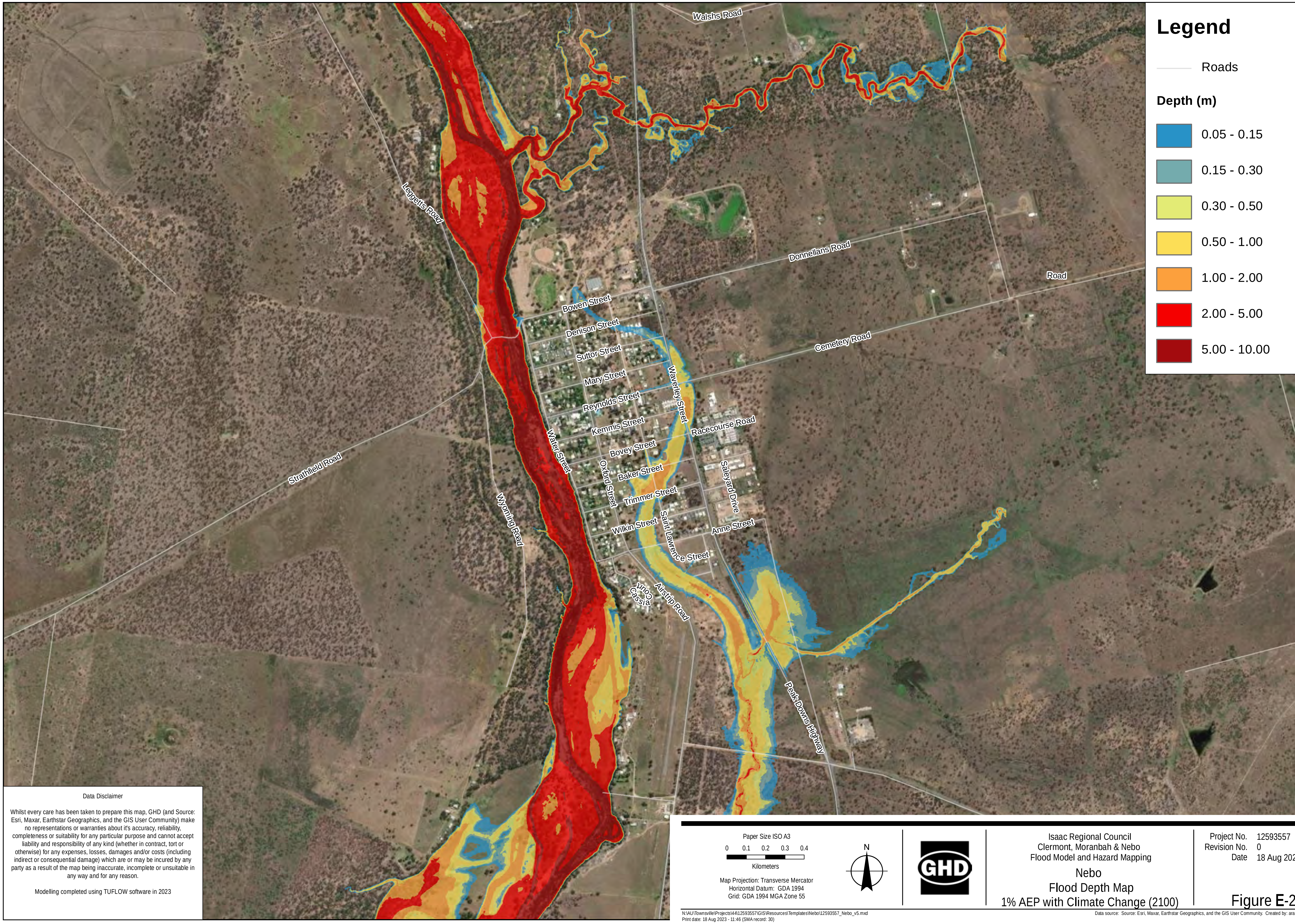
Nebo
Flood Hazard (QRA) Map
1% AEP with Climate Change (2050)

Project No. 12593557
Revision No. 0
Date 18 Aug 2023

Figure E-24

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Nebo\12593557_Nebo_v5.mxd
Print date: 18 Aug 2023 - 11:45 (SMA record: 29)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: aramos2



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Modelling completed using TUFLOW software in 2023

Paper Size ISO A3

0 0.1 0.2 0.3 0.4

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping

Nebo
Flood Depth Map
1% AEP with Climate Change (2100)

Project No. 12593557
Revision No. 0
Date 18 Aug 2023

Figure E-25

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Nebo\12593557_Nebo_v5.mxd
Print date: 18 Aug 2023 - 11:46 (SMA record: 30)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: aramos2

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Modelling completed using TUFLOW software in 2023

Paper Size ISO A3
0 0.1 0.2 0.3 0.4
Kilometers
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

