OVERLAND FLOW IN THE URBAN ENVIRONMENT

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ABSTRACT

Modelled overland flowpaths (OLFP's) are being systematically assessed for their accuracy and impact as part of the Stormwater Catchment Management Planning process being conducted by North Shore City Council. Mitigation measures have been developed for properties at risk of habitable floor flooding.

This paper discusses the field property assessments which record both the effect of the OLFP on impacted property and any obstruction the property development has on the course of the OLFP.

The following key findings are discussed:

- That 49% of properties (land sections) and 14% of houses in North Shore City are impacted to some extent by modelled Overland Flow Paths.
- Approximately 6,650 of the 45,500 properties in the current study area have been individually inspected.
- Of these, approximately 700 (1.5% of properties within the current study area) have been assessed to have a risk of habitable floor flooding from the overland flow during a major storm.
- Roads act as a significant collector and conveyor of overland flow with the locations where stormwater spills off road reserves being a major factor contributing to flood risk for downstream properties.
- Building and site works design for properties is a major factor contributing to flood risk for properties.

This paper outlines the field data collection process, data management, detailed assessments and the integrated approach between Council Departments and affected residents to provide preventative and mitigation measures to minimise the risk of habitable floor flooding from overland flow.

KEYWORDS

Overland flow, flood risk, stormwater management

INTRODUCTION

North Shore City (NSC) is located in Auckland, New Zealand. It is one of the fastest growing cities in the country. There is strong demand for land for both subdivisional development and infill housing, particularly on the coastal fringes where there are sea and harbour views available from the steeply rising terrain.

The majority of the City is underlain by a low permeability clay sub-base. This geological setting combined with the relatively short steep catchments results in high yielding runoff characteristics. Consequently as the pressure on available land intensifies, stormwater issues have become a significant concern for residents.

In 2004 a LIDAR (Light Detection and Ranging) survey was flown of NSC. LIDAR is a technology that uses pulses of laser light striking the surfaces of the earth and measures the time of pulse return generating elevation data points. This data can be used to create a digital terrain model or DTM. A DTM is a simple digital representation of a portion of the earth's surface. This enabled overland flowpaths to be generated citywide and mapped for catchments above 2000 m2. This showed that 49% of properties (land and buildings) and 14% of houses (buildings alone) within North Shore City are impacted to some extent by these modelled Overland Flow Paths.

As an important element of the Integrated Catchment Management Plan process the identified flowpaths are being systematically assessed by a combination of desk study and field study to determine flood hazard risks associated with overland flow. The outcome of this work is the development of options to mitigate potential flooding.

