TOWARDS A NATIONAL DIGITAL TWIN FOR FLOOD RESILIENCE IN NEW ZEALAND

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ABSTRACT

Flood inundation is a frequent, widespread, and impactful hazard, which regularly causes damage to housing and infrastructure along with disruption to communities and businesses. Further, flood risk is expected to increase in future, because of climate change through increased storminess and due to rapid urbanisation. To manage this risk, it is essential that we become more efficient at flood risk management, which in New Zealand is an activity which is devolved to regional councils and, consequently, highly variable. We need to improve land use planning to take account of multiple scenarios for potential flood impact or mitigation. However, the computational modelling and scenario assessment required for such flood risk management and mitigation requires substantial amounts of spatial data related to infrastructure and the environment, making it challenging and expensive. This is particularly a problem for smaller regions or communities where the costs of such analysis may be prohibitive. In this paper, we present our progress towards the development and testing of a "flood resilience digital twin", which comprises of three-waters, flood mitigation and other infrastructure, high-resolution topography, and land cover, which we are building with the aim of facilitating flood risk assessments to be completed more rapidly and at lower cost. We are developing and testing the flood resilience digital twin as a prototype for the town of Kaiapoi in Canterbury. Once completed, follow-on work will enable further development and deployment nationwide, including as part of the NIWA-led national flood hazard assessment programme, "Reducing flood inundation hazard and risk across Aotearoa-New Zealand".

The main purposes the flood resilience digital twin are to (i) automate the process of developing pluvial and fluvial models, (ii) capture and analyse topographical and infrastructure data to model inundation and flow information in an urban setting, and (iii) assess the impact of inundation on infrastructure. Currently, the software we have developed integrates spatial and other data from multiple vendors into databases, then extracts and processes the data for the automated simulation of a range of possible flood scenarios, using the BG-Flood hydraulic model. The data processing includes the extraction and conversion of LiDAR point cloud data into hydrologically conditioned digital elevation models, which are then converted into the formats required to run BG-Flood, along with other data such as land cover which is used to estimate friction and statistically generated pluvial and fluvial boundary conditions. Our development roadmap includes the automated

assessment of the impact of the predicted flooding, including via RiskScape software. In addition, we plan to develop a web-based interface and visualisation tool as the front-end for the digital twin. All software we are developing is available under open-source licencing.

KEYWORDS

Digital Twin, flood resilience, flood risk assessment, flood modelling, BG-Flood

PRESENTER PROFILE

Greg Preston is the Manager of the Building Innovation Partnership (BIP) based at the University of Canterbury. Through BIP, Greg is attempting to change the way that decisions are made in the infrastructure sector. To this end BIP is looking to improve the quality of information to the 3 Waters sector and provide better tools to assist decision-makers. Underpinning this are consistent data standards, improved data quality and the development of a National Digital Infrastructure Model (NDIM) and which the National Pipe Data Portal is the first step. Born and trained in the UK, Greg has lived in NZ for nearly 30 years. In that time, he has been a secondary teacher, a consultant and set up and managed the Quake Centre and the Building Innovation Partnership.

1 INTRODUCTION

Over the last few years, the development of digital twins has accelerated greatly, especially within the manufacturing industry (Jones et al., 2020; Semeraro et al., 2021). Numerous definitions of the concept of a digital twin exist, with definitions tending to vary depending on the field (Fuller et al., 2020); in general terms, a digital twin is a dynamic virtual representation of a physical system (e.g., Madni et al., 2019), with automated data exchange being a key attribute. Digital twins are enabling the development of the next generation of smart cities (Deren et al., 2021); more recently, the concept has expanded to include digital twins of the natural environment (Blair, 2021) and there is, for example, significant investment by the European Union (EU) towards the creation of a digital twin of Earth, with the aim of ensuring climate neutrality by 2050 (Bauer et al., 2021). The EU's "Destination Earth" (DestinE) policy brings together computation and data lakes to create a "seamless fusion of real-time observations and high resolution predictive modelling" for critical application areas including extreme events and climate change adaptation (European Commission, 2022).

The focus of our work here is to build an environmental digital twin which brings together computational models of flood inundation with other data, for hazard assessment, management, and mitigation. A key objective is to enable the automation of flood risk assessment, such that multiple scenarios can be assessed rapidly, such as when given updated information. The digital twin we envisage can bring together and processes the data needed for flood risk assessment and use these for scenario assessment within computational modelling. The digital twin can then analyse the impact of these scenarios and update them given new information. Such a digital twin would enable flood risk assessments to be completed more rapidly and at lower cost, and will facilitate detailed, standardised risk assessments at the national scale.

Digital twins which have a focus on disaster management have been previously developed elsewhere. For example, Ford and Wolf (2020) demonstrate the linkage of a smart city system with a community simulation model in order to improve decision making related to evacuation, while accounting for real-time traffic information. Ham and Kim (2020) illustrate a conceptual framework for the inclusion of crowd-sourced data in a 3D city model, in order contribute to the development of risk-informed decision making. In the area of flood risk assessment, Ghaith et al (2021) demonstrated a digital twin for Calgary, Canada, which included outputs from the HEC-RAS flood model (Brunner, 2002) as part of city visualisations. However, the digital twin didn't automate the application of the model, so it wouldn't be possible to include analysis using updated the simulations based on real-time information. Advanced statistical analysis has been included within digital twins to aid the rapid assessment of flood risk, reducing the computational overhead. For example, Alperen et al (2021) developed a hydrological digital twin for flood simulation in a small catchment in France, using a hybrid physical and statistical approach, where a neural network was used to approximate the outputs from the physical model. However, the transferability of such an approach to other areas may be limited. Similarly, Jiang et al (2021) used physics-informed machine learning for a coastal digital twin for assessing areas of flooding.

In this project, we are developing and testing the specifications needed for a New Zealand flood resilience digital twin and implementing it for a selected small urban area. As part of this, using an expert workshop, we first assessed standards and specifications for the interoperability of spatial data of relevance to flood resilience in urban areas, including but not limited to infrastructure such as pipes, storm water drainage systems, streamlines, culverts and stopbanks (levees), topographic data from terrestrial LiDAR, channel bathymetry, land cover and other infrastructure of relevance such as buildings and roads. We then used these specifications to develop a prototype digital twin which is capable of automated generation of flood inundation models for rapid flood risk assessment. If successful, such a digital twin would be able to automate the process of developing pluvial and fluvial models, capture and analyse topographical and infrastructure data to model inundation and flow information in an urban setting and assess the impact of inundation on infrastructure.