GHD

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping

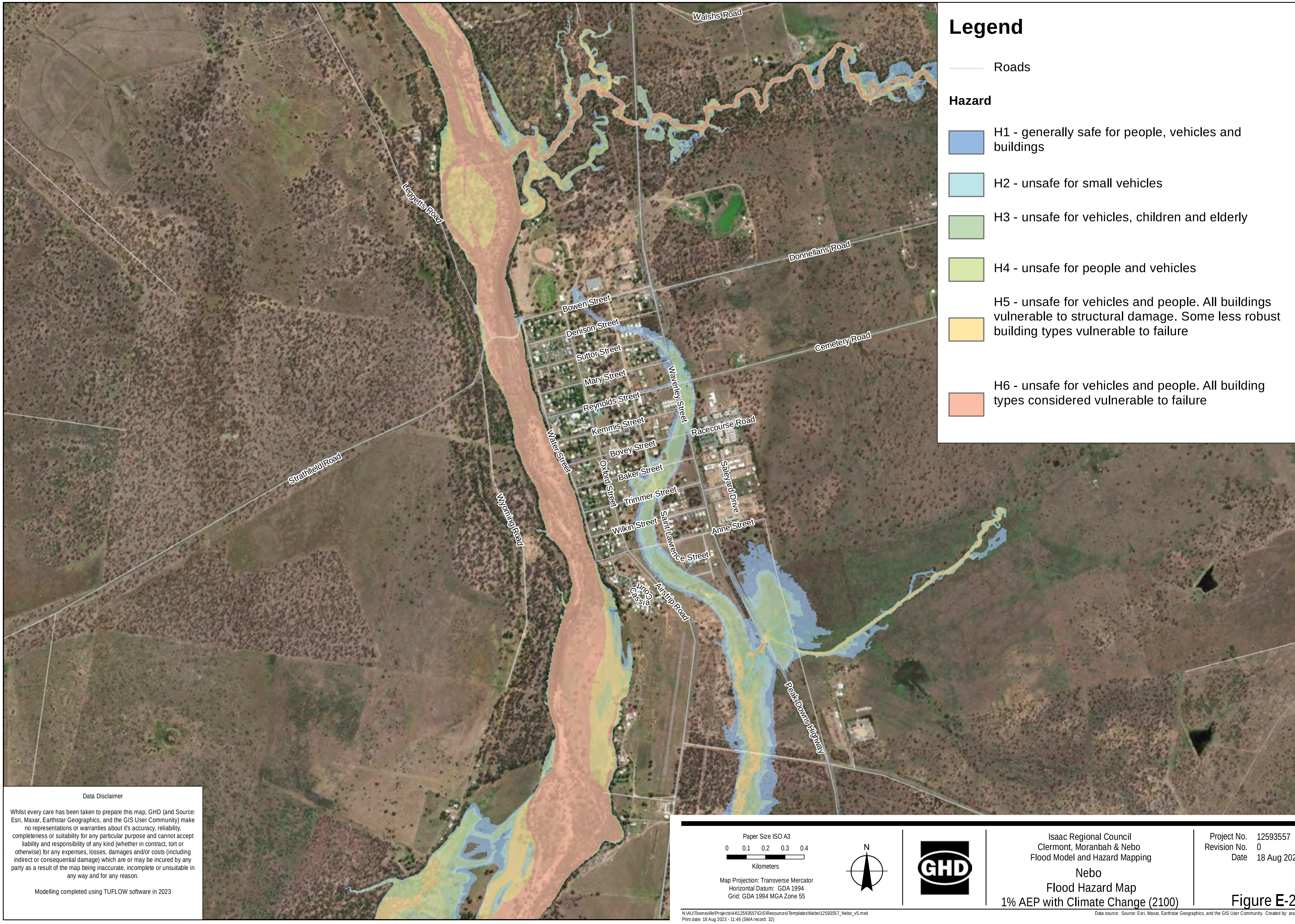
Nebo
Flood Velocity Map
1% AEP with Climate Change (2100)

Project No. 12593557
Revision No. 0
Date 18 Aug 2023

Figure E-26

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Nebo\12593557_Nebo_v5.mxd
Print date: 18 Aug 2023 - 11:46 (SMA record: 31)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: aramos2



Legend

Roads

Hazard

H1 - generally safe for people, vehicles and buildings

H2 - unsafe for small vehicles

H3 - unsafe for vehicles, children and elderly

H4 - unsafe for people and vehicles

H5 - unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust building types vulnerable to failure

H6 - unsafe for vehicles and people. All building types considered vulnerable to failure

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Modelling completed using TUFLOW software in 2023

Paper Size ISO A3

0 0.1 0.2 0.3 0.4

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

GHD

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping

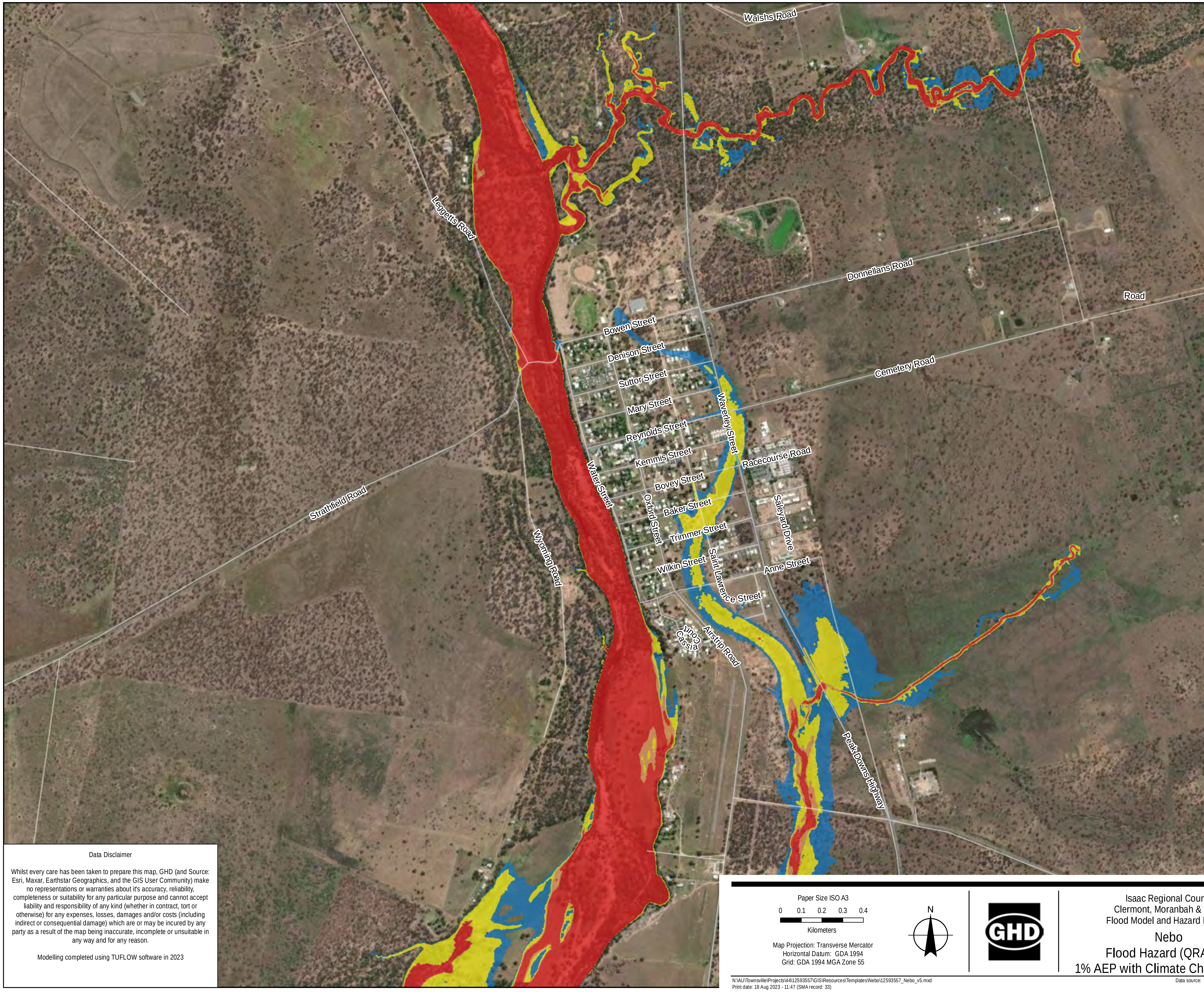
Nebo
Flood Hazard Map
1% AEP with Climate Change (2100)