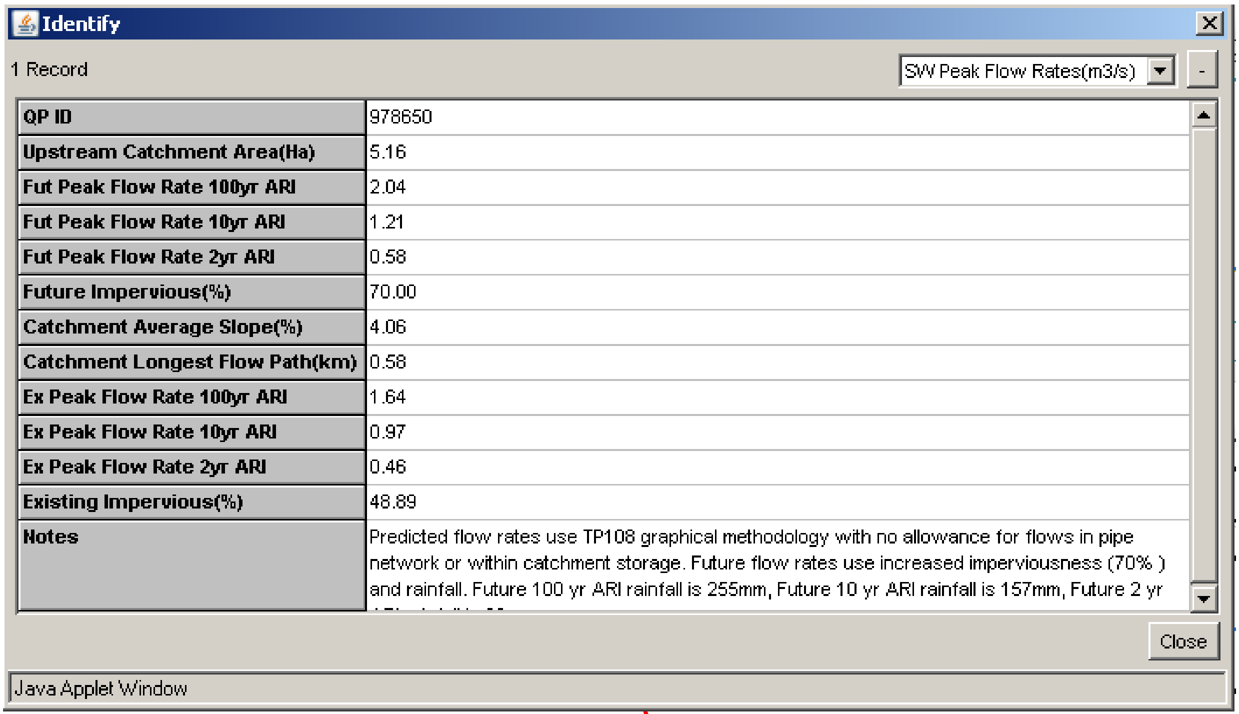
1 OVERLAND FLOW FIELD ASSESSMENTS

The OLFP assessment initially involved handwritten information being collected and collated on paper sheets. This required that the field Engineer had to manually transfer hand written field notes to a spreadsheet. This process was very time consuming and inefficient. It was also not being recorded in an appropriate information database format. As modern technology and cleaner easier data capture techniques are available it was decided that the data should be collected on a handheld Personnel Digital Assistant (PDA) using ESRI ArcPad software for mobile GIS (geographical information system) and field mapping applications. The formulation and development of the field data capture programme is detailed in Overland Flow- an Approach to Flooding Risk and Management (Tate, Carter and Young; 2007)

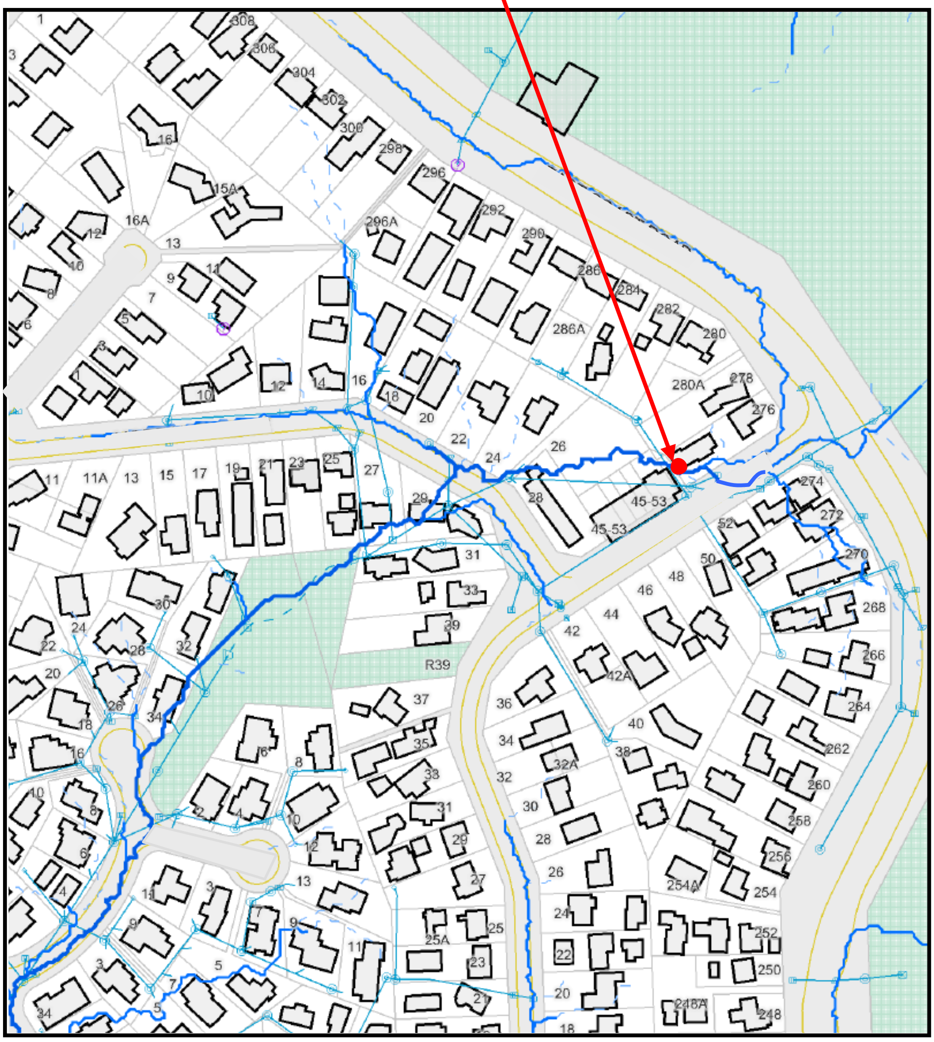
Prior to commencement of data collection in a selected catchment, a desk-top exercise takes place. Printouts of the catchment area showing the overland flow paths and house footprints are studied. Properties that receive flow directly or indirectly off the road reserve and where that flow is in the vicinity of the house footprint are entered on a list of sites requiring field evaluation. Figure 1 presents a typical GIS map with the overland flow paths shown.

