STREAMLINING MINIMUM FLOOR LEVEL ADVICE DIGITALLY

I. Kholodov (Wellington Water)
T. Nation (Collaborations Ltd)

ABSTRACT (500 WORDS MAXIMUM)

National and world news regularly highlight human tragedies resulting from extreme flood events. A major frustration for flood control professionals is the absence of planning that would have prevented this. Since 2015, Wellington Water carried out flood modelling programme with the aim to inform the public of flood hazard and risk.

As flood modelling data coverage expanded, more time for responding to land development queries was needed. At first, there was no consistent procedure for providing flood hazard assessments and advice. This meant that as models progressed from draft to final there was a possibility of multiple and conflicting advice for the same property. Formalisation of advice process improved the quality of advice but the additional documentation increased assessment time and responding to land development queries became a full-time commitment for modellers at Wellington Water. To keep the process sustainable, simplification and streamlining of advice became a necessity.

Investigation into the queries revealed that up to 70% of all queries are nonspecific and do not seek risk mitigation advice and parcel flood summary hosted on an ArcGIS online App with clear step by step instructions for self-service could be sufficient. Using this data, the Land Development team were able to make assessments without modelling input. It significantly reduced work load on the modellers and allowed to allocate more time to projects needing attention. Ultimate transition to an online self-service App is still strongly desired. To facilitate this, the App must allow customers to obtain advice for any location on the fly.

This paper describes the evolution of flood advice process that lead to the development of the on-line App. The specialised spatial analysis tools that have been applied are discussed. The paper highlights the learnings and challenges that were encountered in answering land development queries, and the advantages this App solution provides.

The next step will be, with Council's agreement, to roll this App out for public use. When/If that happens, minimum floor level advice for most proposed developments will be provided online and only large, multi-unit developments will require involvement from Wellington Water staff.

Keywords

Stormwater, LIMs, District Planning, community engagement

PRESENTER PROFILE

Ivan Kholodov is a flood modeller at Wellington Water with over 15 years of experience. Ivan is passionate about bridging modelling with the real world, making it easier for engineers, decision makers and the public alike, to have access to the modelling outputs, making modelling recognised to be essential tool it is.

Tom Nation is a Spatial Consultant and director of Collaborations, an applied science consultancy working on a range of environmental projects. Tom has over 15 years' experience in environmental spatial analysis, asset and data management, online GIS and technical support. Thomas has experience across a range of GIS systems including the ESRI, Safe, ENVI and Smallworld platforms and has been involved in projects throughout New Zealand and overseas.

1 INTRODUCTION

1.1 RMA AND THE BUILDING ACT

National and world news regularly highlight human tragedies resulting from extreme flood events. A major frustration for professionals working in the field of flood controls is that this is preventable through better site selection and planning rules.

In New Zealand context, the Resource Management Act 1991 (RMA)[1] and Building Act[2] were adopted to manage flood risk. City and district councils set their land development policies and procedures to satisfy requirements set out in these acts.

In line with RMA requirements, Councils are working towards implementing the district planning rules where flood hazard definitions are adopted through public consultation. Many councils have defined flood hazards as a flood extent from a simulated 100-year ARI storm event including climate change.

While the RMA deals with higher level context of trying to control activities which impact environment, the Building Act is in place to make sure that buildings are designed and constructed in such a way that the likelihood of flood water entering buildings is no greater than 2 per cent in any one year.

1.2 FLOOD MODELLING

In satisfying the legislated requirements to define flood hazards for the region, Wellington Water has been carrying out region-wide flood modelling. In 2015 Wellington Water established the hydraulic modelling panel and a stormwater modelling programme to provide the detailed, evidence-based modelling tools needed to map flood hazards. The main objective of the models is to inform overland flow, inundation, and stream corridor flooding for District Planning purposes.

Since the models have been built, the generated flood maps have been used for purposes other than just planning, such as asset management, community preparedness, emergency management, and building assurance.

1.3 FLOOD ADVICE FOR LAND DEVELOPMENT

Planning rules adopted or to be adopted by the councils include provisions to ensure that all new dwellings are protected during flood events by setting floor levels above predicted flood levels. Another planning provision is to ensure that the flood plain is not exacerbated, or offsite impacts not created from construction of new dwellings as infill or greenfield developments.