Project No. 12593557
Revision No. 0
Date 18 Aug 2023

Figure E-27

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Nebo\12593557_Nebo_v5.mxd
Print date: 18 Aug 2023 - 11:46 (SMA record: 32)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: aramos2



Legend

Roads

Flood Hazard (QRA)

- Low Hazard
- Significant Hazard
- High Hazard
- Extreme Hazard

Data Disclaimer

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Modelling completed using TUFLOW software in 2023

Paper Size ISO A3

0 0.1 0.2 0.3 0.4

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping

Nebo
Flood Hazard (QRA) Map
1% AEP with Climate Change (2100)

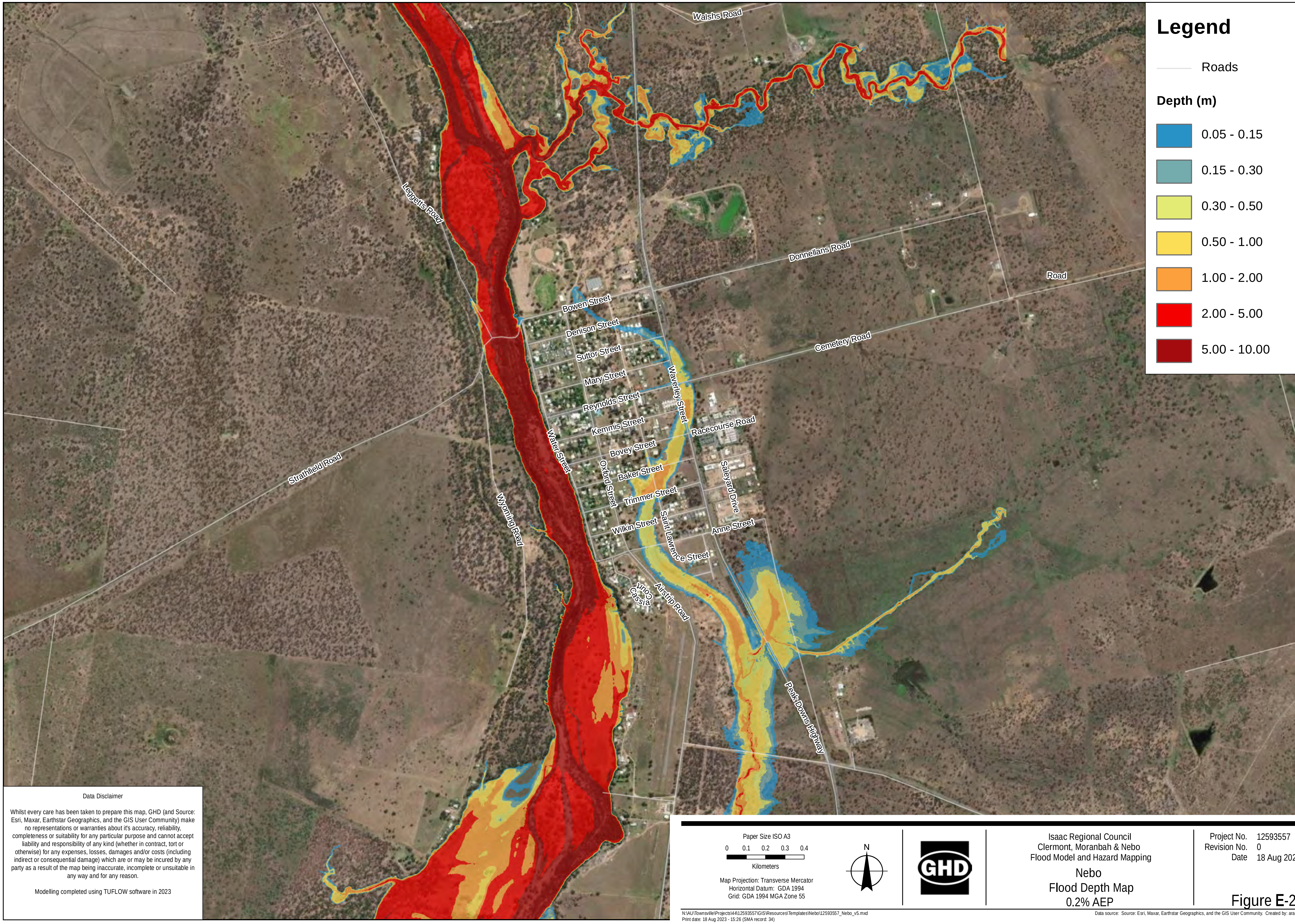
Project No. 12593557
Revision No. 0
Date 18 Aug 2023

Figure E-28

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Nebo\12593557_Nebo_v5.mxd
Print date: 18 Aug 2023 - 11:47 (SMA record: 33)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: aramos2

Document Set ID: 5109910
Version: 1, Version Date: 25/08/2023



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Modelling completed using TUFLOW software in 2023

