A Risk-based Approach to Assessing Asset Performance of Flood Infrastructure

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Abstract

New Zealand has developed a comprehensive, risk-based framework that assesses the performance of flood protection infrastructure. This framework - the Asset Performance Assessment Code of Practice (the Code) - was developed for the river managers across New Zealand, who sought a framework that would assess the overall performance of flood protection assets in a consistent manner across the country. The Code aligns with the requirements set out in the ISO 5500X suite of international standards for asset management. By applying the Code to individual river schemes, using the Asset Performance Tool (the Tool), the performance of flood protection infrastructure along each river is assessed against required service levels, whilst considering the potential impacts posed to communities. Assessments attribute a risk profile along each river, segmented into discrete segments. This risk-based approach has multiple benefits, discussed further in this paper.

Introduction

A comprehensive, risk-based framework to assess the performance of flood infrastructure assets was developed in 2015 [1]. This framework, called the *Asset Performance Assessment Code of Practice* (the Code), was developed for flood risk asset managers across New Zealand. The objective of the framework sought to assess the performance of flood infrastructure in a consistent manner across the country.

The Code aligns with the requirements set out in the ISO 5500X suite of international standards for asset management [2]. Furthermore, a risk-based framework is appropriate under New Zealand's Resource Management Act (1991). The framework is also consistent with and supported by recommendations made following an asset management maturity assessment undertaken on the flood protection activity across New Zealand.

The 'Asset Performance Tool' (the Tool) was developed by consultants in 2017, that allows you to apply the Code to individual flood protection river schemes. By inputting data into the Tool, the performance of all the flood protection assets along the river are assessed against required protection standards (or service levels), whilst also considering the impacts posed to communities.

Once all data has been inputted for a specific river scheme, each assessment derives a risk profile along that river, segmented into distinct reaches (100-200m).

Performance assessments enable the user to:

- Identify critical assets and critical asset systems along the river scheme;
- Identify failure modes for asset systems, in relation to the performance framework;
- Communicate risk to stakeholders;
- Perform risk-based decision-making in relation to asset performance and risk;
- Prioritise remedial actions to the highest risk areas; and
- Identify gaps in knowledge or lack of accurate data.

Asset Performance Framework

In context to flood risk asset management, and as defined within the Code, asset performance is expressed by being able to confidently state that there is an appropriate asset for the defined level of service, in an appropriate condition, that will perform reliably. Understanding asset performance and its contribution to the overall risk will highlight those assets that contribute most to the risk.

The Code is a good-practice guideline document which discusses the theory and methodology with regards to asset performance of flood infrastructure.

The Tool is the system used to store and analyse the data required for each performance assessment, and produces the overall performance scores in terms of risk.

Appendix 1 represents a high-level, schematic breakdown of the Code and the criteria required for the performance assessment. Each criterion is described below.

Consequence is scored between 1-5 (insignificant - catastrophic), for each discrete 100-200m reach of river. The Code prescribes a consequence matrix, aligned to international standards, encompassing economic, social, cultural and environmental aspects.

There is no prescribed methodology within the Code to determine the consequences of asset failure. However, typically flood hazard maps and hydraulic modelling is used to estimate damages from specific flood events.

Capacity, also scored 1-5 (rare – almost certain), is calculated using an equation based on the probability of overtopping, and relates to the available freeboard, flood event levels, and stopbank (levee) crest level. This is assessed using hydraulic modelling and crest level surveys, and other relevant information.

Intrinsic Strength, also rated 1-5 (rare – almost certain), relates to the probability of stopbank failure from the design flood event, and is assessed using surveys, geotechnical investigation, models, engineering knowledge and other relevant information.

Condition, also rated 1-5 (very good – very poor), is based on the physical condition of the assets and is assessed through visual inspections by operational staff. This encompasses all the assets present within each discrete reach, including: channel, riverbank, erosion protection, berm, culverts, floodgates, and the stopbank.

Spatial Map Output

The Tool only produces a series of risk scores related to the areas of river assessed, and does not present these risk scores spatially making it difficult to communicate and present the information to stakeholders in a meaningful way. To effectively communicate the outputs of the assessments, and therefore the risk for each river scheme, the Tool has been linked to a Geographical Information System (GIS). This enables the risk profiles for each river scheme to be displayed visually on a map. Relevant information, such as failure modes, can be also annotated. Appendix 2 represents an example of a map output.

Assessment Results & Lifecycle

The asset performance lifecycle can broadly be broken down into three steps: identification, communication, and management (Figure 1).