As soon as first flood modelling results became available, the Modelling Team became an adviser on flood risk for the Land Development process. An initial trickle of information requests steadily grew to require more and more time for response. At an early stage of the modelling programme, there was no process available to guide modellers on how to advice in relation to flood hazard queries, nor how to interpret implications of the reported information as district plan rules have not yet been adopted. The ad hoc nature of the advice as well as changing status of the models as illustrated in Figure 1, meant that over a period of several years different flood risk assessment for the same property could have been produced with conflicting advice resulting in embarrassing situations.

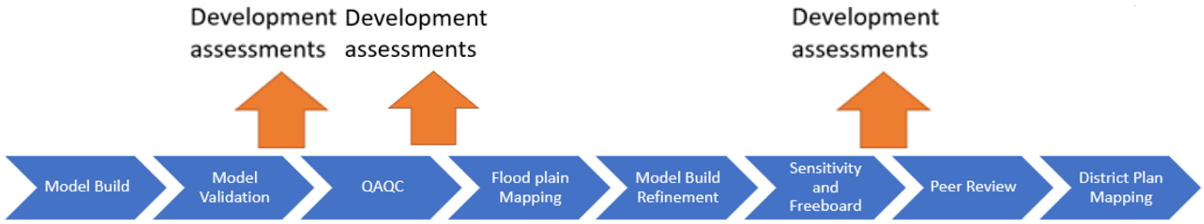

Figure 1: Wellington Waters Model Development Process

The subsequent changes to the process, including introduction of standardised reporting, archiving and spatial mapping of previous assessments improved the quality of advice but introduced additional challenge of increase in assessment time. Responding to land development queries became a full-time commitment for stormwater modellers which meant that other important activities that required modelling weren't given due consideration. The high work volume had created a lot of frustration and demand for change to the status quo.

1.4 THE FIRST STEP TO STREAMLINE FLOOD ADVICE

Flood hazard information requests can be divided in two types – preliminary queries from prospective property byers which don't specify where on-site information is requested (around 70% of all queries) and queries related to resource and building consents that need information for a specific location (remaining 30%). Both types of requests were at first assessed and reported in the same manner which consumed exorbitant amount of time. To respond to general queries more efficiently, a Pilot App shown in Figure 2, to advice flood status and minimum floor level for each site was created.

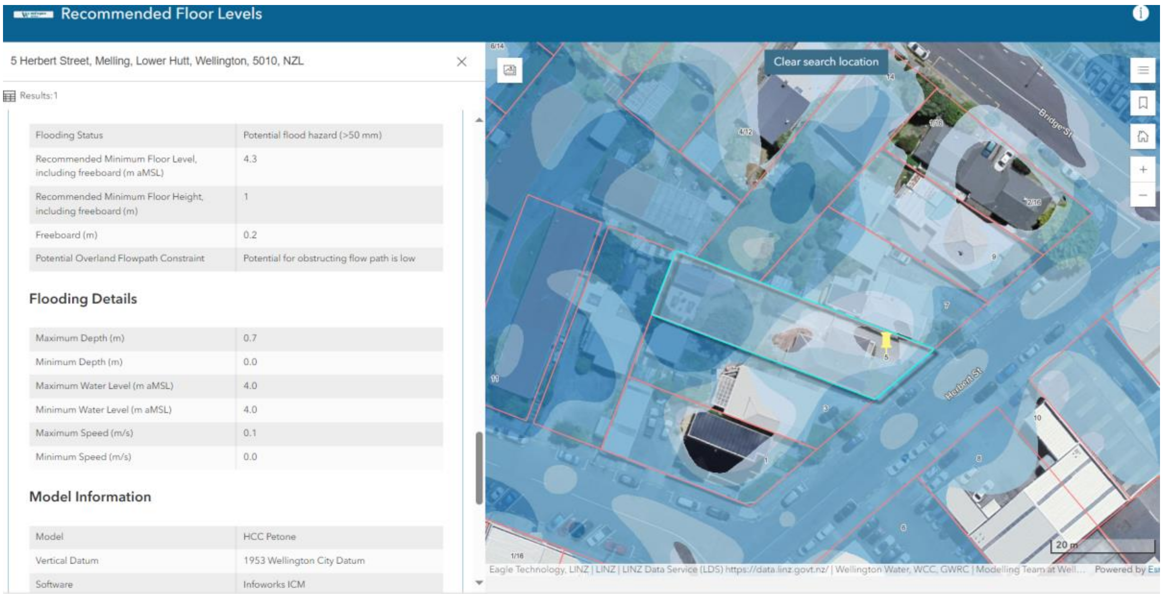

Figure 2: Pilot App for Floor Level Advice

The Pilot App used maximum values for the parcel as basis for the advice. While being overly conservative, as actual levels at desired location could be lower, the Pilot App provided the same level of information as was done prior for general queries and was also adequate to provide minimum floor level advice for resource and building consent queries if flood levels varied only slightly across parcel. In flatter areas such as Miramar, Kilbirnie, Petone and Lower Hutt, many properties could be assessed entirely using the Pilot App.