Here, we present our progress to date towards the development of the flood resilience digital twin. In Section 2, we outline the findings of a spatial data interoperability workshop which guided the requirements of the digital twin development. Then, in Section 3, we detail the current development status of the digital twin before presenting the roadmap for future development in Section 4.

2 SPATIAL DATA INTEROPERABILITY WORKSHOP

Spatial data is a key requirement for flood hazard assessment. For example, these data provide essential inputs into flood inundation models which are needed to map areas at risk for a given rainfall or river flow level. They are further required to assess the impacts that predicted or observed flood inundation has. However, spatial data are available from multiple sources, produced for different purposes, at a variety of spatial scales and with differing standards in use. Consequently, to bring the data together within a digital twin, we first needed to gain an understanding of the challenges and limitations that these differences present. Thus, the first step towards developing the flood resilience digital twin was a three-day expert workshop, held in January 2021, which was run as an experimental "code sprint" that tested the usability of infrastructure and environmental data. The aim was to ensure data interoperability that will enable the digital twin to scale to the national level.

Workshop participants were chosen based on their expertise and ability to provide a good cross-section of the various agencies likely to be involved should such a flood event occur, including local and regional councils, national and local infrastructure owners, researchers from Universities and Crown Research Institutes, and representatives from central government. The scope was limited to the effects of a significant fluvial/ pluvial flood event on an urban area's physical infrastructure. Other concerns such as public safety, social, environmental, and economic impacts of such an event was out of scope. Kaiapoi was chosen as the physical location to study based on its moderate size, good variety of infrastructure in its boundaries, data availability for the region and the proximity to the workshop location (Figure 1).

The workshop was designed to be user-driven and agile. The approach mimicked that defined by the Open Geospatial Consortium in their Innovation Programme, in particular adopting the "Findable, Accessible, Interoperable and Reusable (FAIR)" principles (Ivánová et al., 2019). A key objective of the workshop was to define a use case and, within teams assigned with a set of tasks, develop a prototype digital twin using FME software for data processing and flood model automation (Figure 2). The analytical focus of the prototype was on the NIWA software, BG-Flood (Bosserelle, 2018; Bosserelle et al., 2020) and RiskScape (Crawford et al., 2018; King and Bell, 2005). FME was used as the workbench for merging and transforming the selected data into the inputs required for each of these software, and for analysing the outputs. The thinking behind this workshop design is that it would highlight any data issues, such as required standards. The workshop learnings, particularly the FME prototype, were then used to guide the development of the code base for the flood resilience digital twin (Section 3).

While there are many use cases related to flooding and infrastructure that the workshop teams could have addressed, it was decided that focusing on supporting the NIWA flood modelling tool, BG-Flood, would be most beneficial as they are being used as part of the NIWA-led national flood risk assessment for New Zealand (NIWA, 2022). Questions of standardisation arose with the need to merge the inputs required by the model. Data may come from many different agencies but use varying formats, schemas, vocabularies, spatial definitions, etc. These data commonly vary in quality and, of high importance, for this workshop's purposes, resolution. It was clear that much work would focus on providing standardised inputs consumable by BG-Flood. The RiskScape tool could consume outputs from BG-Flood along with other spatial data. Other tools may consume RiskScape outputs at later points in a larger workflow in future iterations.

Figure 1: Kaiapoi location and situation to the north of the lower Waimakariri River. The town is protected from flooding by a stopbank (levee) system and pumping stations

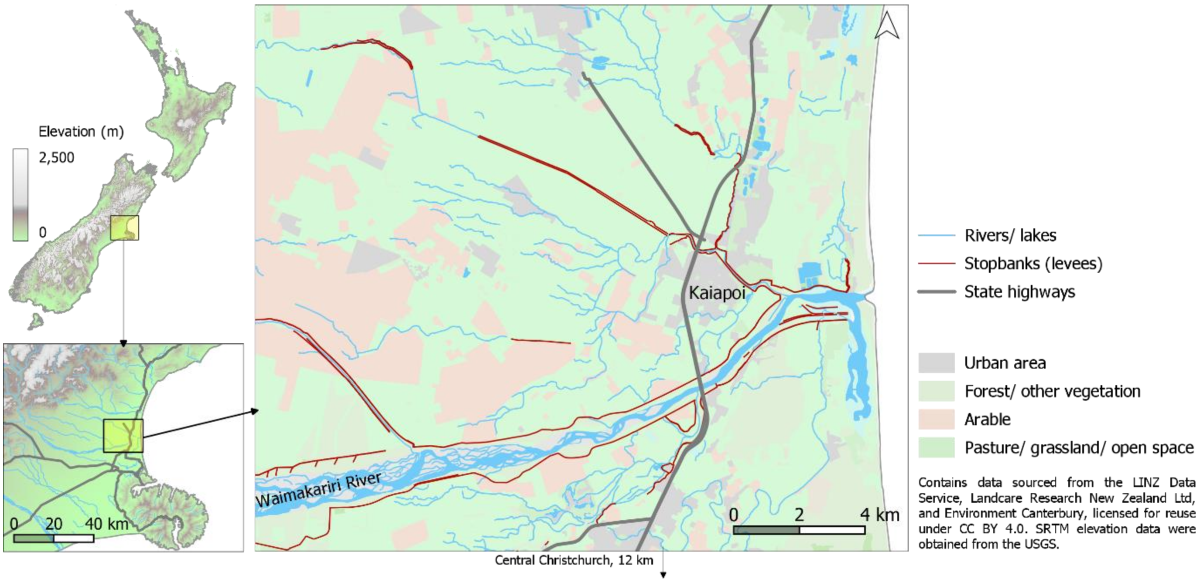
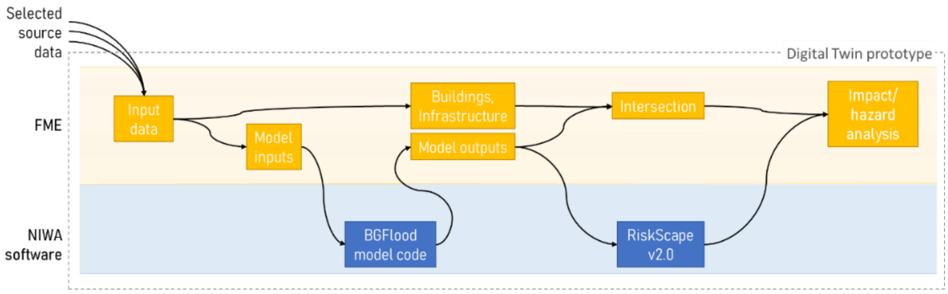