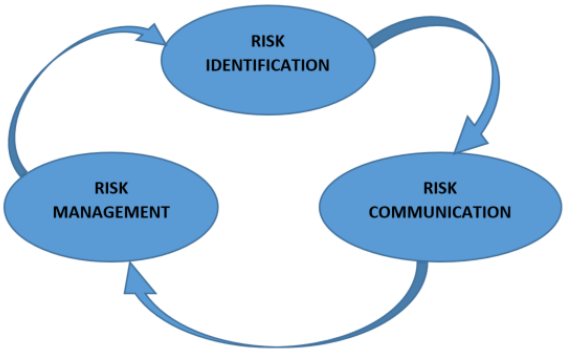

Figure 1. Asset performance lifecycle.

Risk Identification

By using the framework to determine a risk profile, it also facilitates the identification of critical assets systems, together with critical assets and their failure modes. This is an essential process, allowing the user to further target and refine investigative activities, maintenance plans and capital expenditure plans for critical and other high risk areas.

As discussed, following completion of an assessment, outputs are displayed spatially. The maps for each individual river scheme can then be presented to the key stakeholders. It is recommended that results are first discussed with key personnel within each Council, to interrogate the results, review any discrepancies, and ultimately reach agreement with the final outputs.

Assessments will be updated with any new information, such as new condition data following visual inspections, new or disposed assets, and any new investigative material (e.g. hydraulic models). This is discussed in more detail later in *Updating Assessments*.

Risk Communication

The spatial map output allows for an efficient and effective discussion on the current risk profile for each river scheme. The risk profiles can be integrated with the latest asset condition data. This enables a comparison of asset condition versus overall risk (Figure 2).

Figure 2 illustrates a 'very high' risk area (represented by the red shaded area) as well as the physical condition of the flood infrastructure (represented by coloured dots). In this examples the dots are predominantly in either 'very good' or 'good' condition. This indicates that although there is very high risk in this area, it is not related to asset condition.

By presenting risk profiles in conjunction with asset condition, confidence can be provided to decision makers on the current state and performance of flood infrastructure, with transparency on any issues or risks identified.

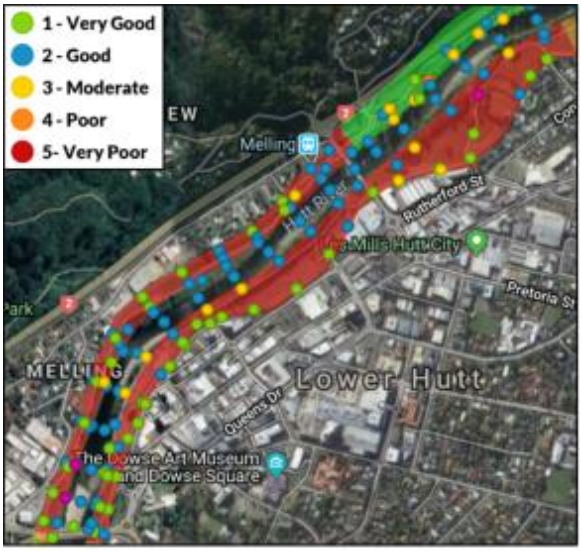

Figure 2. A map illustrating asset condition (coloured dots) versus overall risk (polygons).

Risk Management

Once the risk profiles have been determined, the risks and their specific failure modes can be analysed in more detail. Key operational and engineering personnel review the risks and failure modes, and discuss options to reduce and/or manage the risk.

To facilitate the development of prioritised maintenance plans, an asset defect report is produced following the asset inspection programme. This report lists all the assets which have had defects recorded against them. Corresponding risk scores from the asset performance assessments are assigned to each asset defect, enabling the prioritisation of maintenance plans (Appendix 3).

Asset defect reports in conjunction with the spatial map allows staff to easily visualise where the damaged assets are and what the associated risk score is for that area. This ability to identify, communicate and proactively manage risks increases the confidence of key stakeholders and communities. There is transparency that any risks or damages identified are being monitored, managed and mitigated using sophisticated risk-based decision making.

Updating Assessments

Asset performance assessments will need to be updated regularly as the rivers are dynamic and the risk can often change. For example, following a flood event that resulted in damage to infrastructure, or after new assets have been constructed or existing assets have been maintained, or if a new investigation, survey, or inspection has been completed, this new data should be included in an assessment.