With the appearance of this tool, the workload for the modelling team was reduced by at least 50% and was a dramatic change which allowed modellers to get involved in other activities.

2 CONSIDERATIONS FOR STREAMLINING FLOOD ADVICE

The tremendous success of the Pilot App as an initial step towards streamlining flood advice gave hope that it is feasible to develop an online App that will provide flood advice to customers directly and further reduce the modelling team and land development teams involvement. To achieve this, such App must allow the user to identify on a parcel, location of intended dwelling, sample background layers at that location, issue detailed report with minimum floor level recommendation, and provide conditions based on district plan rules at selected location.

It must be acknowledged based on experience of providing flood hazard advice that blind use of modelling results can result in significant errors. To allow online tool issue assessment reports without human involvement requires careful considerations of all the issues involved. The subsequent sections discuss important factors that must be considered and fully understood to simplify and standardise decision making algorithm for programming the App.

2.1 FREEBOARD ASSUMPTIONS

Freeboard is applied to water level estimates to account for residual risk and/or eventualities that are not typically included or allowed for design event calculations or modelling. Typically, a blanket freeboard of say 500 mm is assumed. This may be a conservative assumption for most areas but at the same time, in some areas not fully account for the risk. Wellington Water mapping process incorporates dynamic freeboard[3] allowance to represent known contributors to flooding risk such as network blockages, sedimentation or vehicle generated waves. By testing sensitivity of the model results to these sources of risk, specific freeboard allowances for different areas are determined.

Once the appropriate freeboard depths were quantified and applied to the base model results, a dynamic freeboard model run was undertaken to determine the final flood hazard depths and extents as illustrated in Figure 3.

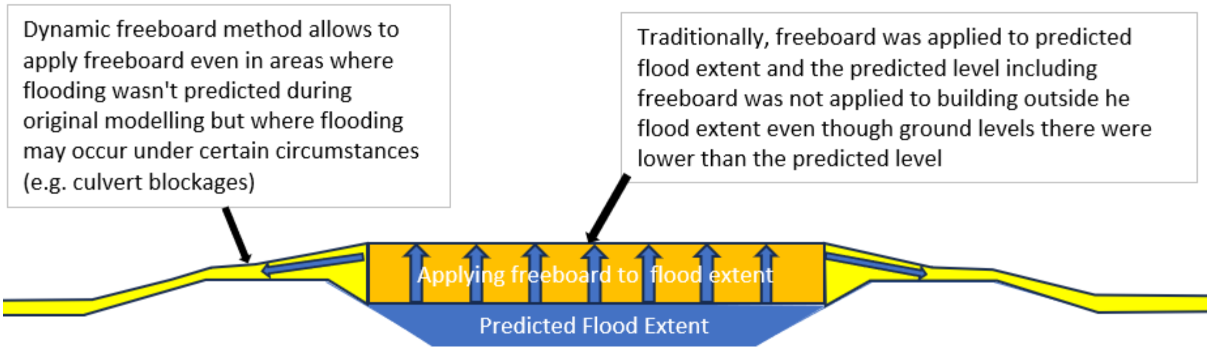

Figure 3: Dynamic Freeboard Application

Dynamic freeboard uses the maximum depth plus the adopted freeboard as an initial condition for the dynamic freeboard run. The model is run for a short period, typically 5 minutes, and the maximum depth results from the run provide the final flood hazard depth layer used to determine flood hazard extents for the District Plan flood hazard overlays and used to recommend building levels.

The App uses freeboard layer which sits in the background to recommend minimum floor level or alternatively, minimum floor height depending on ground slope at specified location.

2.2 SLOPING SITE CONSIDERATIONS

When sites with steep grade are assessed, errors in flood level may arise due to relatively large 2D mesh element size. Figure 4 below illustrates this situation providing comparison of a steep vs relatively flat site. The horizontal rectangles in the diagram represent mesh elements. The diagram allows to visualise that on a steep site, an averaged value of vertices would result in significant divergence from the actual surface level while on a flatter site, that divergence would be much less significant. This problem becomes less prominent if mesh elements in steep areas are much smaller. Wellington Water models' mesh size is already considered small for the size of the catchment, making mesh size finer would be impractical.

