30 August 2024
Job No: 1012667.0100

Taupō District Council
46 Horomatangi Street
Taupō 3330

Attention: Phil Burt

Dear Phil

Taupō Flood Model Review (Stage 2)

1 Introduction

T+T has been asked by Taupō District Council (TDC) to review updated hydraulic modelling for each of the urban areas within the Taupō district. Specifically, the review is to comment on the suitability of the updated models, reporting and outputs (prepared by CDM Consultants (CDM) [1]) for informing TDC's District Plan functions.

An earlier review was undertaken by Tonkin & Taylor (T+T) in 2020[2], which made a number of recommendations for improving confidence in model results. CDM has subsequently made significant updates to the models, documented in their Hydraulic Modelling Report (2024).

T+T's scope was to review documentation provided by CDM (hydraulic modelling) and Te Miro Water (hydrological modelling) that covers hydraulic modelling, hydrological modelling approach, and the flood model results. The models themselves were not reviewed.

This report is an update of our previous report (dated 14 August 2024, T+T ref. 1012667.0100). It incorporates comments by TDC on the previous report[3].

2 Summary

This report provides a high-level review of the available documentation to support the flood maps produced by CDM. Commentary on gaps identified in the course of our review, and recommendations for further updates, are also included. This is important because in general, the documentation provided to T+T is insufficient to enable a robust review of the modelling. This means that we are unable to confirm the suitability of the model results for District Plan purposes at this stage.

Key themes of the review, many of them inter-related and which require further consideration, are summarised below. These topics are expanded upon in the sections that follow. Note that the review comments are made without any T+T knowledge of any scope limitations regarding what CDM and Te Miro were required to provide to TDC.

[1] Taupo Urban Stormwater. Hydraulic Modelling Report. CDM Consultants. Dated 8 March 2024.
[2] Review of Taupo District Council Flood Modelling. Tonkin & Taylor Ltd. Dated 11 May 2020.
[3] Comments received from Phil Burt via email on 23 August 2024.

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- Model purpose: There is a lack of clarity about the specific purpose for which the modelling was undertaken or the model scenarios developed to respond to that purpose. For example, the executive summary states a different purpose of the modelling (i.e. identifying overland flow paths and understanding stormwater network performance) to that of the body of the report (i.e. to support the District Plan).
- Spatial information: No maps or figures are included in the report to describe the model build process or results. These are necessary to explain the many spatial elements of a flood assessment such as catchment extents, model schematisation, pipe networks, dams, flow gauges, rain gauges, District Plan extents, land use, geology and flood maps.
- Hydrology: Very little information is provided on model hydrology in the hydraulic modelling report. This is potentially the most important aspect of the assessment. There appears to be a high degree of uncertainty regarding the hydrology and there are potential inconsistencies between approaches for different areas. The level of documentation to support the decisions is inadequate and there is no evidence of sensitivity testing. Where uncertainty exists, best practice suggests that the potential effects should be communicated in terms of impacts on the modelled flood extents and / or depths.
- Detail: Insufficient detail is provided about key aspects of the model build and simulations, such as the year the LiDAR was flown, how infiltration are roughness are represented, and information about results of the model validation process.
- Exclusions: Many important features are excluded from the model build with insufficient detail about where these exclusions are, where the effects of these exclusions may be realised, or the rationale for their exclusion. This is important for the District Plan. Examples include omission of stormwater pipes and culverts deemed not to affect flooding, pump stations, and outlet conditions for culverts discharging to the lake. Omissions have been attributed to “engineering judgement” without an explanation of that judgement or a map to show the areas in question so that the judgement can be reviewed.
- Uncertainty: A lot of uncertainty exists regarding many of the modelled parameters. Sensitivity assessments of model parameters is very important to reflect the uncertainty.
- Calibration and validation: The report is inconsistent as to whether model validation has been carried out or not. Either way, no information on the nature or outcomes of any validation is provided.
- Executive Summary: The Executive Summary raises topics that are not discussed in the body of the report, such as the 100-year ARI event that occurred in 2011.
- Report structure: The overall reporting structure is not easy to follow, with repetition of page numbers, duplication of material across sections, and misallocated content.
- Report focus: The updated report should be a standalone document for the current set of models only. The report contains irrelevant references to old models, preliminary model runs, and previous review comments about old models.

3 Review of hydraulic modelling approach

The hydraulic modelling review was based on the following information provided to T+T:

- The updated report by CDM[4] (which includes responses to the T+T 2020 review).
- Flood model results for the Nukuhau model only (2D water depths and levels). No other model outputs were provided.
- GIS layer of pipes and culverts included in the Nukuhau model.
- Other points of clarification gained through direct communications with CDM.

The review covers four themes which are set out in the sections that follow.

3.1 Implementation of T+T (2020) recommendations

Part of T+T's scope is to review the implementation of our 2020 recommendations. T+T's 2020 recommendations were presented to help support inclusion of the model results into the 2020/21 District Plan changes. The 2024 models are vastly different to the 2020 models and therefore we consider that the 2024 model review should be seen as a standalone review (i.e. not a continuation of the 2020 review). For example, a comparison of the 2D model extents for the Nukuhau catchment is shown in Figure 2. This shows a significant reduction in the 2D model extent as more hydrology is represented by the HEC-HMS model, i.e. Te Miro's work (Section 4). The consequences of this change on the floodplain is demonstrated in the example area presented in Figure 2.