The magnitude of the flow is noted, with a lesser degree of priority given to the minor flows. Minor flows are indicated on a Council GIS viewer for catchments from 2,000 to 4,000m^2. Significant flowpaths are indicated for catchments from 4,000 to 30,000 m^2 and major flowpaths are indicated for catchments over 30,000 m^2. In addition a peak flow rate calculator has been developed and can be applied at any point on a defined flowpath to obtain estimates of peak flow for 2, 10 and 100 year ARI based on TP108 graphical methodology. See Figure 1 for a screen shot of the output box from the peak flow rate calculator.

FIGURE 1: GIS Map With Overland Flow Path and Screen Shot Of Output Box From Peak Flow Rate Calculator



QP ID	978650
Upstream Catchment Area(Ha)	5.16
Fut Peak Flow Rate 100yr ARI	2.04
Fut Peak Flow Rate 10yr ARI	1.21
Fut Peak Flow Rate 2yr ARI	0.58
Future Impervious(%)	70.00
Catchment Average Slope(%)	4.06
Catchment Longest Flow Path(km)	0.58
Ex Peak Flow Rate 100yr ARI	1.64
Ex Peak Flow Rate 10yr ARI	0.97
Ex Peak Flow Rate 2yr ARI	0.46
Existing Impervious(%)	48.89
Notes	Predicted flow rates use TP108 graphical methodology with no allowance for flows in pipe network or within catchment storage. Future flow rates use increased imperviousness (70%) and rainfall. Future 100 yr ARI rainfall is 255mm, Future 10 yr ARI rainfall is 157mm, Future 2 yr



Letters are sent to all properties on the evaluation list with an invitation to call Council if they wish to discuss stormwater concerns. It is common for 20% of the contacted residents to request a discussion of their concerns. These discussions provide valuable local knowledge. By combining site inspections with pre-arranged visits with interested residents, coverage of approximately 10 properties per day is achieved and is also used as an average for planning forward work.

All data is field recorded on a hand-held PDA that has a wireless connection to a camera. Photos taken on site are recorded directly in the subject property file and can be used later for desk evaluation and reporting.

Field data is regularly transferred to corporate data systems and is subsequently available for viewing in the Council GIS viewer and for database analysis and reporting.

Data are recorded for individual properties inspected under the following headings to determine impacts of floor flooding.