Figure 2: The workshop digital twin prototype



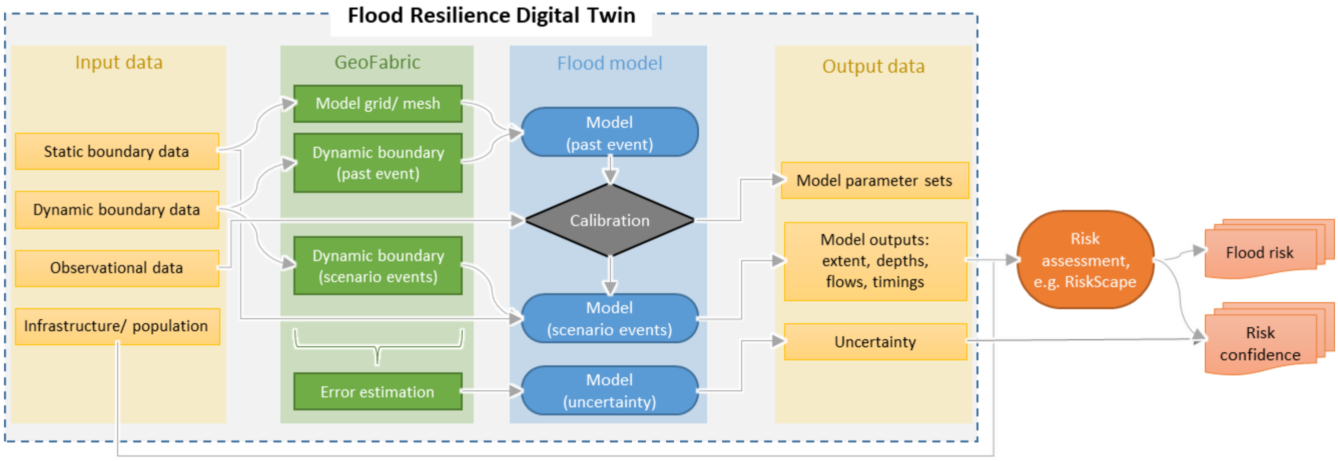
The workshop teams were able to successfully create a fully working prototype digital twin within the FME. For example, LiDAR topographic data were mosaiced with bathymetry to form a model grid (although there were some issues related to differences in the vertical datum used between the different data sources), and friction data were generated based on the Land Cover Database (Manaaki Whenua Landcare Research, 2020), which were imported using the Web Feature Service (WFS) protocol. The experiment also produced many assets to assess flood impact on, incorporating data from Transpower, Mainpower, the New Zealand Transport Agency and LINZ. Issues raised included the limited availability and suitability of bathymetry data, limited hydrological inputs, missing river data, undocumented stopbanks, and spatial mismatches between model outputs and vector data. In addition, national consistency of datasets was raised as a concern, making it challenging to standardise the approach taken.

The workshop was a successful demonstration of the value of industry and research collaboration in developing an innovative approach to tackling the modelling of flood event in an urban environment and assessing the impact on infrastructure. The outputs of the workshop included (1) a prototype digital twin that modelled a flood scenario in Kaiapoi, identification of which data was missing, (2) where these data may be found and areas where other techniques such as Artificial Intelligence (AI) may be need to fill in those data (3) a clear articulation of the issues that need to be addressed in the final model, (4) a validation of the prototyping methodology using the Feature Manipulation Engine (FME) software, and (5) an understanding of the importance of data standards in the development process. These learnings were used to guide the development of the flood resilience digital twin, particularly with respect to the data sources and processing workflows.

3 DEVELOPMENT OF THE PROTOTYPE FLOOD RESILIENCE DIGITAL TWIN

Following the spatial data interoperability workshop and prototyping of data processing within FME, the flood resilience digital twin was implemented. The conceptual design of the digital twin (Figure 3), included geospatial databases to hold the input data, including static data used for boundary conditions (e.g., LiDAR data, stopbanks, storm water, channel geometry and land cover), dynamic boundary data used for model water inputs (e.g., river gauge data, tide levels, rainfall data, design flows), observational data for model comparison (e.g., airborne flood imagery, SAR flood imagery, survey data) and data for infrastructure and population for impact assessment (e.g., buildings, census data, roads and rail). A design principle for the digital twin was that, for a selected area, these data are downloaded from their respective agencies and stored in a local database without modification (i.e., features are kept intact). A local copy of the data is maintained to avoid the high bandwidth which may be associated with multiple downloads, as well as speed up processing when the data are used for multiple analyses. To achieve this, a database of the metadata is maintained, which tracks areas which have been previously processed, and when.

Figure 3: Flood resilience digital twin conceptual diagram



After download and incorporation into local databases, data are further processed within the digital twin to create the "GeoFabric", which refers to the model inputs and boundary conditions, including the scenarios assessed, in the appropriate model format (in this case, BG-Flood). The model is then run using the model, and the digital twin maintaining metadata of simulations run. Finally, model results are incorporated back into the digital twin for analysis, such as identifying flooded buildings. Details of the processing is provided in the following sections.

The code base for the prototype flood resilience twin was developed initially to replicate, then to build on the learnings from the spatial data interoperability workshop (Section 2). To facilitate rapid development and due to the good availability of geospatial code libraries, Python was selected as the primary language, alongside SQL. The developed code is available under open-source licence on GitHub (Khosla et al., 2021), including a Docker implantation for rapid deployment. The database software selected was PostgreSQL, with PostGIS spatial database extensions.