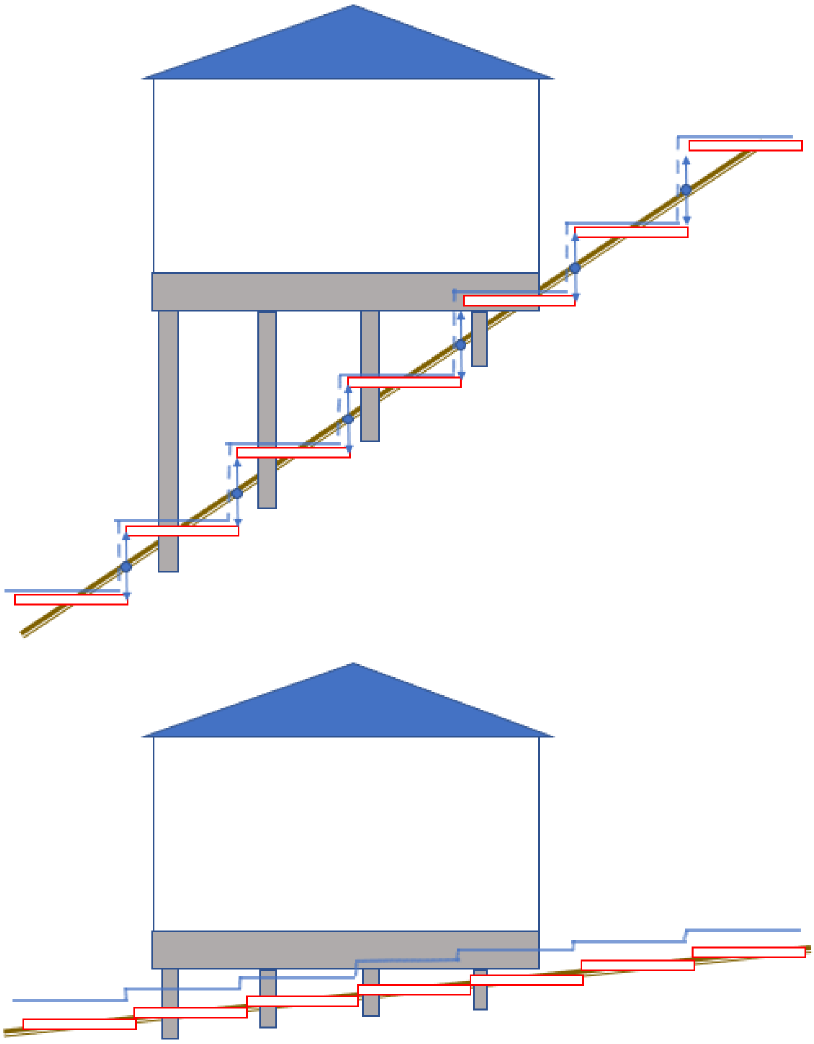

Figure 4: Impact of Ground Slope on Sampling Water Level

To deal with this issue, the App recommends customers intending to build on a sloping site (grade exceeding 0.1) an alternative method for setting minimum floor level. The recommendation is based on largest water depth from the sampled data set. The customer is permitted to set the minimum floor level by measuring off recommended minimum floor height from the highest point on the building perimeter.

2.3 GROUND WORKS CONSIDERATIONS

Minimum floor level recommendations are made based on predicted water levels which depend on ground shape. Construction practices often involve ground works to flatten site for construction. If this happens, minimum floor level recommendations which were based on original modelling results would be inappropriate. Even the use of maximum depth instead of levels is problematic. As illustrated in Figure 5, it is expected that as ground is flattened, the depth of water would increase from the original water depth flowing over steeper ground.