Table 1: Summary of Recorded Data for Floor Levels

REFERENCE	Displays the unique property ID, street address, inspection date and assessors name
SOURCE	Fields that detail source of flow onto that site i.e. road/ neighbour
EXIT	Field to describe downstream property location/ address
SLAB	Construction details of house i.e. slab-on-ground /piles/compliance of Site paving, Habitable /Non Habitable floor flooding risk
SUB	Details of sub-floor development/ Habitable/ Non habitable floor risk
SITE	Flow Path Clear? Pick list of possible obstructions i.e. house / minor bldg
BNDYUP	Details of upstream boundary fence/ hedge/ obstruction.
BNDYDN	Details of downstream boundary
SITE DEV	Details of site drainage/roof disposal/site paving/gully trap compliance
SUMMARY	Assessors estimate of cost of remedial works/ responsibility indication/ magnitude of flow / Council department involved

By observing site conditions and recording the above details the assessor is able to make an initial judgment of the likelihood of habitable or non-habitable floor flood risk bearing in mind the predicted magnitude of flow in a 100 year storm event. Any options apparent for remedial work are noted along with an indication of likely cost within dollar ranges of 0-1,000, 1,000- 10,000, 10,000-50,000, >50,000.

The assessor makes an initial judgment of options and responsibility for any mitigation work with a choice between Council, Resident and Shared.

Factors taken into account in this assessment include:

- If a substantial amount of the overland flow is coming off the road reserve or Council reserve either directly or indirectly this indicates a degree of Council responsibility.
- If the overland flow path was defined and available at the time a building was consented this indicates a degree of Council responsibility.
- If a building is unconsented and or structures and landscaping features lead to increased risks of flooding from overland flow, the property owner will have a degree of responsibility for remedial works.

Often the situation is not able to be clearly defined in the field and further work is required to support the initial field investigation. There are comments fields provided on the data capture forms on the PDA that have been designed to give the field operator enough flexibility to record information about a wide range of situations that are encountered.

Other Council related information is often noted during the catchment walk-over and issues such as broken or missing road signs, damaged footpaths or non-compliant activities are either phoned into the Council call centre or reported by e-mail on return to the office.

2 DETAILED INVESTIGATIONS

Following the field assessments of overland flowpaths the data is analysed and a short list of issues requiring further engineering investigation is compiled. This is generally for properties where the initial field assessment indicated a risk of habitable floor flooding and a degree of Council responsibility.

The detailed investigation includes review of the data captured, calculation of flows and potential flood levels, review of property files and assessment of options including estimates for remedial works. Sketches of preferred remedial works are generated. The investigation reports are produced in a standardized format for use by the projects team in implementation and are recorded in the Council document management system.

Approximately 6,650 properties were inspected out of a total of 45,500 within the catchments covered to date. Out of the 6,650 properties inspected, 700 were found to have potential risks of habitable floor flooding and would require further detailed assessment with recommended options prepared for remedial works. This represents 1.5% of properties in the catchments assessed. Follow up detailed assessments found that a portion of these have a lesser risk of floor flooding or the owners have responsibility for the flood risk. Discussions with those affected owners are part of the catchment planning process.

3 CONVEYANCE OF OVERLAND FLOW

Overland flow in the urban environment is generally either conveyed by the natural or modified terrain or by kerb and channel in the road reserve.

Terrain flow is the natural accumulation of rainwater as it flows downhill. If undisturbed this flow would progress through the ephemeral – perennial stream network and discharge at the bottom of the catchment. In the developed area of the city this natural progression is extremely rare. Typically, the roading infrastructure intercepts, magnifies and diverts terrain flow, changing its characteristics. An overland flow path often enters and leaves several road reserves as it progresses down the catchment.

In the upper reaches of a sub-catchment the flows are typically minor and easily managed on each affected site.

Terrain flows are predictable, identifiable and opportunities to protect their course must be looked at on a property-by property basis as levels of control, obstruction or containment vary widely within each property. In the urban environment it is rare to find an uninterrupted overland flowpath across two consecutive properties.

Kerbed roads form their own overland flow paths. They also intercept flows off higher land. Stormwater will either accumulate in the sag-point of the road or flow along the road gaining magnitude and velocity.

Assuming total blockage of the piped system, spillage of ponded or conveyed flow from the road reserve can occur in 5 recognized situations:

1. At the under-vertical, or sag point in the road. This can be identified as “catchpit spillage” and is often located above an historic gully.