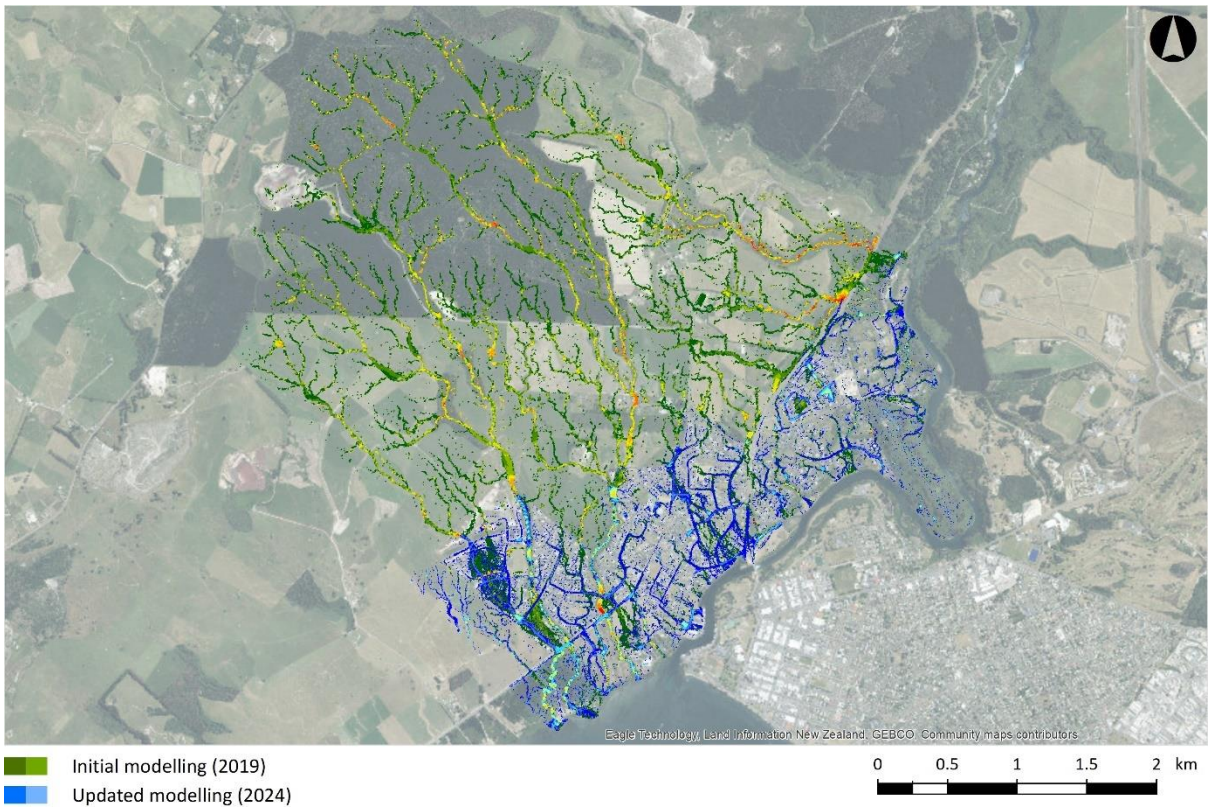

Figure 1. Comparison of 2D model domains for Nukuhau between 2020 (green and blue) and 2024 (blue only)

[4] Taupo Urban Stormwater. Hydraulic Modelling Report. CDM Consultants. Dated 8 March 2024.