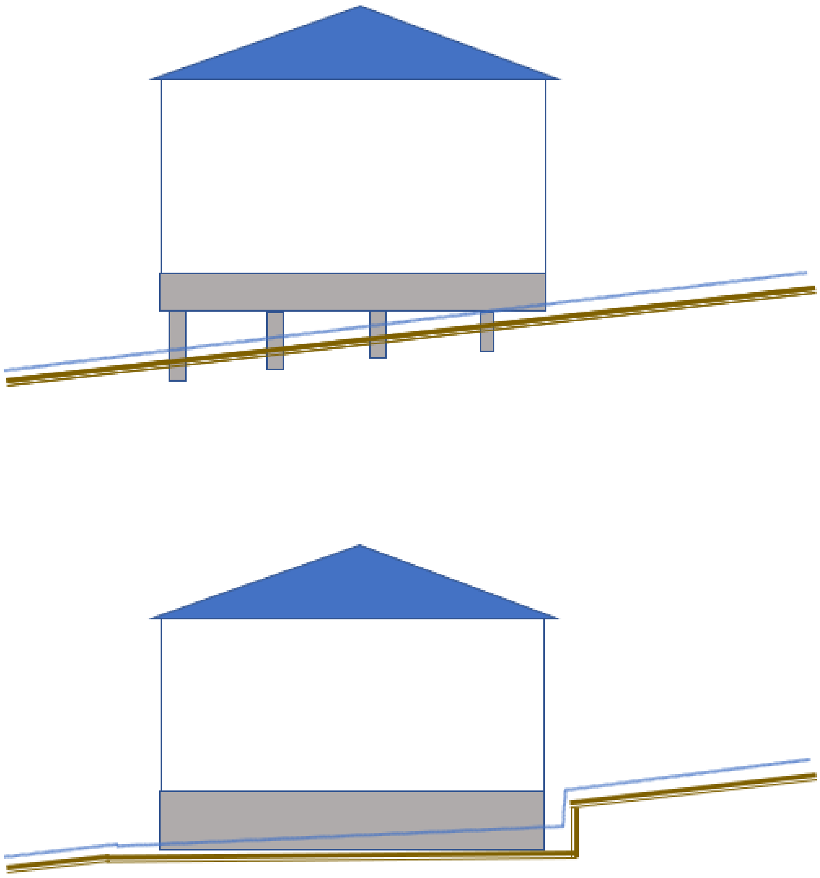

Figure 5: Impact of Ground Modifications on Water Depth

If ground works are proposed, the App sets a condition for the developer to assess impact of ground works on predicted flooding.

2.4 OFFSITE EFFECTS CONSIDERATIONS

The RMA directs authorities to ensure sufficient development capacity at the same time preventing or mitigating any adverse effects of the development, or subdivision. Meeting both these objectives in land constrained and flood prone cities like Wellington is not a trivial matter. In a scenario where there is some flow across a site, it can be expected that the new structure would impede or divert flow and exacerbate flooding effects at neighbouring properties as illustrated in Figure 6.

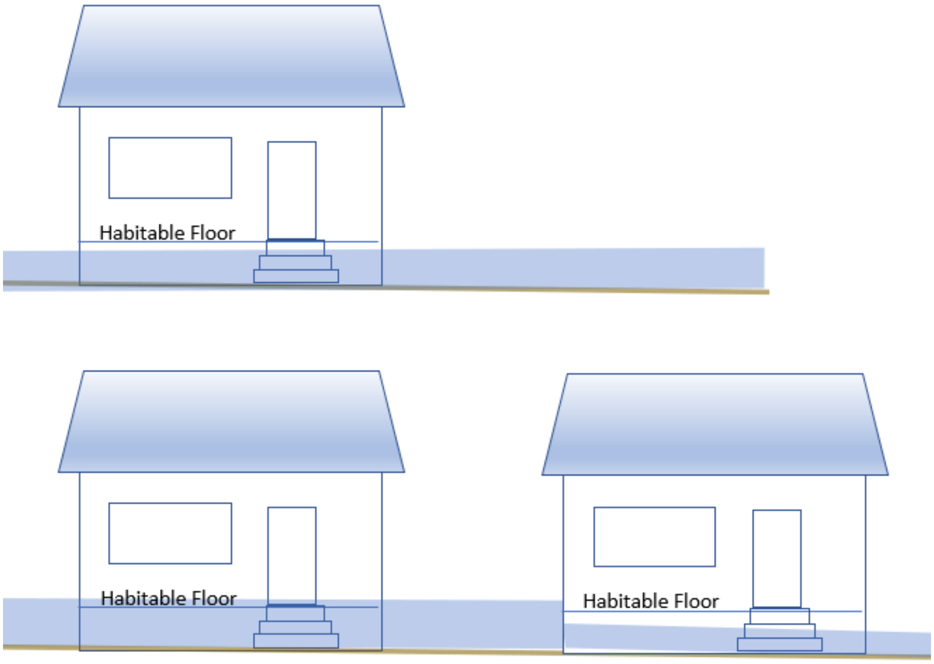

Figure 6: Offsite Effects resulting from Subdivisions

For large developments, the applicant can be expected to engage professionals to carryout assessment of effects as evidence for the consent. However, it was deemed unreasonable to require the same level of assessment for small subdivisions in the past.