All of the above have the ability to influence asset performance and therefore alter the risk profile of the river scheme. Therefore, any new information should be updated within the assessment to account for any change in risk.

By updating the assessments regularly, the asset performance lifecycle reaches full circle. Once the assessments have been updated, then the lifecycle starts again, beginning with risk identification, communication, and so on.

Continual Improvement

As per the ISO 5500X series of international standards for asset management, continual improvement is a concept applicable to the assets, the asset management activities, and the asset management system [3]. Opportunities for improvement can be determined directly through monitoring the performance of the asset management system, and through monitoring asset performance.

Following successful application of the asset performance framework, focus is now shifting to using the information in the final step of the asset performance lifecycle: risk management. Once the risk has been identified and communicated, how do we manage this risk?

To support the risk management process, a cost-benefit analysis could be integrated within the Tool, to support optimising the most beneficial solution for each risk area. The most appropriate solutions for all the highest risk areas can then be prioritised for maintenance and improvement activity.

Another potential improvement action is related to asset inspection frequency. In New Zealand, there is currently no national standard for asset inspection frequency. There is the opportunity to implement a risk-based approach to asset inspection frequency, where frequency is determined by risk score.

The intention would be to perform inspections at a frequency associated with the level of risk for the corresponding section of river. Higher risk assets would be inspected more frequently, and vice versa.

For example, with reference to Figure 4, the inspection frequency for the assets located within the following risk areas could be:

- high and very high risk = 6-monthly;
- medium risk = 12-monthly; and
- low and very low risk = 24-monthly.

		Consequence				
		1	2	3	4	5
Probability	1	very low	very low	low	medium	medium
	2	very low	low	low	medium	high
	3	very low	low	medium	high	high
	4	low	medium	medium	high	very high
	5	medium	medium	high	very high	very high

		Consequence				
		1	2	3	4	5
Probability	1	24	24	24	12	12
	2	24	24	24	12	6
	3	24	24	12	6	6
	4	24	12	12	6	6
	5	12	12	6	6	6

Figure 4. Above: Risk matrix from the Code. Below: same table but with inspection frequency – numbers represent months between inspections.

Conclusion

New Zealand has improved its approach to flood risk asset management, specifically its processes and methodologies surrounding asset performance and risk-based decision making. These new processes allow organisations to identify critical assets, prioritise inspection regimes and maintenance and capital programmes, and communicate the ever-changing risk to its stakeholders, thereby providing greater confidence in the performance of its flood infrastructure.

The asset performance framework supports risk-based decision-making, aligning with the requirements set out in the series of ISO 5500X international asset management standards [2]. Furthermore, it will provide transparency for key stakeholders and communities in understanding how the assets are performing and in communicating the risk.

The framework is dynamic, allowing for changes and updates in information such as climate change, land use change and asset performance data. Furthermore, it can be used to plan next steps and supports continual improvement of the flood protection asset management system.

References

[1] NZ River Managers Special Interest Group, "Flood Protection Asset Performance Code of Practice". New Zealand. 2015.

[2] ISO 55001, "Asset Management – Management systems – Requirements". Second edition. 2024.

[3] ISO 55000, "Asset Management – Overview, principles and terminology". Second edition. 2024.

Acknowledgements

New Zealand River Managers Special Interest Group for developing the Code of Practice.

Waugh Infrastructure Limited for developing the Asset Performance Tool.

National Asset Performance User Group for the workshops that have facilitated development of the Asset Performance Tool.

Luke Turner for his part in producing the spatial map output.

Resume

George Arthur Bowman is a Member of Engineering New Zealand and joined the Board of Āpōpō in 2021. George has been working in New Zealand since immigrating in 2017. George specialises in infrastructure asset management, specifically flood risk asset management. George is Director of Asset BowManagement Ltd, operating since 2019, providing professional services to local government across New Zealand.