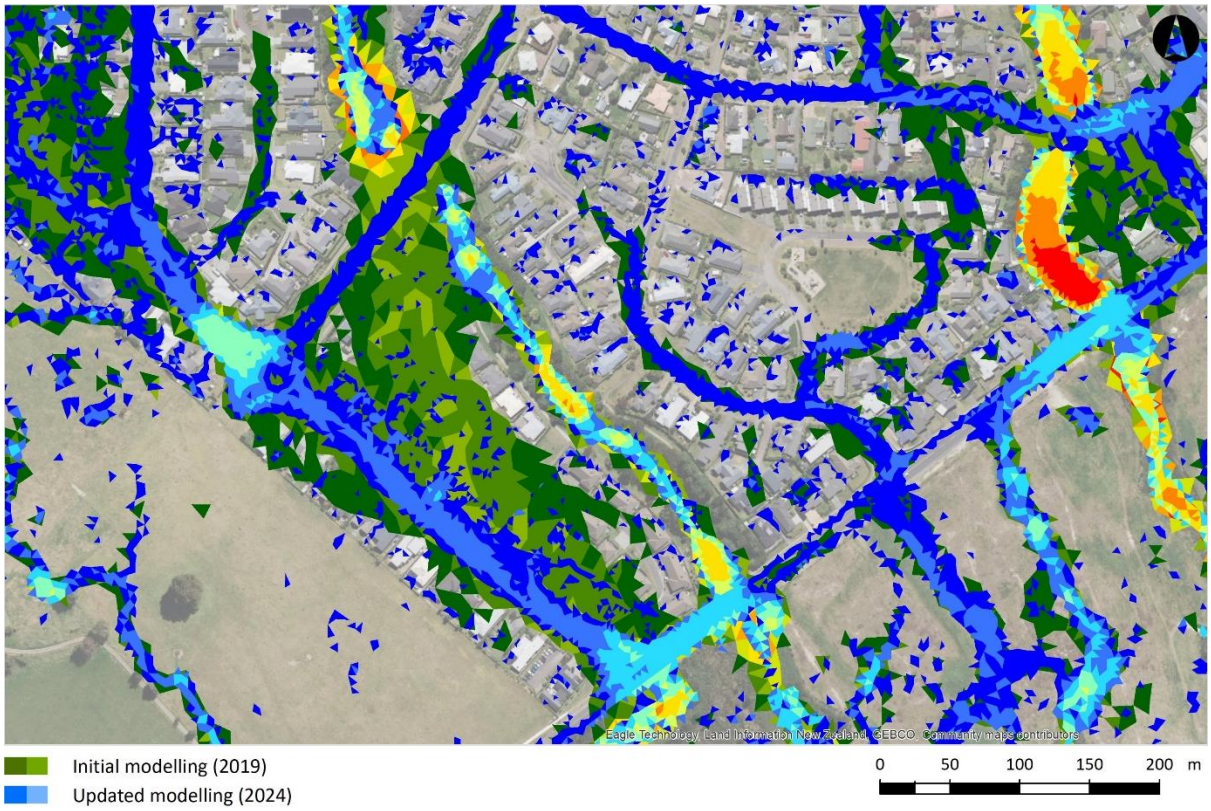

Figure 2. Comparison of initial and updated model results for Nukuhau (1% AEP with climate change)

On the basis that this review should be seen as a standalone review, we have provided comment on the implementation of our 2020 recommendations in Appendix A. This is done intentionally to reduce the emphasis of the 2020 review comments and to focus on the 2024 comments.

3.2 Appropriateness of model scenarios

The models were to have been updated explicitly for use in District Plan functions. This has particular requirements in terms of model scenarios. TDC has previously adopted the 1% AEP event for this purpose. While not entirely clear in the reporting, it appears that the modelling has been undertaken for the 1% AEP with climate change event (RCP 6.0) only, i.e. present day climate scenarios are not included.

The modelling report should include an explicit statement of the scenarios that have been modelled and how they relate to statutory and non-statutory documents (e.g. District Plan, Regional Policy Statements, and climate plans / commitments). While the executive summary refers to the models being used "to better understand the operation of the stormwater network during extreme rainfall events", this is not the intended purpose and nor is the stormwater network represented in the model to a sufficient degree to allow this.

3.3 Hydraulic model extents

The Taupō District has been covered by a number of models (the total number of models created is unclear) although there is insufficient information that describes the catchment coverage[5] and explains similarities or differences between the models.

[5] The 2D model domain information shown in Section 3.1 of the CDM report is a duplicate of the T+T figure used in the 2020 review. We understand that there have been changes to the 2D model domains since that time. However, these changes are not reflected in the figure.

The relationship between the hydraulic model and the wider catchment is important to understand. The manner in which the outputs of the hydrological modelling interface with the hydraulic model is also not clear, despite the criticality of this to understanding the model results.

3.4 Reporting gaps and additional recommendations

Comments relating to each section of the CDM report are listed in Table 1.

Table 1. Reporting gaps and additional recommendations

Report section	Section title	T+T comment or recommendation
1.0	Executive summary	Contains a lot of superfluous information, introduces material that is not part of the main report, and omits core information such as model purpose and scenarios tested. Overall, the executive summary is not an accurate synopsis of the modelling report.
2.1	Model history and purpose	The history of the models is not relevant; the report should only cover the flood maps that will be part of the District Plan. Remove all reference to initial and preliminary models unless relevant to a specific point being made. Remove reference to "existing" models and the T+T 2020 review since these are no longer relevant.
3.1	Catchment extent	Remove reference to initial models. Identify limitations of the current LiDAR which have resulted in a different approach being taken. Include a map showing the urban areas, catchment extents, and point source inflows from Te Miro.
3.2	Topography	Note the year of LiDAR acquisition for each model and provide a map showing the date of LiDAR used for the different areas.
3.3	Rural inflows	No reference is provided to the Te Miro work which is critical to the models. It is not clear where overall responsibility for the hydrological inputs sits. The relevance of TP108 is not clear, and some contradictions with Sections 3.4 and 3.5 are apparent.
3.4	Geology and soils	It is noted that that the initial models used 100% imperviousness but does not comment on whether this has now changed. States that the "worst-case scenario" is considered appropriate for high-level planning purposes. This relates to a broader topic regarding the appropriate use of conservatism for District Planning purposes. Adopting conservatism without consideration of sensitivity and uncertainty may unnecessarily affect landowners
3.5	Infiltration model	Further reference is made to the initial models without a clear statement of how infiltration is applied in the updated models. A uniform rate of 25.9 mm/h is cited but without explanation of whether this is implemented. The infiltration approach is inconsistent with (and contradictory to) the hydrological modelling of the rural catchments. Te Miro field testing showed high infiltration rates and high variability within a single land use type. It is not apparent that any sensitivity testing of hydrological parameters has been undertaken. In light of the level of uncertainty in these values, it is recommended that sensitivity testing is undertaken.
3.6	Surface roughness	Erroneously implies that T+T advised the use of two roughness values. T+T did not advise this. A two-value approach is an oversimplification, and the lack of model calibration is not a justification for the approach taken.