Paper Size ISO A3

0 0.1 0.2 0.3 0.4

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping

Nebo
Flood Depth Map
0.2% AEP

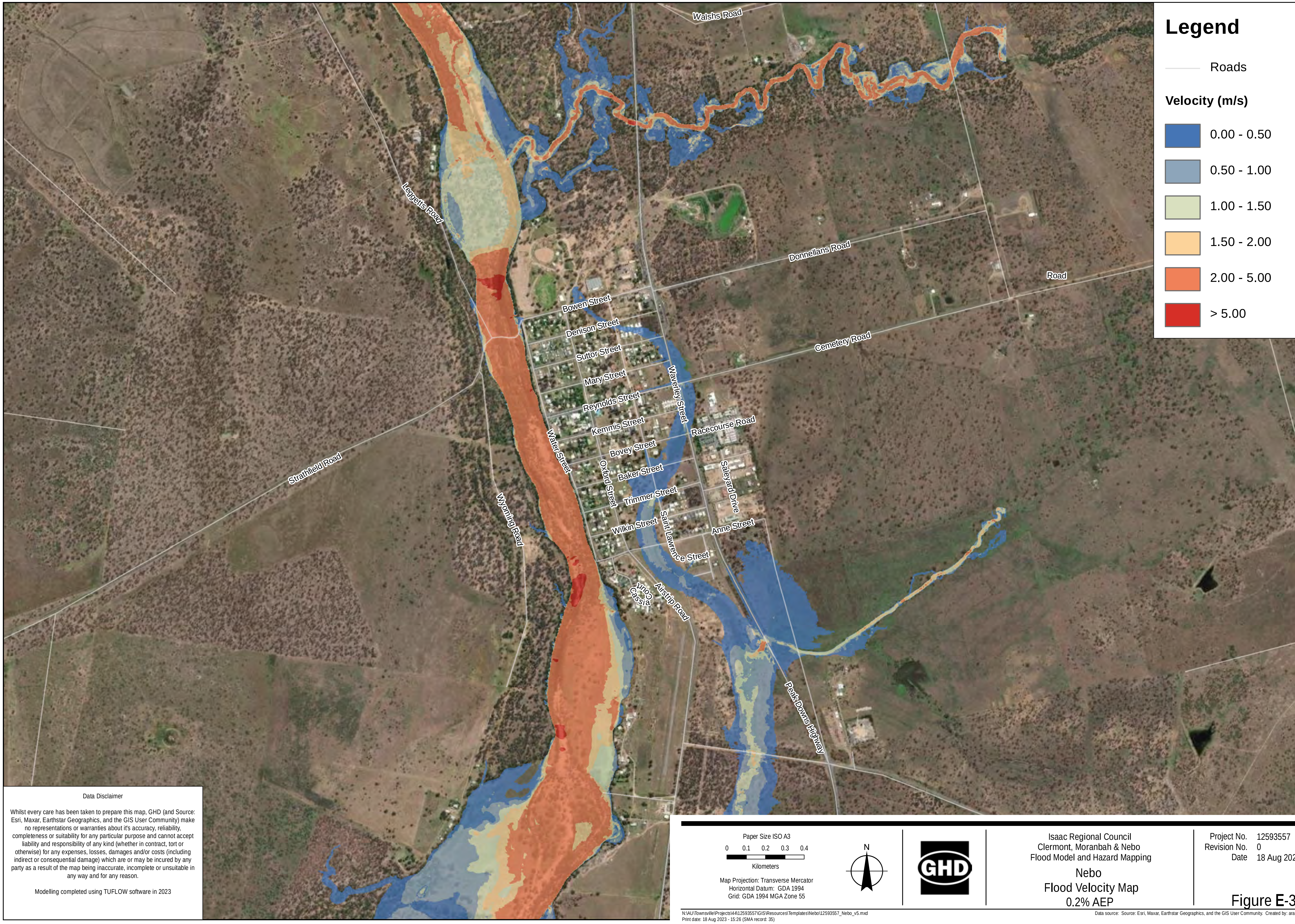
Project No. 12593557
Revision No. 0
Date 18 Aug 2023

Figure E-29

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Nebo\12593557_Nebo_v5.mxd
Print date: 18 Aug 2023 - 15:26 (SMA record: 34)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: aramos2

Document Set ID: 5109910
Version: 1, Version Date: 25/08/2023



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Modelling completed using TUFLOW software in 2023

Paper Size ISO A3

0 0.1 0.2 0.3 0.4

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping

Nebo
Flood Velocity Map
0.2% AEP

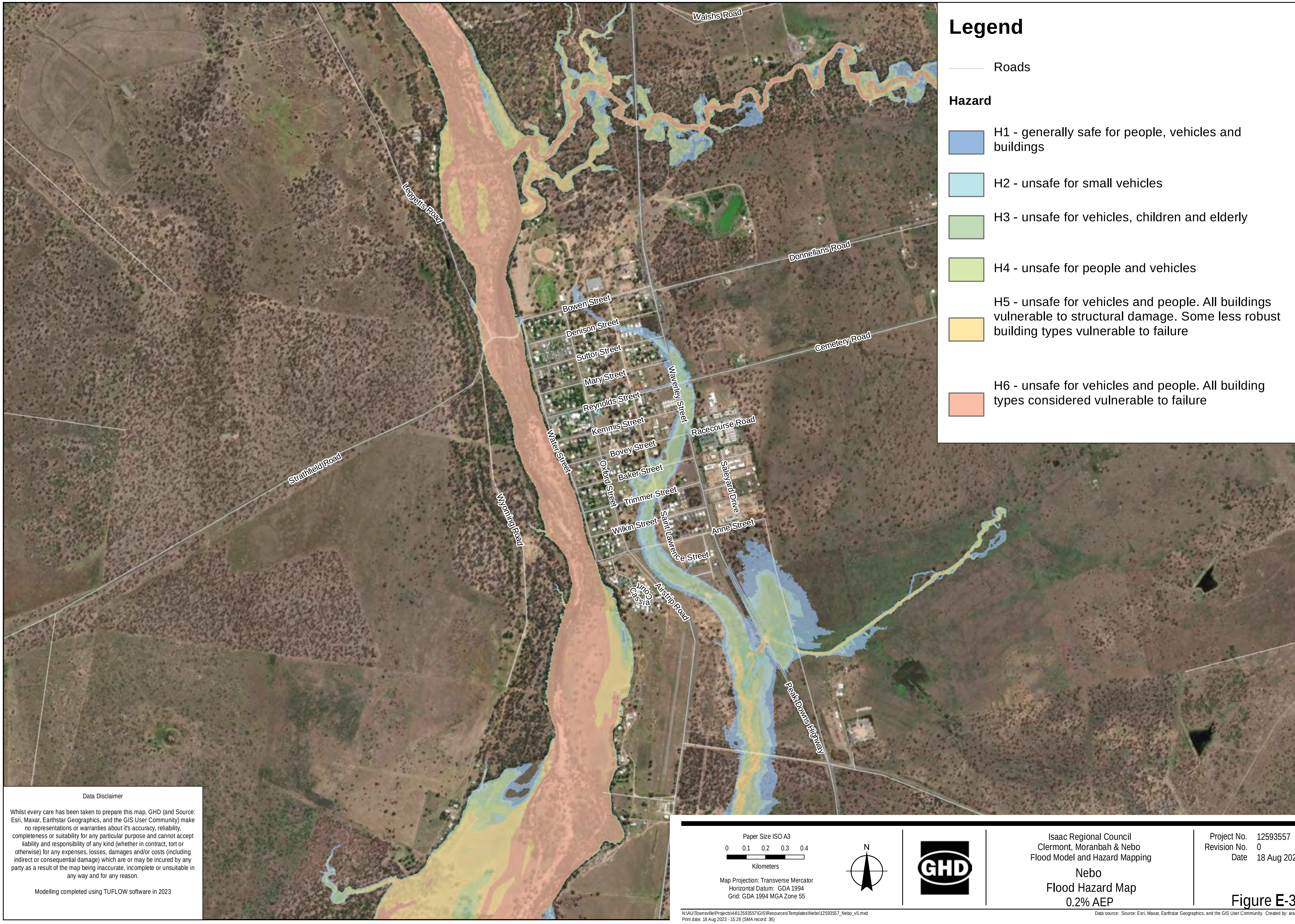
Project No. 12593557
Revision No. 0
Date 18 Aug 2023