To facilitate infill subdivisions, no offsite effects were assumed if flow velocity was less than 0.2 m/s, and if it exceeded 0.2 m/s, building was permitted if construction was done on piles and cladding was designed to facilitate unobstructed flow through building footprint.

Flow velocity trigger for offsite effects was examined[4] to reveal that trigger even as low as 0.1 m/s may not be used as a blanket rule as there were significant number of exceptions. It was also realised that while construction on piles can in theory facilitate unobstructed flow, without operative District Plan, there was no enforcement mechanism to ensure this.

2.5 DISTRICT PLAN OVERLAYS

The aim of the District Plan is to ensure that new developments are in sensible locations to avoid hazards altogether or alternatively, provide consent conditions to minimise the risk. Development proposals are assessed against District Plan development rules[5] based on identified level of flood risk at proposed location.

The flood hazard overlays illustrated in Figure 6 below, are a key component of the App allowing assessment of proposed development applications against rules in the District Plan.

Figure 6: Flood Hazard Overlays from the PCC District Plan

The flood hazard overlays show flooding hazards in the following categories:

2.5.1 STREAM CORRIDORS

Stream corridors typically consist of a buffer of 5m either side of the stream centerline. Open water courses in urban areas are selected to be included in the stream corridor layer. Flooding in stream corridors is the most hazardous of the three types due to it being deep and fast flowing water.

Activities that fall within this overlay are 'Restricted discretionary' and require land use consent. The App for this hazard requests developer to provide evidence that:

1. Flood waters are not displaced onto neighbouring properties and do not increase the risk to people and property;
2. The stream and flood water pathways are not impeded or blocked because of the building;
3. Mitigation measures have been incorporated to reduce the potential of damage from flooding over the lifespan of the building; and
4. There is no increase in risk to life because of the building being located in a Flood Hazard - Stream Corridor or Flood Hazard - Overland Flow Overlay.

2.5.2 OVERLAND FLOWPATHS

Overland flowpaths convey stormwater when the pipe or stream network capacity is exceeded or blocked. The flowpaths were identified and mapped using the modelled results backed up with flood records considering depth and velocity to identify hydraulically significant paths. This type of flooding is generally less hazardous than in stream corridors as the water is shallower and slower.

Activities that fall within this overlay are also 'Restricted discretionary' and require consent. The App for this hazard requires developer to provide the same evidence listed in Section 2.4.1 above.

2.5.3 INUNDATION/PONDING

Inundation/Ponding are the low velocity flood extents which have ponding deeper than 50mm. This is the least hazardous of the three types of flooding, however it is important to manage its effects on damage to property.

Within this overlay, the District Plan permits for small scale additions to buildings provided the finished floor levels are located above the 100 year flood level including Climate Change. For construction of new buildings, the applicant has to demonstrate that appropriate mitigation measures are incorporated into the design of the development so that the risk to people's lives is low or the potential for damage from flooding is reduced to a low level.

For this hazard zone, the App recommends as appropriate mitigation measure, a construction on piles with gap at the base of the structure left unobstructed to allow free flow through building footprint. The gap is to be at least as wide as maximum depth of flooding predicted at proposed location. Alternatively, the applicant has to provide the same evidence listed in Section 2.4.1 above.

3 RECOMMENDED FLOOR LEVEL APPLICACATION (THE APP)

Collaborations Ltd, a specialised GIS consultant, were engaged to develop the Pilot App into something that can be made an online tool for public use. Having agreed on basic App functionality and taking into account above-described considerations, it was agreed to proceed to the App development by leveraging the latest tools in ArcGIS Online which allow users to draw a feature within a browser to generate specific advice for any location.

3.1 CONCEPT OF THE APP

The improved function of the App compared to the existing Pilot App would:

- Report minimum floor level based on actual dynamic freeboard datasets as opposed to blanket 200 mm freeboard assumption as was done in the Pilot App. Dynamic freeboard concept has been described in Section 2.1.
- Use of the latest modelling data and flood hazard overlays with the tool acting as a 'source of truth'. This means the land development team, modellers, councils, and the public are all using the same data.
- By leveraging arcade code in ArcGIS Online, create an App functionality to interact with the browser at any location. This allows user to draw a feature (building footprint) within a browser and generate advice specific to that shape based on authoritative source of truth data.
- Split the application by Territorial Authorities (TA) to improve loading time and useability and allow for custom advice depending on respective councils planning rules.

3.2 APP FUNCTIONALITY

To make the App an online tool for public use, the App must have simple interface and each step applicants need to make is well explained by either the App itself or via external documents provided to the applicant. Figure 7 is the current interface of the App and is still being developed.