Report section	Section title	T+T comment or recommendation
		Variable roughness is more appropriate for floodplain modelling for District Plan purposes. There is extensive literature providing guidance on appropriate roughness values for different land use types. It is recommended that model roughness is updated in line with these. The effect on flood extents of adjusting roughness is unclear since some areas will experience more conveyance, passing more flow downstream, and other areas may experience more attenuation and increased flood depths.
3.7	Terrain and resolution	Remove reference to initial models. Resolution is important in representing watercourses and floodplains too, not just around dwellings. Additional information is required on storage basins, wetlands, dams, and how they are represented in the models.
3.8	Stormwater network overview	Notes omission of some pipes “as agreed” but without detail on who this was agreed with or why. The implications of this assumption on the floodplains in the District Plan are not stated. A map showing the areas where pipes are omitted is important to help identify areas where the floodplain may be larger than currently shown and to allow the “engineering judgement” behind omitted pipes to be reviewed. No statement is made on whether properties are affected by this decision. Where pipe invert data is lacking, this can be inferred from other sources.
3.9	Land use	A map of land use categories is required as well as an explanation of how this information been accounted for in the model in terms of hydrology, infiltration, roughness, buildings, roofs, etc.
4.1	Hydraulic model	Surface flows are only able to enter the stormwater network at manholes; this assumption is important because it does not represent the stormwater inlets which are located along flow paths. This assumption can reduce the amount of stormwater able to get into the primary network. No information is provided on the horizontal and vertical accuracy of the LiDAR surfaces used, nor on any modifications required to better represent e.g. watercourses, buildings, kerb lines, or stopbanks. The report should be updated to include this information.
4.2	Asset data	Repeated reference to pipe elements included only where “considered to have an effect on property flooding” and the use of “engineering judgement” to determine this. See Section 3.8 comments. Pump stations are not included in the models. It is understood that there are no network pump stations but there are pump stations which drain ponding areas. The location of these is not provided nor is any statement on their importance or the implications of their omission. It would be useful to have the pump station locations shown on a map and a comment included to describe their function.
4.3	Hydrological model and approach	Virtually no information is provided in this critical section. It needs to reference inflows from the upstream catchments (i.e. Te Miro’s work) with a map showing the relative extents of the hydraulic and hydrological models.
4.4	Rainfall and climate change	Remove irrelevant commentary about old models. Comment only on the rainfall that has been used to produce the flood maps that will be used in the District Plan. Commentary is required on whether the approach to climate change adjustment is consistent with scenarios required by Waikato Regional Council and TDC in terms of the RCP emissions scenarios and timeframes. An explanation is required as to what is meant by the 24-hour design rainfall patterns being “adapted”.

Report section	Section title	T+T comment or recommendation
		No information is provided on design rainfall depths, the variability of depths across the models, the temporal distribution used, or the relationship with rainfall used in the hydrological models. The report should be expanded to include information of each of these. It is understood that the models use a nested storm profile. This is only referred to only in the 'Audit Response' section and should be made clear in the main report.
4.5	Boundary conditions	No lake level or river level boundary conditions have been applied in the models yet the report notes these could be necessary for the District Plan flood hazard review. Given that is the express purpose of the modelling, it is recommended that these levels be included or an explanation provided for their continued omission.
4.6	Data issues	Pipe invert levels were assumed or interpolated where these were missing, "as agreed". No information on determining pipe gradients is provided nor about who this approach was agreed with. All assumptions about asset parameters should be clearly stated, including those which are surveyed and those which are assumed, and a map of asset locations, should be included in the report. A map of areas with known data limitations should also be included.
4.7	Assumptions and simplifications	Significant differences are apparent in assumptions about hydrological losses (including infiltration) among the rural, rain-on-grid urban, and rain-on-grid non-urban model components which do not align. While recognising current limitations in available data, this only makes it more important to clearly state and justify assumptions made and to consider model sensitivity to these decisions. Outlet conditions for culverts discharging to the lake are not assessed and therefore there may be an important hydraulic process that is omitted. The consequences of this omission are unclear, although likely greatest near on properties closest to the lake edge and in flatter areas. Lake flooding has not been included in the modelling. However, this should be an important floodplain for the District Plan to identify. It is understood that this information is available on the TDC online mapping platform 'Mapi'.
5.1	Sensibility checks and ground truthing	The apparent existence of flood records to use for model validation noted in this section contradicts the previous section which suggests there are no records of actual flooding. A comment on the nature and extent of available flood observations would be useful.
5.2	Calibration and validation	The value of model calibration and validation for improving confidence in the modelled flood extents is noted but is not undertaken due to a stated lack of observed records. More information on what data do exist would be useful, such as how long the records have been available, what the maximum recorded flow rates are, and to what return period event they relate.
5.3	Mass balance checks	Mass balance checks are noted as being within expected tolerances. A comment on the specific values with respect to the tolerances would be useful.
6.1	Model confidence	A high level of confidence is ascribed to the location of the modelled overland flow paths, with which we agree, and by extension to the flood hazard areas, with which we do not agree. As noted throughout the review, comments on hydrology and the inclusion or exclusions of pipes and other assets could significantly impact the flood hazard areas such that current confidence cannot be high level.