Figure E-30

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Nebo\12593557_Nebo_v5.mxd
Print date: 18 Aug 2023 - 15:26 (SMA record: 35)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: aramos2

Document Set ID: 5109910
Version: 1, Version Date: 25/08/2023



Legend

Roads

Hazard

- H1 - generally safe for people, vehicles and buildings
- H2 - unsafe for small vehicles
- H3 - unsafe for vehicles, children and elderly
- H4 - unsafe for people and vehicles
- H5 - unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust building types vulnerable to failure
- H6 - unsafe for vehicles and people. All building types considered vulnerable to failure

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Modelling completed using TUFLOW software in 2023

Paper Size ISO A3

0 0.1 0.2 0.3 0.4

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping

Nebo
Flood Hazard Map
0.2% AEP

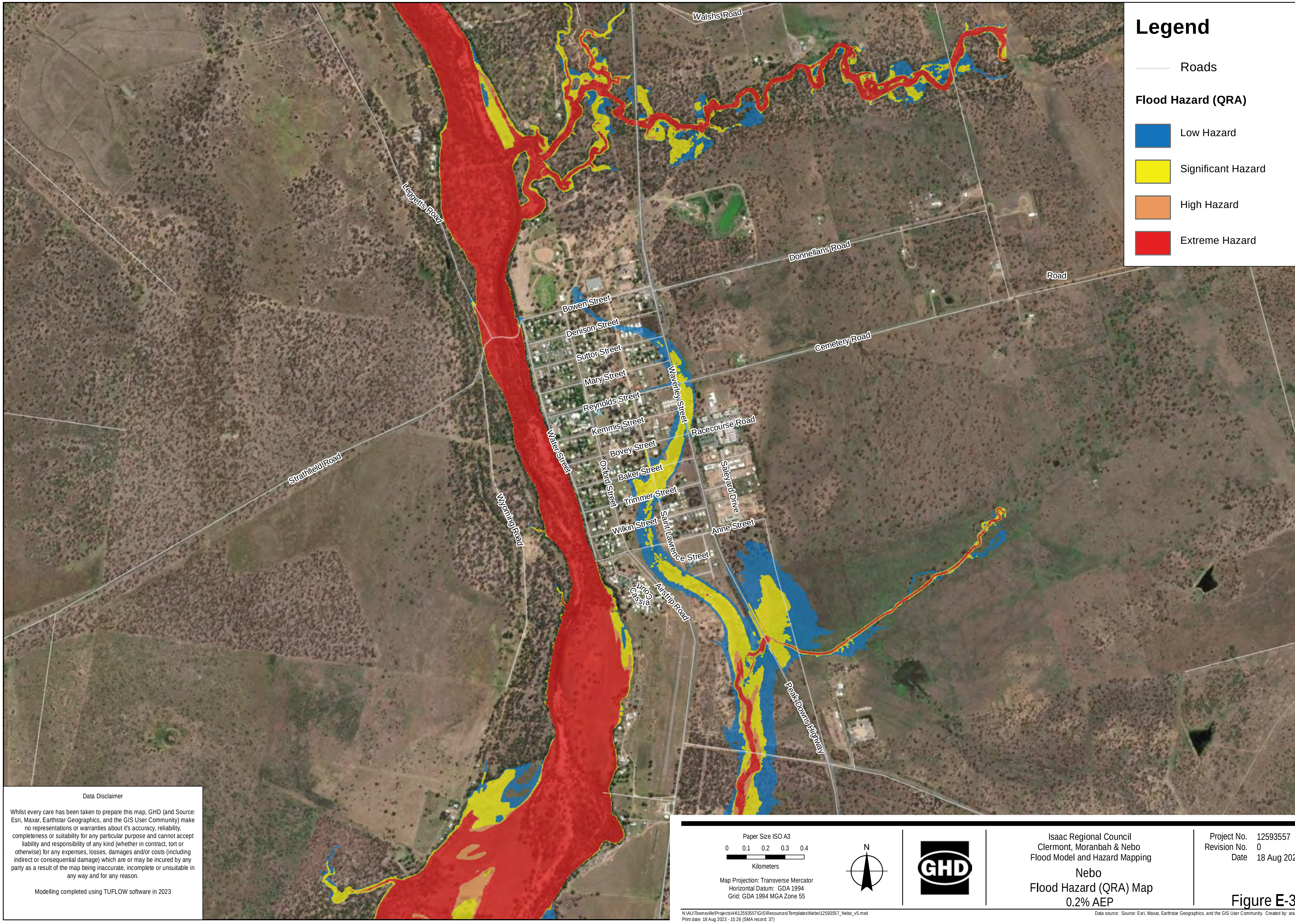
Project No. 12593557
Revision No. 0
Date 18 Aug 2023