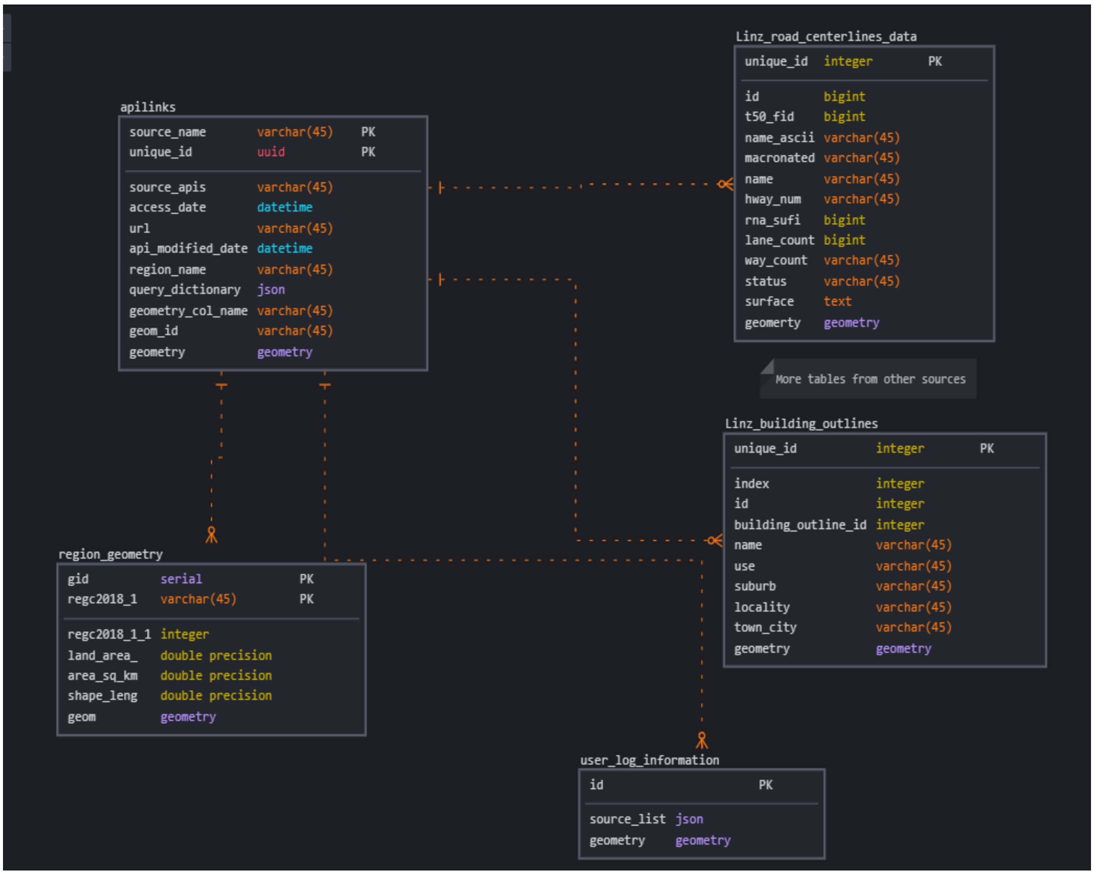
3.1 RELATIONAL DATABASE STRUCTURE AND DATA DOWNLOAD

Of primary importance within the flood resilience digital twin database are the relational databases which define the available source data and store local copies for user-defined areas of interest (AOIs) (Figure 4). The spatial table `apilinks` defines the available sources of data, their spatial coverage (polygon), the access information including the API keys needed, which are required to be provided by the user.

The `user_log_information` geospatial table keeps track of all requests made by a user and the data already available in the database. This means that if a local copy of the data already exists for a requested AOI, the download and processing will not be repeated. This is achieved by defining a smaller, unique AOI where no data have already been downloaded. When an AOI is requested, after validation, the digital twin will first complete a geospatial query against the `user_log_information` table to check whether the requested area has already been downloaded (Figure 5), then obtain any sources defined in `apilinks` which are needed. If only part of the area has been downloaded (i.e., part of the area is missing data), for each source, the code will perform an intersection between the AOI and the geospatial data coverage stored in `user_log_information` so that only the non-intersecting (i.e. missing) areas are obtained.

Downloaded data are inserted in raw form into an individual geospatial table for each source. Within these source data tables, the structure of the source data is maintained, except for an additional column which records the date of download. In addition, whole features are maintained, i.e., features are not clipped at the boundary of the AOI. This simplifies the processing and maintenance of the database but means that some data from outside the AOI will also be stored, particularly for spatially extensive features.

Figure 4. Relational database structure (top), used to download and store spatial data within the digital twin, and the `apilinks` table (bottom) which determines the sources and coverages of required data.

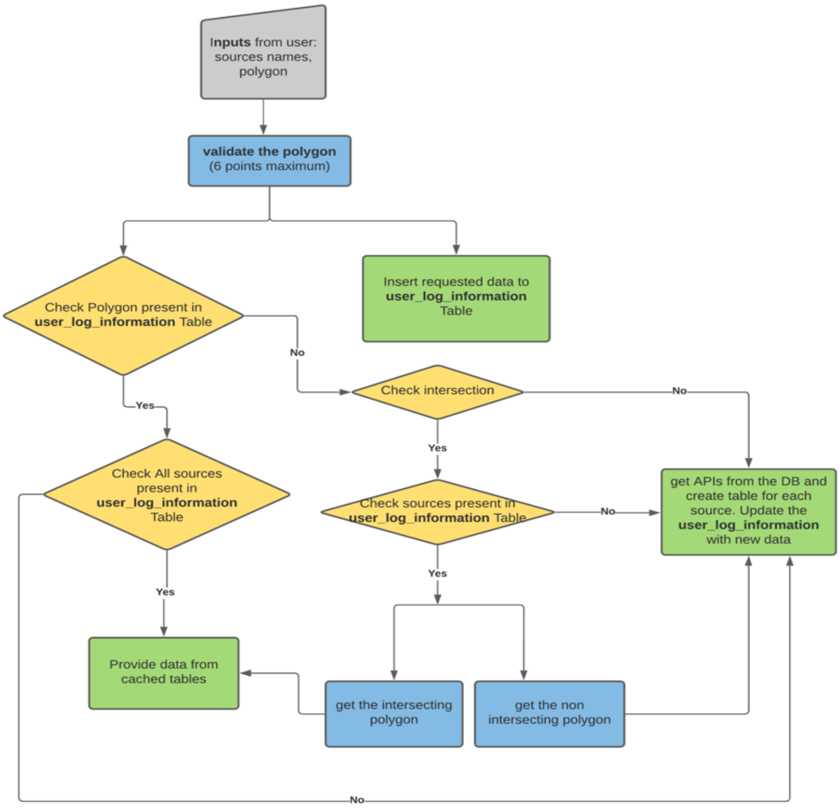



```sql
SELECT * FROM public.apilinks
ORDER BY source_name ASC
```