Report section	Section title	T+T comment or recommendation
		The report notes that model validation has been achieved in "some areas". While this directly contradicts the statement in Section 5.2, it appears to have been undertaken against previous model results which may themselves be unvalidated. Either way, the results of any validation should be included in the report. The relative absence of stormwater network data is noted in the report as not having a significant influence on flood effects during a 1% AEP event. This may not be a reasonable assumption as noted in previous comments.
6.2	Recommendations	The report observes that critical outlet conditions for culverts discharging to the lake could be modelled to improve model accuracy "where considered necessary". A statement on what constitutes "necessary" would be useful.
7.0	Audit response	Remove from report as this relates to old versions of the models and implies that a greater level of review of the 2024 models has been carried out. Does not include any of the comments raised in this review.

In the future, the District Plan will adopt flood maps that have been generated by the models. There were no flood maps provided in the CDM report and no documentation regarding the post-processing of model results to create flood maps for publishing. This is an important point because commonly the post-processing process will make assumptions regarding the refinement of modelled outputs.

4 Review of hydrological modelling (Te Miro Water)

A key recommendation from the 2020 review was to develop inflow hydrographs to account for runoff from the rural catchments into each 2D (urban) model domain. These hydrographs were prepared by Te Miro Water (Te Miro) for CDM. This section refers to the inflows from the rural catchments to the 2D model domains. It does not include rainfall-runoff processes within the 2D model domain, which were covered in the previous section.

The hydrological modelling review was based on the following information provided to T+T:

- Spreadsheets of parameters used in each model.
- A memorandum[6] summarising the model build process and assumptions.
- Other points of clarification gained through direct communications with Te Miro.

We understand that the memorandum was created as a summary document for CDM rather than as a standalone modelling report. However the consequence of this is that there is inadequate documentation of the regarding the overall approach taken and key parameters adopted in the modelling. It is suggested that the memorandum content be expanded in line with the recommendations of this review and brought into the CDM report so that all modelling information is contained within a single reference document.

4.1 Hydrological modelling methodology

Te Miro used the software package HEC-HMS to simulate runoff from rural catchments into each of the 12 hydraulic models. While the CDM report says the TP108 method for rainfall-runoff modelling was used, the memorandum makes no mention of this. TP108 is an Auckland-specific guideline and should be used with caution outside that region. In common with TP108, however, it uses the SCS curve number approach to account for rainfall losses. There are many further aspects to the TP108

[6] Taupo Region Hydrology Runoff to Support Hydraulic Flood Modelling (April 2022).

guidelines and it is unclear whether all these aspects have been represented in accordance with the Auckland guidelines (e.g. temporal rainfall patterns, areal reduction factors, channelisation factors, and initial abstraction considerations).

The rural catchments have been delineated from multiple terrain sources and are displayed in the spreadsheets, although not at a resolution that enables their review. It is not clear if the LiDAR sources cited in the memorandum are the same as those used in the hydraulic models as the dates are not provided in either document. Model time-step and curve number selection are appropriate for the level of modelling undertaken, with catchment-specific curve numbers calculated from soil drainage and land use maps.

In common with the CDM report, the memorandum would benefit from the inclusion of maps to describe spatial aspects of the model build such as the catchment extents, how these interface with the hydraulic model domains, and the location at which HIRDS rainfall depths apply. Some inconsistency with the CDM report is apparent in terms of the scenarios modelled, climate change projections, and the way infiltration is represented. There is also some inconsistency in derivation of times of concentration between the spreadsheets (provided separately) and the memorandum.

As with the hydraulic models, the hydrological models are not calibrated. This introduces significant uncertainty into the resultant hydrographs in terms of their total runoff volume, peak flow rate, and timing, all of which influence the nature of flood levels. The memorandum refers to a sensitivity run being undertaken but without detail on the simulation or results. Sensitivity testing of key model parameters is necessary to understand the range of possible outcomes that may result from variable parameter values.

4.2 Inflow transfer to hydraulic models

The hydrographs form inflow boundary conditions of the 2D rain-on-grid models. No information is provided in the memorandum (or the hydraulic modelling report) on how the inflows are transferred to the hydraulic model. While catchment outlets are evident on the spreadsheet maps, the scale of presentation does not allow identification of where these discharge to the 2D model domains or the manner in which they are applied, e.g. as discrete 2D source points or spread across a wider area.

No temporal distribution of design rainfall is provided, nor any discussion of how this compares to rainfall patterns used in the hydraulic model. Spatially-varying hydrological losses are applied, with field testing undertaken to understand infiltration rates. Testing showed infiltration rates well in excess of the Soil Type A category (i.e. most infiltrative) used to select the model curve numbers, and emphasised the high variability in infiltration that can exist within a single land use class. The loss models used are at odds with the no or low infiltration assumptions of the hydraulic modelling.