Figure E-31

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Nebo\12593557_Nebo_v5.mxd
Print date: 18 Aug 2023 - 15:26 (SMA record: 36)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: aramos2

Document Set ID: 5109910
Version: 1, Version Date: 25/08/2023



Legend

Roads

Flood Hazard (QRA)

- Low Hazard
- Significant Hazard
- High Hazard
- Extreme Hazard

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Modelling completed using TUFLOW software in 2023

Paper Size ISO A3

0 0.1 0.2 0.3 0.4

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping

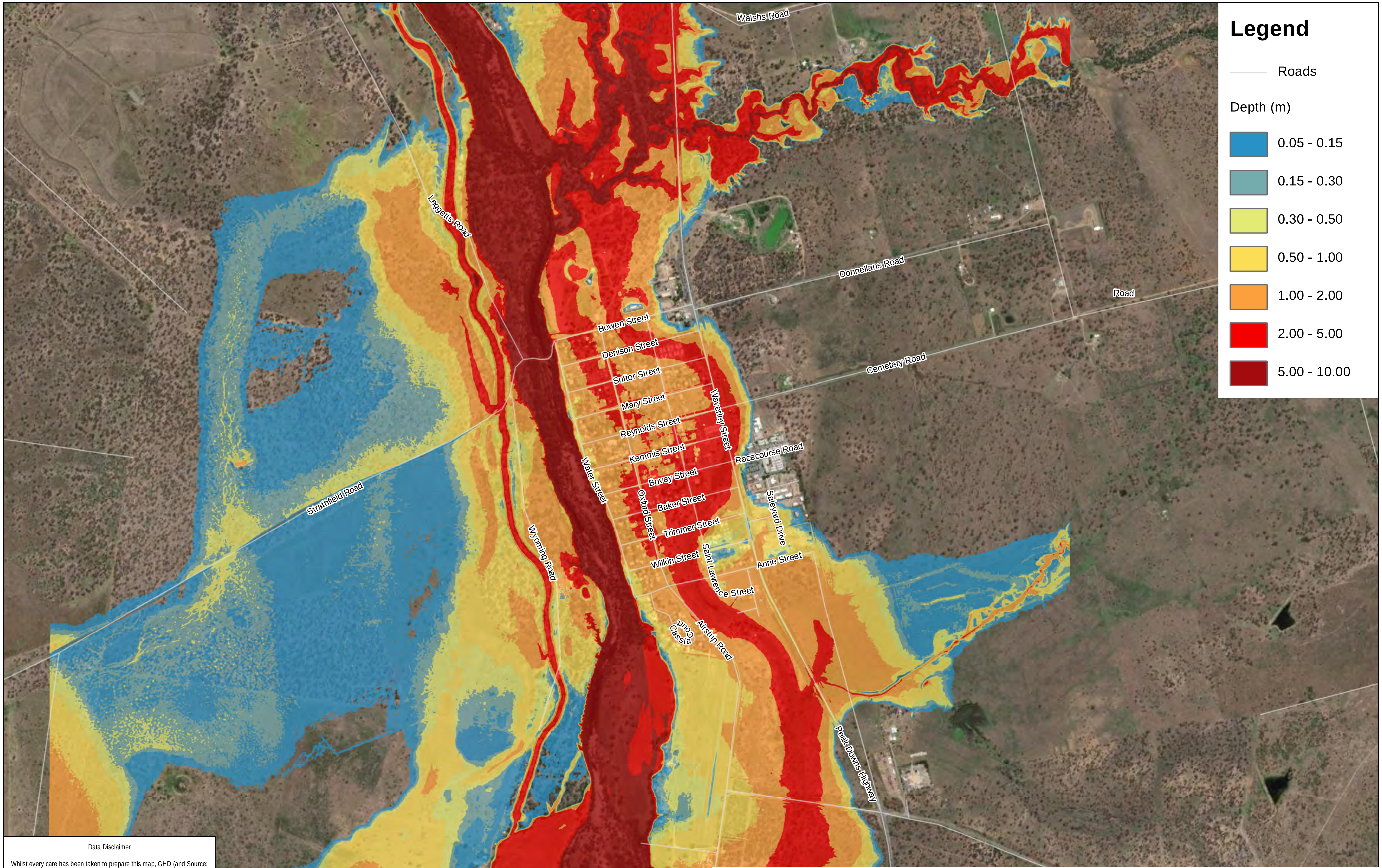
Nebo
Flood Hazard (QRA) Map
0.2% AEP

Project No. 12593557
Revision No. 0
Date 18 Aug 2023

Figure E-32

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Nebo\12593557_Nebo_v5.mxd
Print date: 18 Aug 2023 - 15:26 (SMA record: 37)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: aramos2



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Modelling completed using TUFLOW software in 2023