Notifications Data Output Explain Messages

	data_provider character varying	source_name [PK] character varying	source_apis character varying	url character varying	api_modified_date date	region_name character varyi	access_date timestamp without time zone	query_dictionary json	layer character varying	geometry_col_name character varying	geometry geometry
1	LINZ	_101292-nz-building-outlines	https://data.linz.govt.n...	https://data.linz.govt.n...	2021-06-14	New Zealand	2021-09-23 14:28:41.135249	"{\"service\": [\"WFS\"]...	101292	shape	010300002091080...
2	LRIS	_104400-lcdb-v50-land-cover	https://lris.scinfo.org.n...	https://lris.scinfo.org.n...	2020-01-29	New Zealand	2021-09-23 14:34:16.929653	"{\"service\": [\"WFS\"]...	104400	GEOMETRY	010300002091080...
3	StatsNZ	_105133-regional-council	https://datafinder.stats...	https://datafinder.stats...	2020-12-01	New Zealand	2021-10-05 10:50:20.690113	"{\"service\": [\"WFS\"]...	105133	Shape	010300002091080...
4	LINZ	_50319-nz-railway-centrelines	https://data.linz.govt.n...	https://data.linz.govt.n...	2021-09-09	New Zealand	2021-09-23 14:21:09.541952	"{\"service\": [\"WFS\"]...	50319	GEOMETRY	010300002091080...
5	LINZ	_50329-nz-road-centrelines	https://data.linz.govt.n...	https://data.linz.govt.n...	2021-09-09	New Zealand	2021-09-23 14:22:02.940825	"{\"service\": [\"WFS\"]...	50329	GEOMETRY	010300002091080...
6	StatsNZ	testing	https://datafinder.stats...	https://datafinder.stats...	2020-12-01	New Zealand	2021-10-08 10:51:27.528551	"{\"service\": [\"WFS\"]...	105133	Shape	010300002091080...

Figure 5. The processing steps for downloading and storing source data within the database.



3.2 LIDAR DATA DOWNLOAD AND PROCESSING

LiDAR topographic data are crucial to the flood resilience digital twin since they are used to create the model grid used in the flood model. The data are downloaded in point cloud format from the OpenTopography data repository ([https://opentopography.org/)](https://opentopography.org/), using the GeoFabrics Python library (Pearson, 2021). Within New Zealand, most of the data available within OpenTopography were provided by LINZ and their partners and are available under an open data Creative Commons licence. The point cloud data are obtained from OpenTopography (rather than processes raster data directly from LINZ) to enable advanced processing of the data specifically for flood modelling, and to improve transferability of the code to other countries which have extensive LiDAR datasets within the portal, such as the United States. Although a complete national LiDAR coverage for New Zealand is not yet available, for the majority of areas without existing data, the LINZ National Elevation Programme is either processing collected data or has surveys planned or in progress (LINZ, 2022).

The GeoFabrics library (Pearson, 2021) enables both download and processing of LiDAR data. GeoFabrics obtains a tile index of the available data within the unique AOI and downloads only those compete LiDAR tiles that are required for processing (Figure 6). This ensures that no unnecessary LiDAR tiles are downloaded, minimising bandwidth usage. These tiles are downloaded as point data (LAS format). While this can increase the overall download size, it reduces the overhead on the remote server (e.g., due to selection), and facilitates easier tracing within the Digital Twin databases. The GeoFabrics library additionally allows for processing of the LiDAR point cloud into a raster grid which is hydrologically conditioned (i.e., bare earth, with vegetation and buildings removed), and therefore suitable for use within a flood model (Figure 7).

Figure 6: LiDAR download and processing steps: (left) building the LiDAR database and downloading LiDAR tiles; (right) creating the hydrologically conditioned DEM.

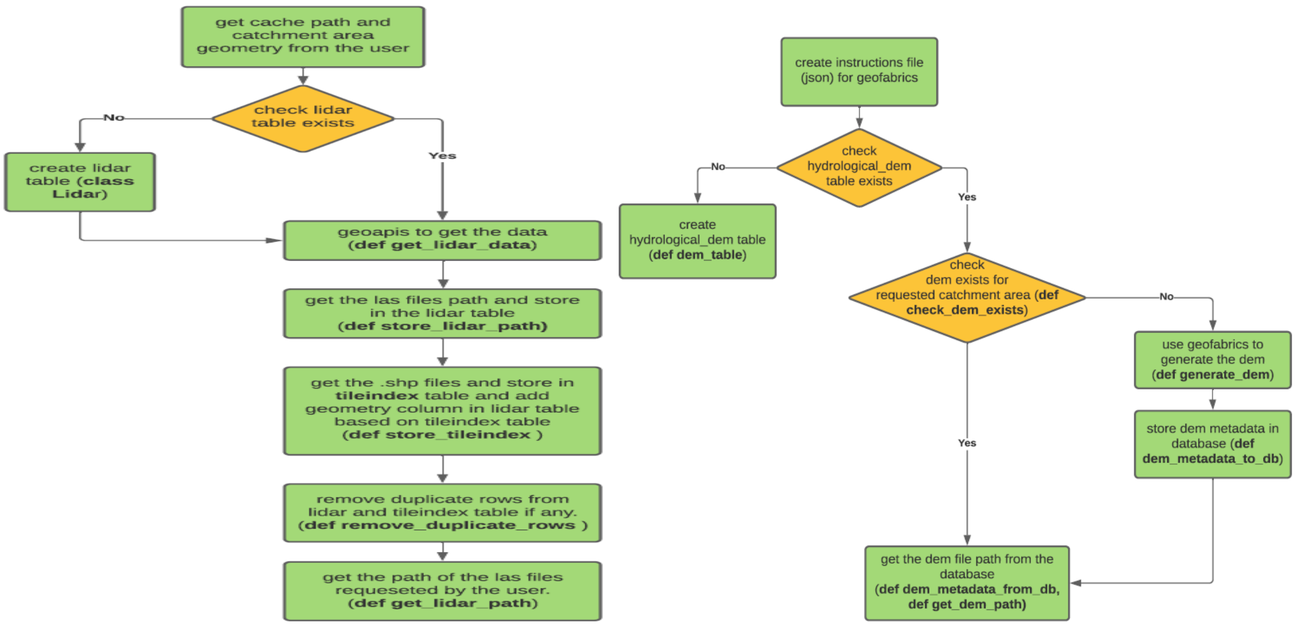


Figure 7. LiDAR point cloud data are downloaded for the AOI, then processed into a model grid using the GeoFabrics library (Pearson, 2021).