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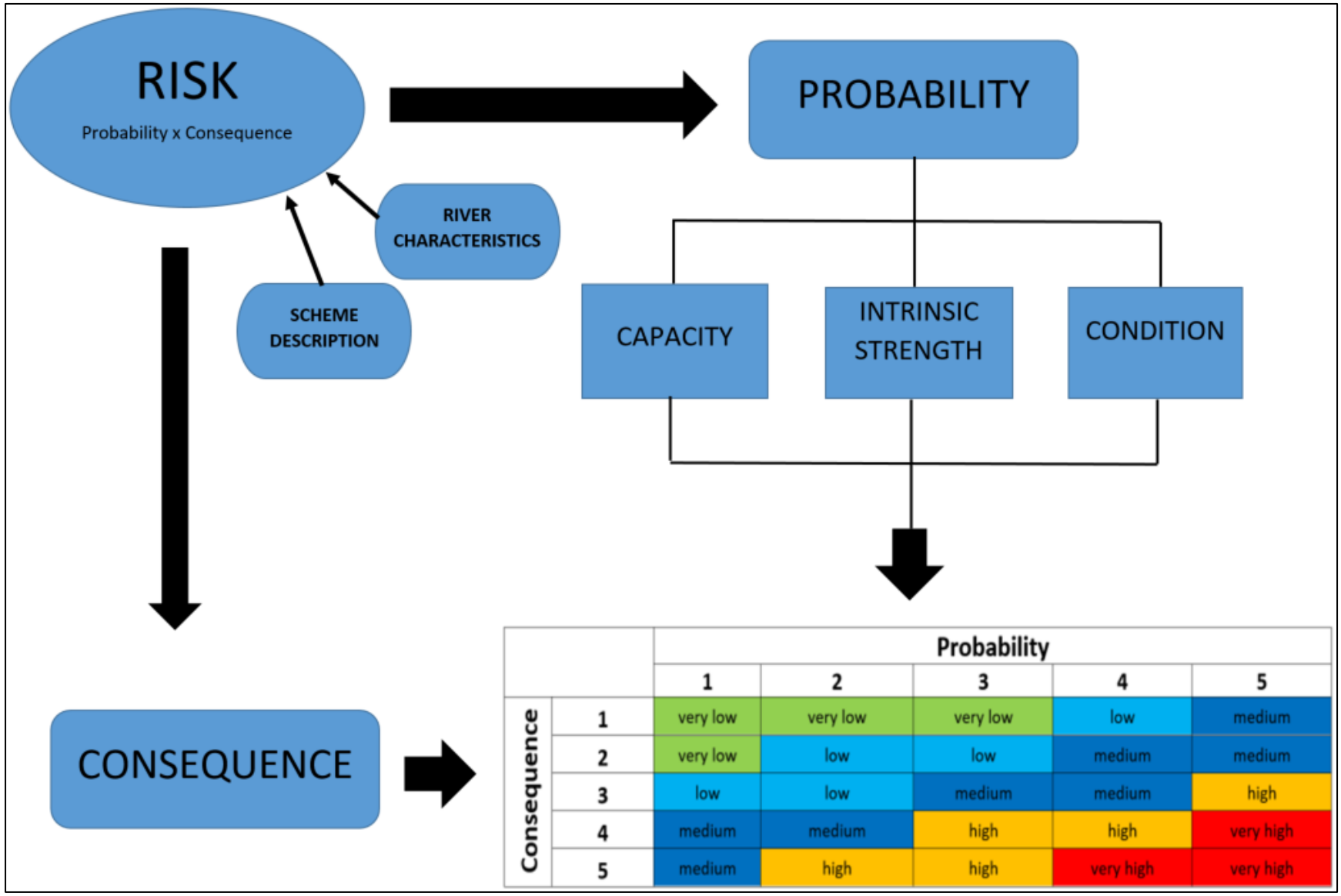