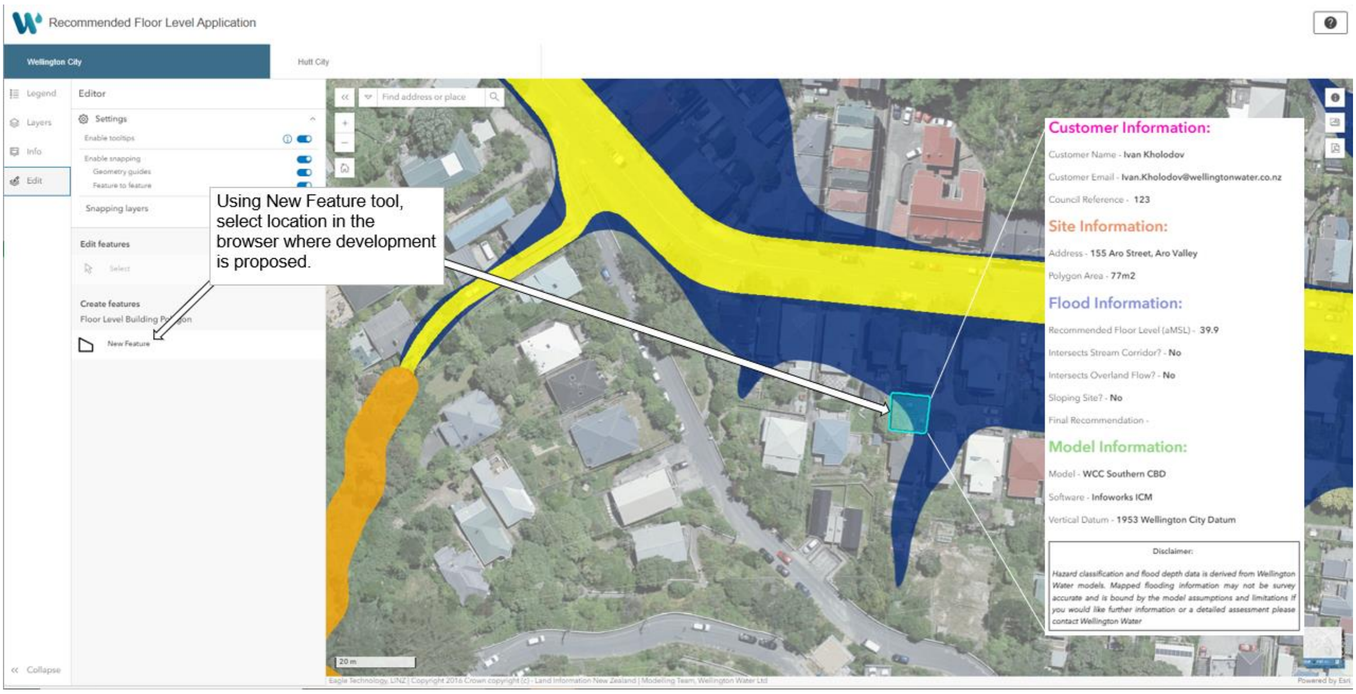

Figure 7: Recommended Floor Level Application Interface

As users enter the App, they proceed through following steps:

- Splash screen outlining how to use the tool appears. It must be read prior to proceeding. This information is accessible at any stage via the information tab.
- The user selects territorial authority where they want to develop.
- The user clicks the create tool to generate a new building footprint. The app generates attributes on the fly using arcade code and the building footprint drawn. For example, there is a field indicating whether the development intersects the district plan stream corridor overlay. The arcade code attached to that attribute field is looking for the intersection between the feature that has just been digitised and the underlying stream corridor layer. If there is an intersection, the field is populated with 'Yes' and subsequent advice is given. A similar process is carried out for several attributes.
- Once the user is happy, they click 'create' to lock that feature into data/memory. The results from the arcade code that has been generated on the fly in the background is then locked into the attribute fields and becomes part of the layer.
- The user exits out of the edit tab and clicks on the feature to bring up its pop-up. This pop-up includes user generated attributes (name/email) as well as attributes from the arcade. The pop-up contains some final arcade formatting code that looks at the various attributes and provides advice accordingly. For example, it doesn't matter what the recommended floor level is, if the stream corridor intersection attribute was returned with 'Yes', the pop up will advise the user to discuss with the council as this overlay is 'Restricted discretionary' and any activity would require land use consent.