Paper Size ISO A3

0 0.1 0.2 0.3 0.4

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

GHD

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping

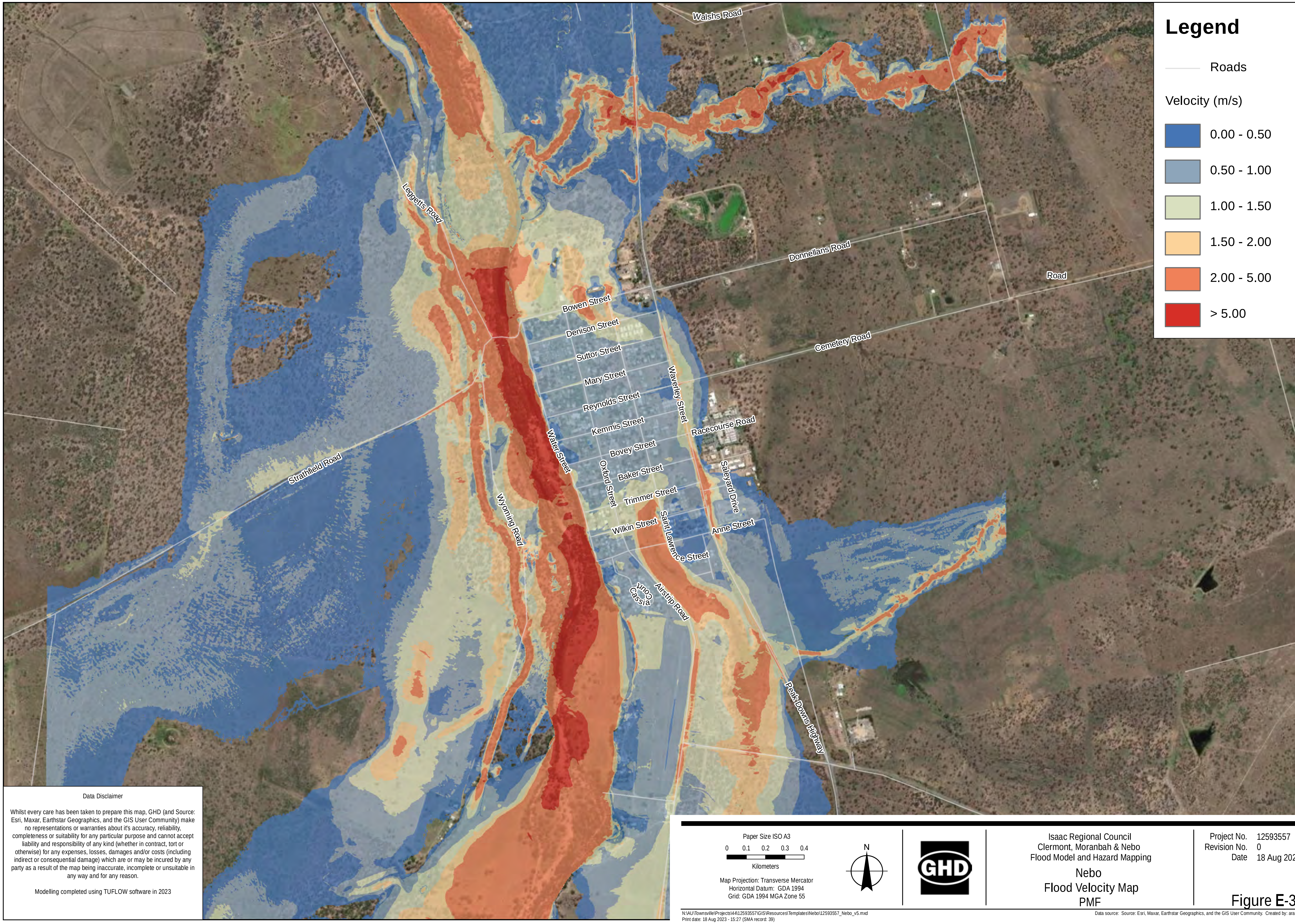
Nebo
Flood Depth Map
PMF

Project No. 12593557
Revision No. 0
Date 18 Aug 2023

Figure E-33

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Nebo\12593557_Nebo_v5.mxd
Print date: 18 Aug 2023 - 15:27 (SMA record: 38)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: aramos2



Legend

Roads

Velocity (m/s)

- 0.00 - 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- 2.00 - 5.00
- > 5.00

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Modelling completed using TUFLOW software in 2023