4.3 Additional recommendations

Key review findings, the potential effect of these findings on modelled flood extents, and recommendations for amendments to the models and clarification of documentation, are summarised in Table 2.

Table 2. Hydrological modelling review summary

Item	Review observation	Possible impact on flood levels	Recommendation or comment
1	Areal reduction factors are not applied to total catchment area (i.e. rural plus LiDAR-based), i.e. a point rainfall value is applied uniformly over the full catchment area.	Over-estimation of runoff volumes and peak flow rates due to excessive application of rainfall to catchment (especially relevant for very large catchments).	Consider the use of areal reduction factors and comment on whether they are / should be adopted. For example, the Waikato stormwater runoff modelling guidelines recommend they are applied to catchments of greater than 20 km^2.
2	HIRDSv4 rainfall data used are tabulated but not shown on a map or with coordinates.		Provide a map showing the location to which the point estimates of rainfall depth apply.
3	Areas between the rural catchments and the LiDAR extents do not appear to be fully accounted for, leaving gaps in surface runoff potential.	Under-estimation of runoff volumes and peak flow rates due to reduced catchment areas.	Extend LiDAR domain (in hydraulic models) to cover areas not represented by the hydrological modelling.
4	Modelled scenarios are for climate change adjusted design rainfall events only (50%, 10%, and 1% AEP[7]), i.e. no present day climate simulations were undertaken.	Climate change scenarios represent extreme future conditions. Present day scenarios are also required for consistency with the hydraulic modelling. The CDM report identifies "The current scenario for the 100-year rainfall has also been included in the modelling." However, the Te Miro report does not provide 100-year ARI rainfall without climate change. It is therefore unclear where the hydraulic model has obtained the inflows for this scenario from.	Clarify, confirm, and document target events for District Plan purposes and ensure these align with the hydraulic modelling.
5	Scenarios are stated as being for existing development only yet subsequent reference is made to maximum probable development.		Clarify, confirm, and document the exact scenarios and development conditions modelled.
6	The RCP6.0 emissions scenario was adopted as the basis for climate change adjustment of rainfall.	MfE guidance[8] uses RCP4.5 with sensitivity testing using RCP8.5. RCP4.5 would likely result in lower runoff volumes and peak flow rates than the RCP6.0 outputs. RCP8.5 would likely result in higher runoff	Clarify, confirm, and document the appropriate climate change emissions scenario used in the modelling. This may require comparison with Waikato Region, Taupo District, and MfE policy and guidance for

[7]Annual Exceedance Probability

[8] MfE (2021). A guide to local climate change risk assessments. Ministry for the Environment, September 2021.

Item	Review observation	Possible impact on flood levels	Recommendation or comment
		volumes and peak flow rates than the RCP6.0 outputs	alignment, e.g. the Waikato stormwater runoff modelling guideline directs practitioners to the latest MfE guidance. State the rationale for using RCP6.0.
7	Climate change projection of HIRDS rainfall is to 2130 (2120 also stated earlier in the memorandum).	Greater rainfall depths associated with more futuristic timeframes lead to increased runoff volumes.	HIRDS data stop at the year 2090[9]. Provide reason for using 2130 and describe method used to extrapolate to 2130.
8	Inconsistency in time of concentration and catchment slope estimation methods between the spreadsheets and memorandum.		Clarify methods used. The 'equal area' slope method is the approach generally used in the time of concentration formulae in New Zealand.
9	The hydrological models use Type A soils (highly infiltrative / low runoff potential) with field testing to verify the suitability of this approach.		The high rainfall losses are inconsistent with the apparently low (or no) infiltration assumed in the hydraulic modelling. Weighted curve numbers for each catchment should be tabulated in the report.
10	The hydrological models are not calibrated on the grounds that no historical flood observations exist.	Uncalibrated models have increased levels of uncertainty, thereby increasing the need for sensitivity testing to that uncertainty can be communicated effectively.	Based on this topic, and other comments throughout the review, it is recommended that model calibration, validation, sensitivity testing and uncertainty are reviewed and discussed more fully.

5 Review of flood model outputs

Flood model outputs were reviewed for the 1% AEP with climate change event, using the Nukuhau model as a representative case (only output provided). The objective was to comment on the degree to which aspects of the model build may lead to over- or under-estimation of flood extents.

The updated Nukuhau flood extent is shown in Figure 3. Stormwater pipes and culverts that are included in the model[10] are shown in red. The rationale for including or excluding these assets (and not others) is unclear in the reporting.

The omission of large culverts may lead to over-estimation of flood depths upstream of the culvert position and under-estimation of flood depths downstream, as flows are artificially detained upstream of the road embankments in the models.

Culvert omissions may also translate to elevated flow depths across the road surface. For example, the maximum water depth on the road surface at the point where the triple-barrel culvert is shown crossing Acacia Bay Road in Figure 3 is 2.14 m in the initial model (which includes no culverts) and 0.49 m in the updated model (which includes the triple-barrel culvert). This reduction is likely the

[9] Mid-point of the 2081-2100 range provided by HIRDS.