3.3 MODEL REALISATIONS AND HAZARD ASSESSMENT

After required spatial data have been obtained for the selected AOI, the digital twin is able to generate a model realization. Currently, the dynamic boundary conditions (i.e., water inputs to the model) that have been implemented include (i) Intensity-Duration-Frequency (IDF) curves which are part of the High Intensity Rainfall Design System (HIRDS) (NIWA, 2017; Thompson, 2002); (ii) river flood statistics (flow levels) at selected annual exceedance probabilities which are available with the River Environment Classification (version 1) from NIWA (NIWA, 2018); (iii) rain gauges and river flow gauges, currently from Environment Canterbury only.

At present, only the HIRDS flood statistics data are used within the live flood model generated by the digital twin, although future versions will incorporate a variety of available data. In order to generate the rainfall inputs required for the flood model, a storm hyetograph is created from the HIRDS statistics using the Chicago method (Alfieri et al., 2008; Yen and Chow, 1980), which enables the representation of all rainfall durations within the timeseries.

The digital twin proceeds to run the flood model using the process outlined in Figure 8. At present, only BG-Flood is implemented: after checking that this exists, the digital twin will create a unique directory into which to save all model inputs/ outputs and save metadata regarding the simulation within its databases. Model input files are exported in the correct format (NetCDF for BG-Flood), then the model software is run via a system call. The outputs of the model are then imported into the digital twin databases. An example model output produced in this way is shown in

Figure 9.

Once model simulations are available, it is straightforward to intersect spatial data within the digital twin with predicted flood depths and flows to obtain a rapid assessment of likely impact (Figure 10). This analysis can be expanded as additional infrastructure data are incorporated within the digital twin, and may also include, for example, route optimisation in the presence of a flood event. Further, the digital twin can be connected to existing tools such as RiskScape (Crawford et al., 2018), enabling a standardised risk assessment to be completed, and accounting for building type and potential damage (e.g., using depth-damage curves).

Figure 8: The Digital Twin will check for required input data (e.g., a processed DEM), then export files in the required for the selected flood model (currently only BG-Flood). The model will then be run, and the outputs from the model included within the databases.

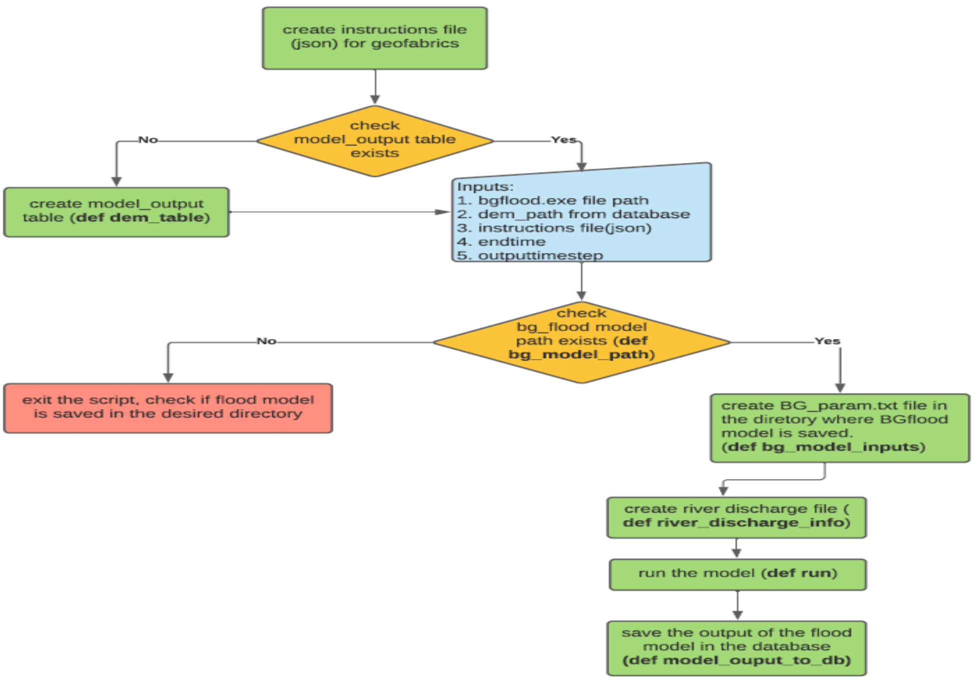


Figure 9. an example of a model scenario realization for a pluvial flood event, based on the LiDAR and other data within the Digital Twin.