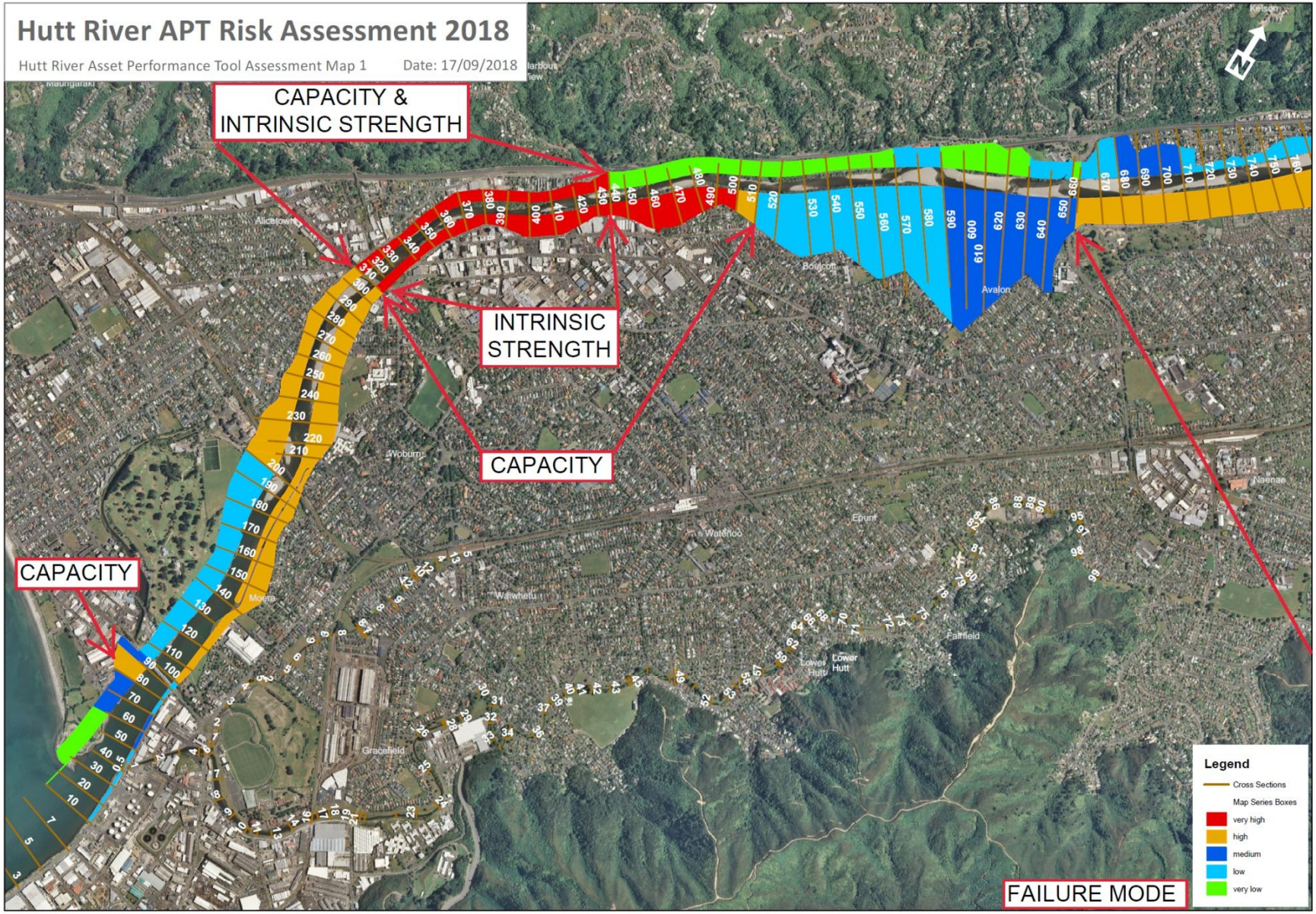
Appendices