[10] Stormwater assets included in the models were provided separately to T+T on request as a GIS shapefile on 19 July 2024.

combined effect of the increased conveyance allowed for by the culverts and the reduced inflows reaching Acacia Bay Road via the gully due to other model updates (especially hydrological inputs).

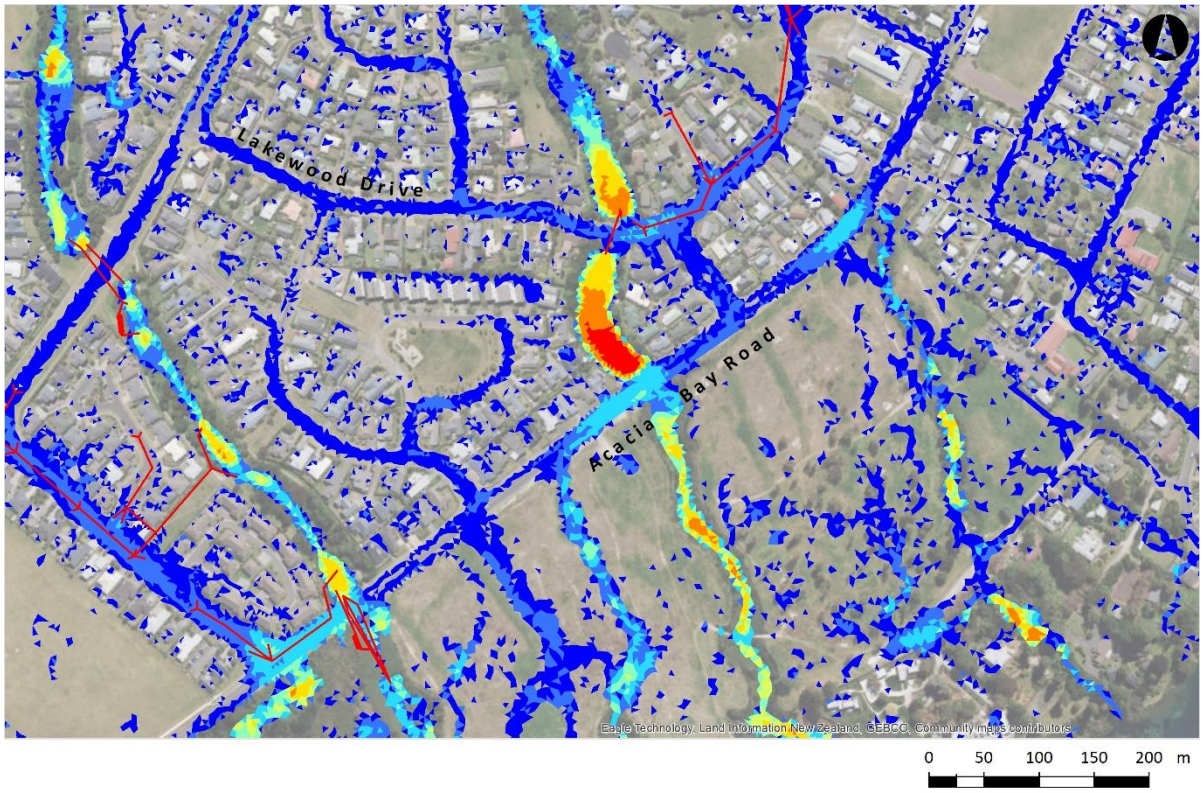

Figure 3. Nukuhau 1% AEP with climate change flood extent (pipes and culverts included in model in red)

6 Conclusions

Updates to the hydraulic modelling since 2020 have improved confidence in the flood outputs. In particular, the use of inflow boundary conditions, a finer model resolution, and spatially varying inputs (in the hydrological modelling) that reflect the diverse landscapes of the Taupō district have reduced some of the conservatism that characterised the model results reviewed in 2020.

However, there are two broad reasons we are currently unable to support the use of the model results for District Planning purposes:

1 Inadequate documentation to explain how the flood maps have been derived. This is due to gaps in reporting information and contradictory information, suggesting errors.

2 Low confidence in the floodplain extents and depths, due to:

- Omission of important hydraulic features (e.g. pipes, culverts, bridges).
- Limited consideration of floodplain uncertainty, caused by lack of sensitivity testing of important assumptions regarding hydrology and hydraulics (e.g. lake levels, impervious assumptions, hydrophobic conditions).
- Inadequate documentation (refer point 1).

7 Applicability

This report has been prepared for the exclusive use of our client Taupo District Council, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

Tonkin & Taylor Ltd

Report prepared by:



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Reuben Ferguson
Water Resource Engineer

Authorised for Tonkin & Taylor Ltd by:



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Jon Rix
Project Director

Appendix A 2020 review comments & implementation

T+T's 2020 review recommended updates to 14 aspects of the model build to improve confidence in model results. Of these, seven had a 'very high' or 'high' priority.

Key updates that have brought some rigour to the models and increased confidence in the results are the use of inflow hydrographs to account for rural flows entering the urban areas, and the adoption of a finer resolution mesh. However, concerns remain at the partial or non-implementation of other recommendations made.