2. Often with a steep driveway on the lower side of the road there is no allowance for a protective roll-over in the vehicle crossing to retain channel flow in the road reserve. The driveway then serves as a conveyor of water off the road reserve into the property. Where a vehicle crossing is on the outside of a bend in the road, velocity of the channel flow will project it across the vehicle crossing and footpath onto private property.

3. At intersections where the crown of the side road projects out to meet the crown of the through-road. This creates ponding in the upstream channel, producing uncontrolled spillage off the road onto lower properties.

4. In the transition from a steeply sloping road to a flatter gradient road, the loss of velocity of water in the channel will result in deeper channel flow. Where the berm is low at this point uncontrolled spillage will occur.

5. Cul-de-sac roads are often sited on spurs that fall steeply from ridge roads. Driveways off the head of the cul-de-sac often mean there is no effective kerbing, allowing channel flow to run directly onto private property. Often this channel flow is generated off the ridge road and has gained considerable volume and velocity prior to impacting the downstream properties. Catchpits in the channel at the cul-de-sac head typically are not effective for flow entry because they often coincide with vehicle crossings, have limited driving head and are prone to blockage.

Road spillpoints are not readily recognizable and often produce large volumes of flow onto private property. Historically they have not been recognized in either road design or building consenting considerations. They often pose serious risk to impacted properties.

In particular, the lack of effective control over the construction of vehicle crossings has created a situation where relatively minor flows spill from the road channel onto private property.

The ongoing reliance on catchpits, stormwater pipes and the standard kerb profile without consideration of the impacts of overland flow when the capacities of any or all of the above are exceeded is a fundamental design issue that needs to be addressed. Opportunities to manage overland flow or utilize less hazardous spillpoints are seldom recognized in road, footpath and berm design.

In ridge road situations the minimization or elimination of the kerbline to allow natural flow into reserve land is one such opportunity.

Successive seal overlays in the road carriageway compromise the conveyance capacity of the channel and contribute to the spillage down flat vehicle crossings.

The above issues require an integrated approach ideally to prevent stormwater management problems in new developments and where necessary to mitigate existing problems.

Road spillpoints signify high risk for Council.

4 THE SIGNIFICANCE OF ROAD SPILLAGE ON DOWNSTREAM DEVELOPMENT

With the on-going demand for residential housing sites across the city the pressure for infill housing development continues.

The great majority of houses at risk of flooding from overland flow are in the “recently built” category.

Typically the available sites are restrictive in size and to comply with building regulations excavations for basement garages and slab-on ground construction are very common and the building footprint occupies a large part of the site.

Where the development is below the road on steep terrain, an equally steep driveway is necessary to service the site. Often there is no possibility of creating a roll-over at the top of the driveway to retain channel flow in the road reserve and the driveway falls directly from the channel to the garage entrance. The driveway provides ready access to both vehicles and the bulk of the channel flow from the road above. In many instances the entry foyer to the habitable floor of the house is adjacent to the garage door and at the same level. Photograph 1 illustrates this point.

Photograph 1: Vehicle Crossing Installed By the Developer Without Roll-Over To Retain Flow In Road Channel. Channel Flow Estimated To Be 0.2m³/sec In A 50% AEP Storm

Photograph 2: At the Bottom Of the Driveway

The significance of risk to properties below the recognized spill points in roadways was not fully appreciated prior to mapping of overland flowpaths.

It is a major concern related particularly to infill housing and to new development in general.

5 COMMON PROPERTY ISSUES

The infrequent occurrence of significant rainfall events across the area of North Shore City is both a blessing for our residents and a hindrance for those wishing to alert them to the potential risk of inundation from overland flow.

A typical residential property owner puts full reliance on minimal drainage facilities for the protection of their house from flooding. Often that drainage consists of sub-soil drainage with extremely limited inlet capacity- but it has “worked just fine for many years”.

Minimal drainage strips across the frontage of a double garage at the foot of a steep concrete driveway- and below the sag point in the road- typically has the downpipe from the roof feeding into it. Clearly it will be full when it is most needed, and the garage at least is at risk.