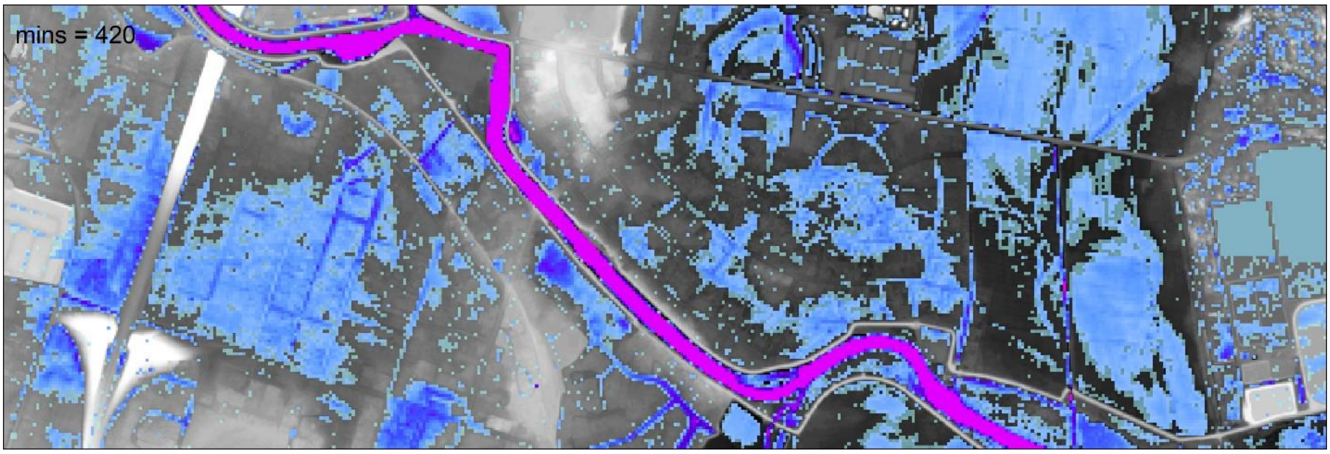
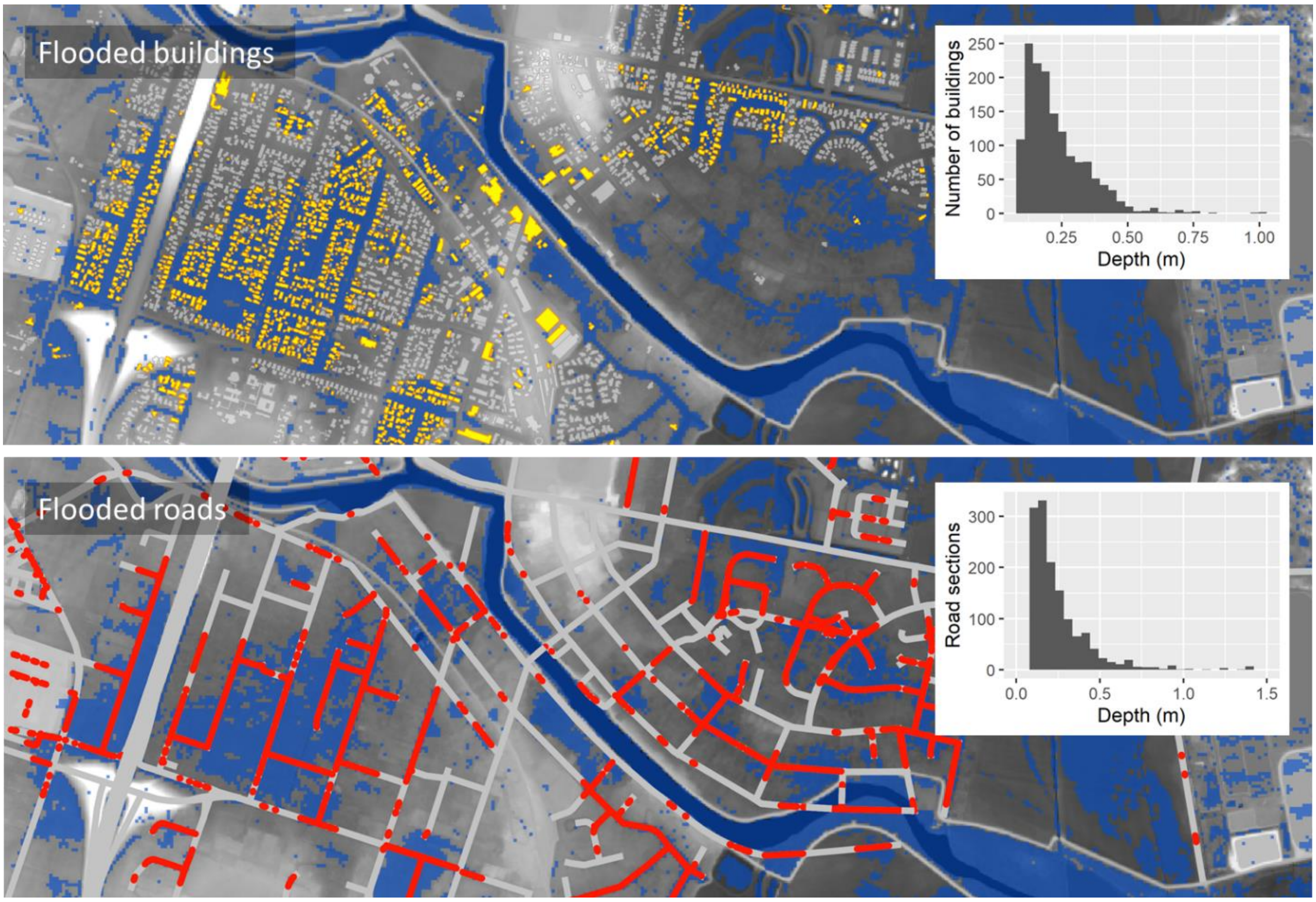


Figure 10. Example analysis within the digital twin, intersecting a model realisation with spatial data for infrastructure.



4 ROADMAP FOR FUTURE DEVELOPMENT

The current development version of the digital twin allows rapid ingestion of spatial data from available open sources within New Zealand, with a mature code base which would be relatively straightforward to expand to other data sources. At present, only a very simplistic pluvial scenario has been implemented, for one flood model code, and there is no front end or user interface.

As part of the planning of the future development roadmap, we held an additional ½-day follow-up workshop with practitioners in January 2022. This was attended by representatives of industry (e.g., Tonkin & Taylor, Mainpower and Transpower), local/ regional government (Waimakariri District Council and Environment Canterbury), central government (LINZ), Crown research institutes (Manaaki Whenua Landcare Research, NIWA) and universities (Canterbury, Auckland, Waikato). Discussions were held regarding prioritisation for a possible front-end development, as well as further developments of the existing back-end server. These discussions have guided the next ~12 months of software development. Here we summarise the areas of focus for further development in the near-term, which we define as around 1 year. Potential developments in the medium (2-3 years) and long term (>3 years) are also highlighted but are subject to continued funding.