Appendix 1. Schematic breakdown of the the Asset Performance Code of Practice, illustrating the performance criteria involved in the assessment.

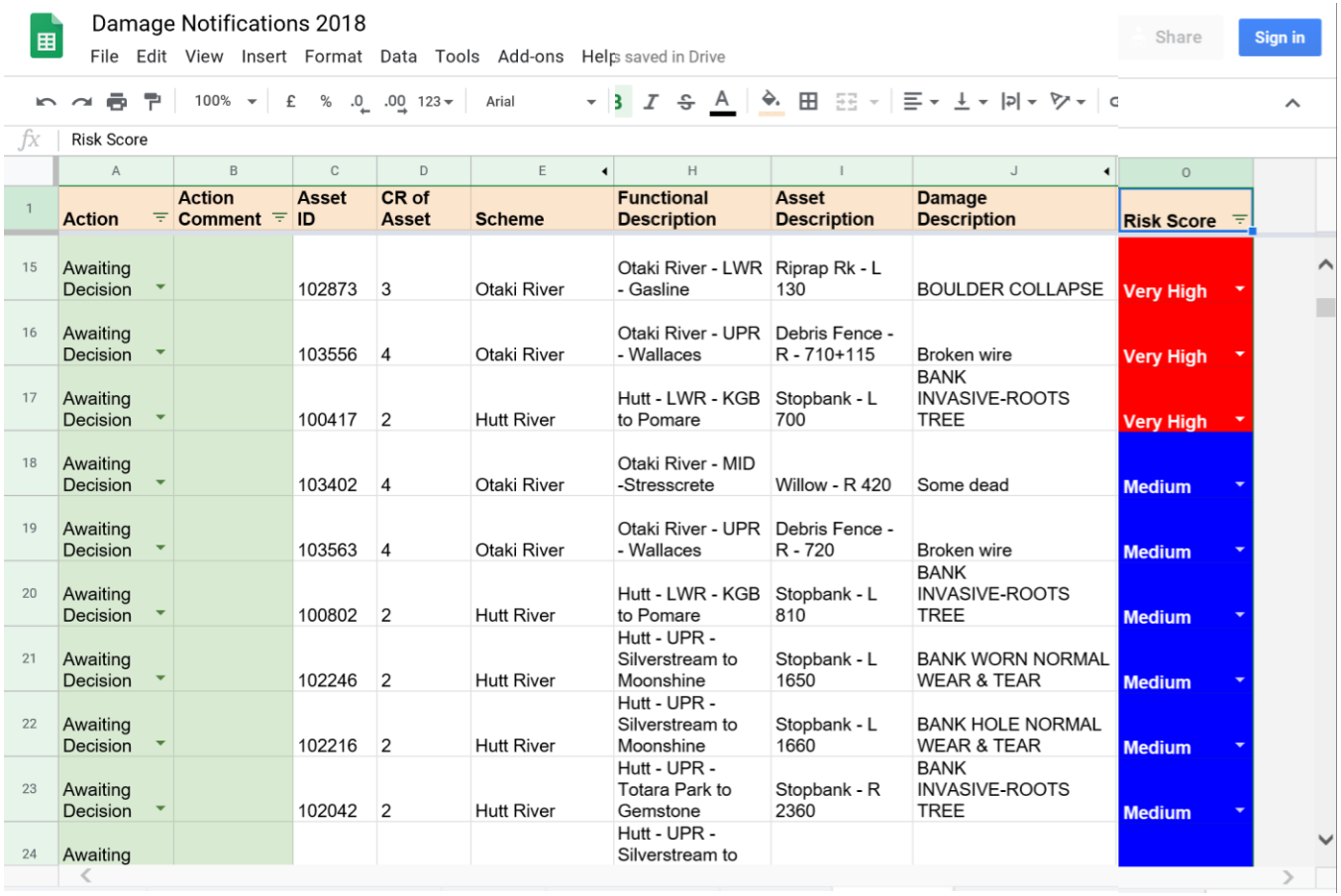


Consequence	Probability 1	2	3	4	5
1	very low	very low	very low	low	medium
2	very low	low	low	medium	medium
3	low	low	medium	medium	high
4	medium	medium	high	high	very high
5	medium	high	high	very high	very high

Appendix 2. A spatial map output from an asset performance assessment for a flood protection river scheme.



Appendix 3. Asset defect report representing all asset defects recorded during the asset inspection and condition rating programme. Information includes relevant attribute data in combination with the corresponding asset performance risk score.



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Risk Score

	A	B	C	D	E	H	I	J	O
1	Action	Action Comment	Asset ID	CR of Asset	Scheme	Functional Description	Asset Description	Damage Description	Risk Score
15	Awaiting Decision		102873	3	Otaki River	Otaki River - LWR - Gasline	Riprap Rk - L 130	BOULDER COLLAPSE	Very High
16	Awaiting Decision		103556	4	Otaki River	Otaki River - UPR - Wallaces	Debris Fence - R - 710+115	Broken wire	Very High
17	Awaiting Decision		100417	2	Hutt River	Hutt - LWR - KGB to Pomare	Stopbank - L 700	BANK INVASIVE-ROOTS TREE	Very High
18	Awaiting Decision		103402	4	Otaki River	Otaki River - MID -Stresscrete	Willow - R 420	Some dead	Medium
19	Awaiting Decision		103563	4	Otaki River	Otaki River - UPR - Wallaces	Debris Fence - R - 720	Broken wire	Medium
20	Awaiting Decision		100802	2	Hutt River	Hutt - LWR - KGB to Pomare	Stopbank - L 810	BANK INVASIVE-ROOTS TREE	Medium
21	Awaiting Decision		102246	2	Hutt River	Hutt - UPR - Silverstream to Moonshine	Stopbank - L 1650	BANK WORN NORMAL WEAR & TEAR	Medium
22	Awaiting Decision		102216	2	Hutt River	Hutt - UPR - Silverstream to Moonshine	Stopbank - L 1660	BANK HOLE NORMAL WEAR & TEAR	Medium
23	Awaiting Decision		102042	2	Hutt River	Hutt - UPR - Totara Park to Gemstone	Stopbank - R 2360	BANK INVASIVE-ROOTS TREE	Medium
24	Awaiting					Hutt - UPR - Silverstream to			