The extent to which CDM has addressed the 2020 recommendations is summarised in Table 3. Where a lack of information has been identified, this does not necessary mean the model has not been updated but rather that it has not been documented. Where updates have been made but only recorded in the 'Audit Response' section of the report, these need to be stated in the relevant section of the body of the report.

Table 3. Implementation of 2020 recommendations by CDM

Item	2020 recommendation	CDM response	T+T comment
Terrain and resolution			
1.1	Update LiDAR as available and compare with existing surface.	New LiDAR noted as becoming available and models "continuously updated" with this. Unclear if the updated models have been run with new LiDAR.	CDM to clarify the spatial extent of LiDAR datasets used and the dates that they were flown.
1.2	Refine resolution as appropriate in models. Ensure long-term needs of TDC are accounted for, e.g. future land uses and stormwater interest areas.	Model resolution reduced in all models from 25-112 m^2 to 4-16 m^2 mesh size to better reflect areas around dwellings.	Improved resolution in floodplains, noting that Model resolution is also important in representing watercourses and floodplains.
1.3	Apply spatially varying roughness to the models.	Roughness changed to 0.015[11] (urban areas) and 0.035 (rural areas) from a previously uniform 0.025. No further discrimination was justified on the basis of a test scenario which showed that flood levels did not change "significantly" when roughness values were changed.	The updated roughness values remain an overly simplistic representation of the range of land uses within the Taupō District. Further information is required to explain the approach taken. A map showing the distribution of roughness values should be provided.
Hydrology			
2.1	Adopt HIRDSv4[12] rainfall depths that are specific to each catchment.	No information is provided on rainfall depths or temporal profiles used, or any variability	Apply catchment-specific rainfall depths in accordance with the observed variability noted in the 2020 review.

[11] Adoption of 0.015 is erroneously attributed to a T+T recommendation.

[12] High Intensity Rainfall Design System

Item	2020 recommendation	CDM response	T+T comment
		in rainfall depths across the various model domains.	Alternatively, provide justification for using a uniform rainfall depth across all models.
2.2	Account for climate change in accordance with the latest MfE advice.	Rainfall has been adjusted for climate change using RCP6.0 projected to 2100.	Inconsistency in approach with the hydrological modelling which uses RCP6.0 projected to 2130 (or 2120). Providing clarity on the range of scenarios in the rural hydrological model and rain on grid models is required, including why the scenario is important.
2.3	Develop hydrographs for all catchments that drain into the model domains and add these to the 2D extents as point source inflows.	Hydrographs have been developed by Te Miro Water. No information on this is provided in the report nor any comment on how the hydrographs are applied to the 2D models.	Expand and combine the 'Hydrology' and 'Rural inflows' sections of the report to include background on hydrograph development and the manner in which the hydrographs are applied to the 2D models.
2.4	Apply an initial and continuing loss to the 2D model based on conservatively low infiltration rates for the surface geology from local studies or literature review. This precautionary approach is due to uncertainty about the behaviour of the pumice-based geology.	Reiterates position on the value of model conservatism based on 100% runoff in a 100-year ARI[13] storm to define a "worst case scenario". Also refers to a literature-based infiltration rate of 25.9 mm/h but without saying whether this was applied in the models. No reference is made to how losses are represented in the rural catchments.	Determining the appropriateness of such a precautionary approach is the key aspect here. No progress on understanding this process further is apparent since the initial review comment. The question is whether TDC and CDM are happy with only representing a worst case flood scenario that has the potential to adversely affect some property owners unfairly.
Stormwater assets			
3.1	Add all stormwater pipes to models.	Stormwater pipes are included "where appropriate". No map or table of pipes is provided, nor an explanation of what constitutes "appropriate". Report notes that invert estimation "not likely important" for 50-year ARI or 100-year ARI events.	Provide a map of those pipes included in each model. Explain the rationale for inclusion or exclusion in the model. The District Plan deals with property level flooding issues and therefore the omission of some pipes could be important.
3.2	Ensure high-level representation of culverts and bridges in all modelled areas.	Culverts are included where "of significance". No map or table of modelled culverts is provided, nor an explanation	Provide a map of those culverts included in each model. Explain the rationale for inclusion or exclusion in the

[13] Assumed to mean 100-year ARI with climate change storm.

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		of what constitutes "significance".	model, e.g. diameter threshold. The District Plan deals with property level flooding issues and therefore the omission of some culverts could be important.
Calibration and validation			
4.1	Develop a programme of works to develop hydraulic model calibration.	The report notes that model calibration cannot be undertaken due to the absence of observed flood records. It says these have not been provided by TDC. It is not clear whether such records do exist.	Request flood records that may be held by TDC. Discuss and develop a strategy for collecting flood levels and flow rates in the event of future storms.
4.2	Develop a hydrological model calibration and validation programme to develop an understanding of catchment response to rainfall.	No reference to hydrological calibration is made in the hydraulic modelling report. The Te Miro memo states that the hydrological models are uncalibrated.	Develop a strategy to calibrate the model parameters to observed conditions. This is especially important in light of uncertainty in current parameter settings.