3.3 STAKEHOLDER CONSULTATION

Seamless transition to a new way of doing things requires careful planning. There are many stakeholders that currently partake in the existing land development workflow including modellers and Land Development engineers at Wellington Water, planners, land and building consent officers at participating councils as well as the land development community. At this stage of the App development, it was decided to first consult Land Development team and Wellington City District Planning Team to get a feel for how the tool will help streamline processes within Wellington Water and how the advice relates to the end customer - an applicant going through a council consenting process.

- Land Development Team – Needed to work out what part of their current internal processes could be improved without adding more work/confusion. Key aspect is to define where the app advice stops and detailed assessment requiring human involvement starts.

- WCC – Needed to work out how they were intending to use the proposed district plan process to include rules on the flood hazard overlays and what advice this tool triggers. Need to identify how this process relates/overlaps with the existing building consent process.

The next stage in the consultation will involve other stakeholders.

3.4 BACKGROUND LAYERS

The reporting provided by the App is be based on information contained in the following layers:

- Model output layer containing flood depth and freeboard level information. To reduce file size and load time, this dataset was dissolved using both fields to reduce number of elements from original model export.
- District Plan flood hazard overlays – used to identify if developments intersect flood hazard layers and therefore trigger certain rules/advice.
- Parcel boundaries to help users digitise their developments.

4 CHALLENGES

There were many challenges encountered during the App development. Some of them have been resolved while others are still being addressed. The key challenges that still pose problem are discussed below.

4.1 OFFSITE EFFECTS ASSESSMENT

As things stand, many applicants requesting consents will have to provide evidence that offsite effects won't be created because of proposed activity. Such assessments entail significant price tag for the developers. While for large developments expense of such assessment is relatively minor compared to potential profit, for small infill developments, assessment cost could be prohibitive. From the point of view of the consultant, this kind of work is not ideal as it is tricky from technical perspective and challenging with respect to client management.

As Proposed District Plans become operational and development rules are finalised, expected stream of assessment requests is likely to encounter the bottleneck in availability of consultants prepared to do this work.

4.2 MANAGING LARGE MODELLING DATASETS

The background layers, especially the freeboard layer consists of very larger number of elements that equate to large dataset size. The way such data is handled has a strong implication on the App processing speed. This issue has been partially solved by splitting up datasets by TA.

4.3 APP REPORTING

The reporting in the App is still at conceptual stage. Details provided in the report need to be agreed with stakeholders prior to the App made available for public use.

4.4 DEFINING THRESHOLD FOR SPECIAL ASSESSMENTS

Some flood advice assessments in the past required detailed involvement from engineering and modelling staff. It is important to set thresholds in the App to trigger an alternative assessment pathway through Wellington Water Land Development team.

4.5 ADVISING FOR BUILDING CODE COMPLIANCE

The App must satisfy the need of both building and land consent teams. It is challenging for a single tool to consider resource consent requirements (i.e. through the hazard chapter of a district plan) and building consent requirements (i.e. via the building act) and provide advice fully consistent with these mechanisms.

4.6 PRIVACY AND PERSONAL DATA ISSUES

The issue of privacy of personal data and commercially sensitive information about the location of proposed developments has not yet been addressed.

5 CONCLUSION

The evolution of flood hazard advice is a good case study of process optimisation and automation. At first a need arises which is satisfied through ill-conceived measures addressing the need but at the same time, imposing significant challenges and limitations. With no prior experience doing this activity, it takes time to connect the dots and understand situation in its entirety. Once quantity of experience reaches a certain threshold, a qualitative change occurs revolutionising the process and produces leap in productivity.

When operational, the App will reduce flood hazard assessment requests for the Modelling Team by 90% which would free critically needed resources for the dozens of projects in need of modelling.

ACKNOWLEDGEMENTS

Wellington Water staff and our consultants Collaborations, AWA, Stantec, GHD, and Jacobs.

We would also acknowledge Wellington Water Client Councils:

- Greater Wellington Regional Council (GWRC),
- Hutt City Council (HCC),
- Porirua City Council (PCC),
- Upper Hutt City Council (UHCC); and
- Wellington City Council.

REFERENCES

(1) https://www.legislation.govt.nz/act/public/1991/0069/latest/DLM230265.html

(2) https://www.legislation.govt.nz/act/public/2004/0072/latest/DLM306036.html

(3) Stokes, K; Fountain, B; Nitsche, N (2020) The Use of Dynamic Freeboard in Managing Urban Flood Risk

(4) McCoy, R (2022) Assessment on Impacts of Building within Floodplains

(5) Proposed District Plan - Proposed District Plan (poriruacity.govt.nz)