Paper Size ISO A3

0 0.1 0.2 0.3 0.4

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping

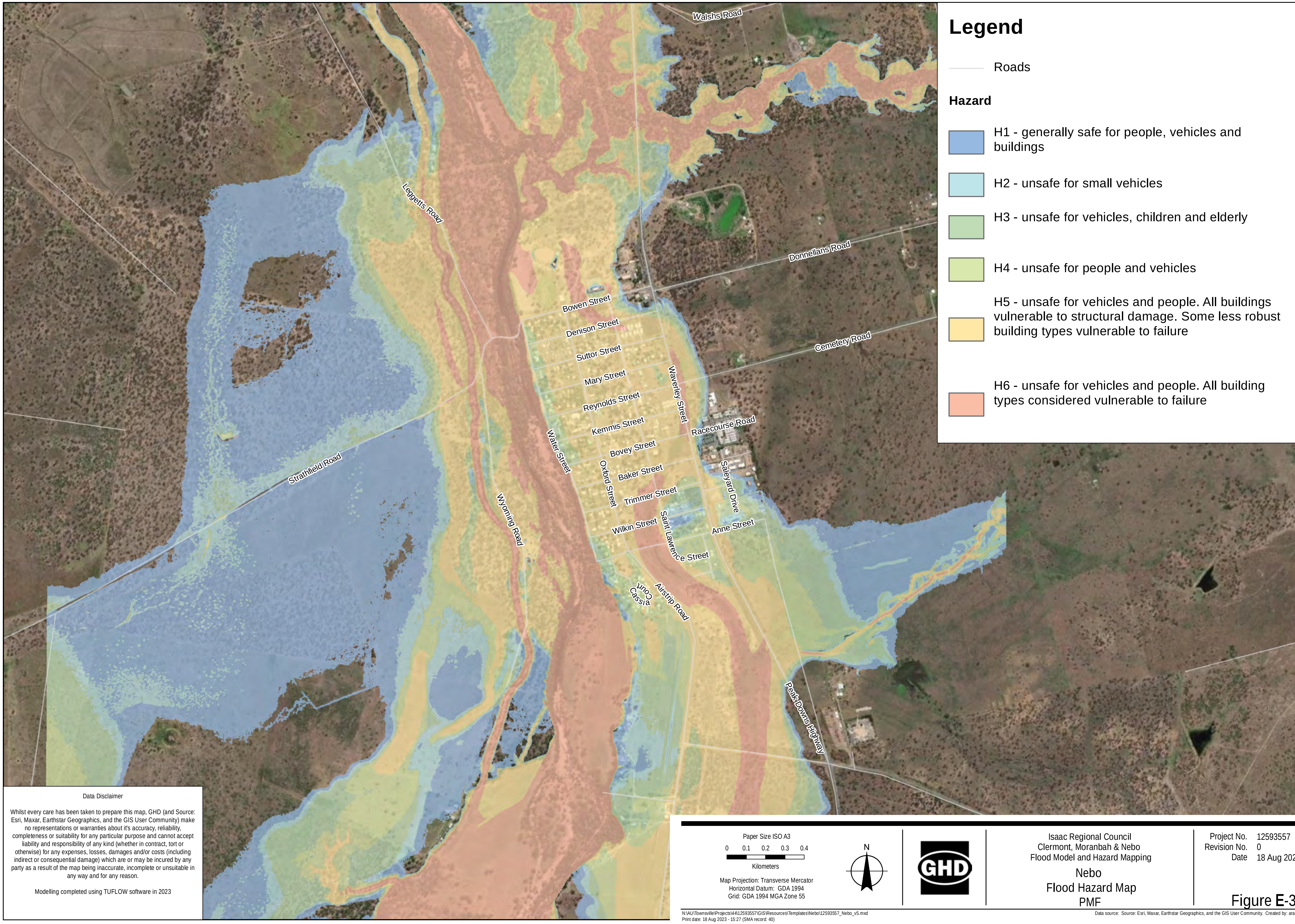
Nebo
Flood Velocity Map
PMF

Project No. 12593557
Revision No. 0
Date 18 Aug 2023

Figure E-34

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Nebo\12593557_Nebo_v5.mxd
Print date: 18 Aug 2023 - 15:27 (SMA record: 39)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: aramos2



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Modelling completed using TUFLOW software in 2023

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping

Nebo
Flood Hazard Map
PMF

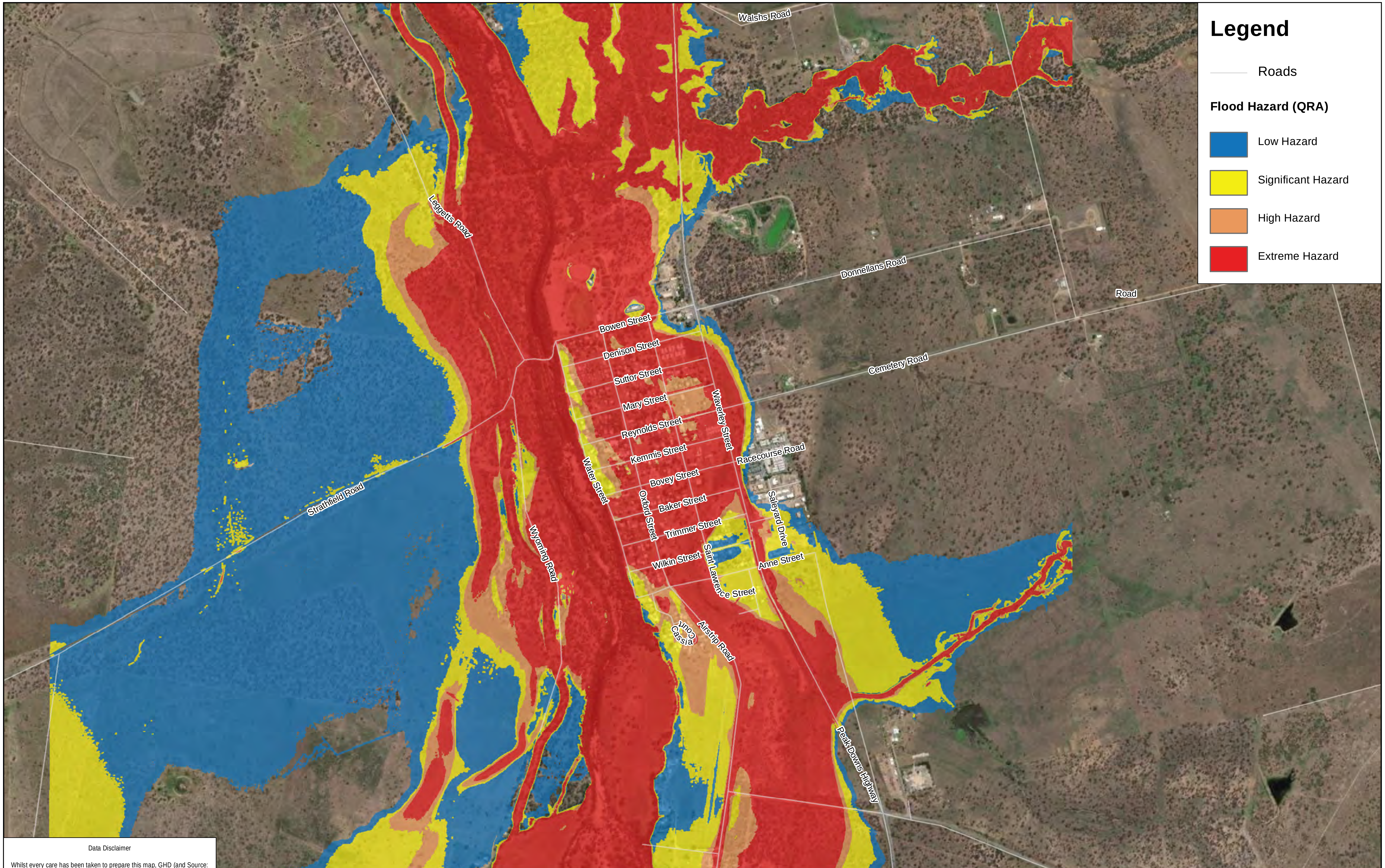
Project No. 12593557
Revision No. 0
Date 18 Aug 2023

Figure E-35

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Nebo\12593557_Nebo_v5.mxd
Print date: 18 Aug 2023 - 15:27 (SMA record: 40)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: aramos2

Document Set ID: 5109910
Version: 1, Version Date: 25/08/2023



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Modelling completed using TUFLOW software in 2023

Paper Size ISO A3
0 0.1 0.2 0.3 0.4
Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

GHD

Isaac Regional Council
Clermont, Moranbah & Nebo
Flood Model and Hazard Mapping

Nebo
Flood Hazard (QRA) Map
PMF

Project No. 12593557
Revision No. 0
Date 18 Aug 2023

Figure E-36

N:\AU\Townsville\Projects\44\12593557\GIS\Resources\Templates\Nebo\12593557_Nebo_v5.mxd
Print date: 18 Aug 2023 - 15:28 (SMA record: 41)

Data source: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community. Created by: aramos2

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