4.1 BACK-END DEVELOPMENT (DATABASE SERVERS)

While the codebase for the spatial databases and the data download and update processing is mature, additional development work is required regarding temporal data including river flow, rainfall, and tide levels, especially for observed previous events. Rain radar data are currently not included but may overcome some of the limitations with using rain gauge data to assess flooding from high-intensity storm events. Further, it would be possible to incorporate rainfall from weather models into the digital twin, either in hindcast or forecast mode. In addition, for combined fluvial/ pluvial events, currently there is no method in the digital twin to predict river flow levels where observations are lacking, which is a key issue for flood risk ungauged catchments. Ideally, in a future version, a catchment model could be incorporated within the digital twin to simulate river flow from upstream rainfall. However, the current priority for development is: (i) to further develop the existing code to incorporate observational data (rainfall, tides, flow levels) and expand this to include all available sources with a temporal query alongside spatial; (ii) include statistical methods for estimation in the absence of available dynamic data; and (iii) further develop standardised scenarios, using HIRDS and REC1 data, to enable a rapid initial assessment of flood risk for a selected AOI. Other near-term development priorities include (i) the incorporation of model outputs within database; (ii) development of a database for model simulation metadata (enabling transparency in modelling, repeatability, direct comparison with other models); and (iii) automated analysis of output, including a connection to RiskScape software.

During the follow-up workshop, a desire was expressed for the inclusion of real-time information within the digital twin, enabling updated assessments of flood risk. Enabling rapid responses to real-time observational data is one of the perceived key benefits of the digital twin paradigm (Jones et al., 2020; Uhlemann et al., 2017), and it would be relatively straightforward to include current observations of rainfall or river flow within the flood resilience digital twin, for example using the Application Programming Interface (API) for water data provided by Environment Canterbury (https://apidevelopers.ecan.govt.nz/). Given sufficient computational resources, it would be possible to run a new scenario model on request given updated information such as this, at least for small areas. However, it is likely to be substantially more challenging, due to the amount of computation required, and further investigation is required, for example regarding the tolerable latency in obtaining new analysis. However, there is a potential alternative approach: given a range of modelled scenarios, code can be included within the digital twin to estimate flood depth and extent via interpolation of previously generated model results, methods which we plan to implement in the medium term. Further scenarios, such as stopbank (levee infrastructure) breaches were also highlighted as a key desirable feature, either as part of a simulation library, or conducted on demand.

One workshop participant identified a potential real-time use of the digital twin in the provision of safe detour routes for trucks and other traffic during a flood event where roads become impassable. This analysis would be dependent on either rapid model simulations, or interpolation of a model output library of simulations, both of which are in the medium-term roadmap. The inclusion of additional flood models other than BG-Flood are also not considered as a priority in the near-term, as BG-Flood is being used in national assessment and we aim for our digital twin to underpin these assessments. However, although stormwater is included within the digital twin, this is not used in BG-Flood; in the medium- to long-term, additional models which include stormwater can be included, although this is likely to be a significant task.

4.2 FRONT-END DEVELOPMENT (USER INTERFACE)

Feedback from our follow-up workshop suggested that a full-featured front end is not a priority for flood risk practitioners, and that focus on back-end development is supported. However, a basic front end user interface should be prioritised (near-term) over one which is more advanced (medium-term), such as including 3D visualisation or a virtual reality interface, particularly to enable engagement with the flood resilience digital twin and its deployment. Following this and other feedback, a current priority is to develop a web-based user interface which provides the ability to define the AOI of interest and include user-defined scenarios alongside those which are included by default. However, to enable user-defined scenarios, some additional questions for this development will need to be addressed, specifically regarding the computation environment used to run the flood model (e.g., local computer provided by the user, or a cloud computing service).

After an initial assessment of the available web visualisation options, currently we have selected the CesiumJS library (https://cesium.com/platform/cesiumjs/) to develop a prototype front end (Figure 11), due to its adoption for visualising numerous other digital twins (e.g., Ana et al., 2021). CesiumJS will enable future developments in 3D visualisation (e.g., visualisation of water movement through urban areas), as well as having a plugin to the Unreal Engine which would allow us to develop a virtual reality component. As well as basic control options, the web interface will additionally need to allow for query, such as point-based or feature-based). Further, practitioners have indicated that they would value the ability to extract the results of analysis from the digital twin, particularly so that they can include them within existing systems used for risk assessment, e.g., via an API.

4.3 APPLICATION PROGRAMMING INTERFACE

A key outcome from the from the January 2022 workshop is that organisations would value being able to extract data and information from the flood resilience digital twin programmatically, and particularly to connect their existing systems to the system. This would also enable visualisation and the assessment of user-defined scenarios while integrating with existing system used by organisations. Thus, the digital twin may become a data collation and processing service, which could either be self-hosted or offered as a web service. In the near-term, additional work will be required for the design of the API, including the standards to be adopted which would enable multiple instances of the digital twin platforms to communicate.

Figure 11. Initial mock-up of flood visualisation using the CesiumJS web development library, showing buildings over modelled flood output, coloured red if they are flooded over 0.1 m. Further developments will enable control of the visualisation, including displayed features and animation of the flood model output.

5 CONCLUSIONS

We have presented the current development of a prototype open-source digital twin for flood resilience, which may enable improved management of the large volume of spatial data which is required for flood risk assessment. The digital twin enables automated download and processing of these spatial data for a selected AOI, completes a flood risk scenario simulation using the BG-Flood model, then ingests model results to provide an assessment of the impact of the flood inundation on infrastructure. The key idea behind the digital twin is to reduce or remove the difficulty and expense associated with the processing of spatial data related to infrastructure and the environment, which may increase the amount of flood scenarios that may be assessed. The digital twin has been created alongside the NIWA-led national flood hazard assessment programme, "Reducing flood inundation hazard and risk across Aotearoa-New Zealand", and shares software with the programme. A key aim is for the flood resilience digital twin to enable transparent and updatable flood hazard assessments across New Zealand.

As near-term priorities, further development is required to: (i) include additional dynamic data such as weather data from models or RADAR; (ii) manage multiple flood scenarios, including standardised scenarios for risk assessment; (iii) connect the digital twin to the RiskScape hazard assessment software; (iv) implement a basic front-end for communication of results and control of the digital twin analysis; and (v) design and implement an API which allows the digital twin to be connected to other existing systems. In the medium to long term, we hope to continue to develop the digital twin to include other flood model codes, particularly those which incorporate storm water drainage in urban areas.

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