Site paving is often installed at habitable floor level when the property is at risk of flooding from overland flow. In addition, raised gardens, planting and landscaping is often laid out in such a way that overland flowpaths are obstructed and cause ponding and entry of water to habitable floor areas during heavy rain.

The downstream property boundary fencing is often purposefully strengthened to limit or prevent the egress of stormwater off the site. Sheds, garages are often constructed at the egress point on the downstream boundary. Photographs 3 and 4 illustrate flooding caused by a restrictive downstream boundary wall.

Having mapped overland flowpaths available for building consent staff at NSCC has been very valuable in assisting with the assessment of flood risk. However the issue of approving slab-on ground construction without control of future site landscaping development frequently results in flood risks for new properties and compromises the overland flow path.

Photograph 3: Overland Flow Obstructed By Restrictive Fence behind the Garage Resulting in the Flooding of the Garage and Habitable Floors

Photograph 4: Breaking Restrictive Fence to Allow Overland Flow Through (Action Taken Too Late In This Case)

6 INTEGRATED MANAGEMENT

With flow off the road reserve often being the focus of potential habitable floor flood risk, remedial work often involves multiple parties. The Stormwater, Transport and the Consenting sections of Council, and the resident(s) concerned are common participants.

Consultation with affected residents from an early stage in the process is vital in achieving a mutually beneficial outcome. This often involves neighbourhood meetings when multiple properties are involved.

Developing a joint understanding of the problems and collectively developing practical remedial options is the key to resolving overland flow issues.

An example of integrated management can be demonstrated in a recent North Shore City Transport Department project aimed at replacing standard footpaths with an extra-width combined cycle / pedestrian facility along the wide berm of a busy arterial roadway.

At an early stage in the planning it was recognized that habitable floor flooding from spillage off the road reserve had occurred historically to several of the properties within the project scope.

The Stormwater section commissioned the design of a swale which was then constructed as part of the road upgrade project carried out by the Transportation Section. Photograph 5 shows the swale which is currently being constructed.

Affected residents were consulted at an early stage and without exception were happy for the added benefit of protection from flows off the road reserve whilst the other work in the road berm progressed.

This co-operative approach afforded the affected residents protection with minimum disruption.

Photograph 5: An Example Of Mitigation Works To Retain Overland Flow in The Road Reserve

To date remedial work identified from overland flow studies has been carried out for 14 properties at risk of habitable floor flooding at a cost of $140,000.00 (an average of about $10,000 per property.) The forward programme for overland flow mitigation is intended to ramp up significantly in the next 2 years.

7 CONCLUSIONS

The identification and assessment of overland flow is seen as an essential element of the Stormwater Catchment Management Planning process and provides a basis for evaluation of options for mitigation projects.

A significant proportion of improvement projects recommended in Catchment Plans being prepared at present involve remedial works on overland flow paths and far outweigh improvement works associated with piped reticulation or flooding associated with flood plains. This reflects the experience of recent years where in the order of 90% of recorded habitable floor flooding during major storm events has been associated with overland flow.

Approximately 1.5% of houses in the 11 catchments assessed to date have been assessed as having a risk of habitable floor flooding during a major storm event. Extrapolating the 1.5% through the 77,089 houses in the North Shore City, this would represent 1,156 houses with risk of habitable floor flooding due to overland flow citywide. Works identified to mitigate flood risks have been scoped and estimated for some 105 properties at an average of about $15,000 per property.

The recognition and protection of overland flow paths is an integrated concern involving Transport, Consenting and Stormwater sections of Council and affected residents.

The road reserve forms a significant part of the overland flowpath network and presents many opportunities in the management of stormwater. There is a need for overland flow to be managed as a fundamental component of road reserve design and for designers to stop designing stormwater systems that are totally reliant on catchpits and pipes.

Education of the public, relevant Council staff and design consultants is an important function of the stormwater division of Council.

Careful attention to conditions of building consents for site-specific building design and site development is vital for the protection of overland flow paths as a stormwater management tool.

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REFERENCES

Overland Flow- an Approach to Flooding Risk and Management (Tate, Carter and Young; 2007)