LIDAR Survey, Modelling and GIS as tools used in the Sustainable Management of Urban Drainage Systems

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Abstract

It is man's ability to hold things in his hand which has enabled him to make use of tools, where other animals have had to rely on their strength and agility, their teeth and their claws. The pathway in the development of humankind is in many ways analogous to our ability to use tools and has correspondingly improved the way we live. Today as we strive to successfully progress into the coming centuries it is once again the tools we use that offer hope for the future.

Overland flow paths (OLFP's) are an important and fundamental component of the stormwater drainage system of all catchments. However, until recently there has been no formal recognition of their location, course or scale in North Shore City (NSC) NSC, making management of this aspect of the stormwater system difficult.

Through the use of mobile data capture technology's (such as Arc Pad with a PDA) multiple data criteria can be collected about OLFP's providing site specific information for further analysis. This paper describes the results from the pilot field assessment and details the way in which these tools can be used to benefit the community, supporting the delivery of sustainable outcomes.

Key Words

LIDAR, Overland Flow Path, Modelling, Geographic Information System.

Introduction

In 2005 an exercise began in NSC in Auckland to simulate, map and assess Overland Flow Paths (OLFP). The simple aim to was gain a better understanding of where water comes from, where it flows to and what impact it has on the way as it flows through the urban landscape. This paper describes the methodology (the Method) for the assessment of overland flow paths in NSC and considers the tools used in carrying out the project.

This Method was developed as part of a pilot exercise examining the potential impacts of overland flow paths in the Hauraki, Eskdale and Lucas Creek Stormwater Catchments. The pilot study was undertaken in the summer of 2005/06 by NSC officer Engineer John Tate. This field exercise involved the capture of multiple data relating to the OLFP's.

LIDAR Survey, Modelling and GIS technologies can be used as important sustainability tools in the assessment and management of urban drainage networks. As the problem of management of OLFP is a national one the subject of this paper is relevant to all major urban developments in New Zealand.(and internationally).

METHODOLOGY

LIDAR Survey, Modelling and GIS Technologies as Sustainability Tools

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.

The elevation data is expressed in raster format in GIS (Geographic Information System). GIS is a computer system designed for storing, manipulating, analysing, and displaying data in a geographic context. The raster plot is based on data where a cell has a single elevation which represents the entire area covered by the cell. This type of DTM can be used for

- Modelling hydrologic function from the topographic form of a drainage basin
- Determining the drainage network and associated drainage divides
- Estimating slopes for understanding drainage patterns and processes

To gain a better understanding of where water comes from, where it flows to and what impact it has on the way as it flows through the urban landscape, flow paths have to be mapped in detail. This means that the flow across the landscape has to be simulated.

By using Auckland Regional Council (ARC) Technical Publication 108 standard design rainfall runoff rating curves a rainfall runoff relationship was developed on the basis of landuse type for each 2m x 2 m node across NSC. A MIKE 21 (Danish Hydraulic Institute) model was then constructed and overland flow paths simulated using the background DTM.

The result of this modelling process is that NSC now has generated defined OLFP's for the entire City. This information has been represented spatially in GIS and is available to users throughout NSC.

The mapped courses/paths of the OLFP were then used by a field Engineer to evaluate the impacts of and to the OLFP from the built environment. This included:

- roads
- stormwater infrastructure
- buildings and;
- all other major obstructions

What is an Overland Flow Path?

Overland flow paths occur both in developed and undeveloped areas. They are the accumulation of surface flow that drains to the lowest point in a catchment.

Definitions for overland flow paths and their varying magnitudes have been developed. These definitions reflect the amount of flow expected to accumulate along a drainage path and have been fundamental in assessing the impacts of OLFP during the field survey study undertaken by NSC.

The detailed definitions used in this assessment are as follows:

Key Words	Definition
Overland flow	Stormwater that flows overland until it enters the formal stormwater network, stream or the sea.
Overland flow paths:	The route followed by stormwater which runs over the surface of the ground (overland flow) when it becomes concentrated as it makes its way downhill following the path of least resistance towards streams and watercourses, or the sea.
Secondary flow paths	The path which surface water will follow if the primary piped drainage system becomes overloaded or inoperative.
Major overland flow paths	Overland flow path with an effective catchment area exceeding 30,000 m^2 (3 Ha) Flows during a 100 year storm generally exceed 0.75 m^3/s (equivalent to a 600 mm pipe flowing full).
Minor overland flow paths	Overland flow paths with an effective catchment area between 4,000 m^2 (0.4 Ha) and 30,000 m^2 (3 Ha). Flows during a 100 yr storm generally exceed 0.1 m^3/s (equivalent to a 300 mm pipe flowing full)
Overland flow cautionary warnings	Too small to be classed as minor overland flow paths with effective catchment area between 2,000 m^2 (0.2 Ha) and 4,000 m^2 (0.4 Ha). Flows during a 100 year storm generally exceed 0.05 m^3/s
Primary drainage system:	The route that stormwater would normally follow. This could be a pipe, channel, stream, culvert, swale or overland flow path.
Flood plain	The area adjacent to watercourses that is likely to be inundated by floodwaters during a flood event having a 1% probability of occurring in any given year. Also referred to as a 100 year event occurring on average once every 100 years

Data Collection and OLFP Survey Method

Traditionally before the advent of modern hand held computers collection of data in the field was on paper sheets. This required that the field personnel had to manually transfer hand written field notes to a spreadsheet or similar. This process was very time consuming and inefficient.

Modern technologies and cleaner easier data capture tools are now available. In response to this it was decided that the survey of NSC OLFP's should be undertaken on a handheld Personnel Digital Assistant (PDA) using ESRI ArcPad software for mobile GIS and field mapping applications.

By standardising the data capture process, with standard forms and pick lists, the resulting information is in an appropriate database format and affords significant improvements in the integrity and accuracy of data being collected. Furthermore, through the use of PDA and mobile Arc Pad software there is the potential to speed the process of data collection and time spent in the field. This mode of assessment and data capture in turn empowers field personal in on-site decision making.

The following NSC GIS spatial datasets where available on the PDA to the field Engineer while in the field assessing the OLFP's:

I. Cadastral Property Boundaries
II. Roads
III. Aerial Photographs
IV. Stormwater Network
V. Wastewater Network
VI. Parks and Reserves
VII. Overland Flow Paths

This information was used to guide the field Engineer to the locations of the specific features to be surveyed. The layers are served to the PDA (all except the Overland Flow Path property shape file that contains the assessment data) via the internet and Arc IMS. Arc IMS is a system that can deliver dynamic maps and data via the Web. The advantage of not storing all the spatial data on the PDA is that this reduces the need for system (memory/processing) resources and the time for set up.

The detailed site assessment has been designed to determine the following:

I. Is it "public" or "private" water? (responsibility/land ownership of contributing catchment)
II. The source of the flow;
III. Points of entry and exit of the overland flow path on that site;

IV. The effect the overland flow would have on the house/ buildings or physical features on the site;
V. The effect the house/ buildings or physical features have on the overland flow path;
VI. Are floor areas (either habitable or non-habitable) likely to be affected?
VII. Details of the house construction and site development that may affect the risk of damage from flooding;
VIII. Site obstructions to the overland flow path;
IX. An assessment of severity of anticipated overland flows (based on topographical detail/ size of catchment area)
X. Assessment of responsibility for reinstatement of the overland flow path where required i.e. council, resident, or shared.
XI. Estimated value of any measures required to reinstate the overland flow path within a property. (Where it is perceived to be a Council issue and after detailed feasibility assessment)

The wide range of features that have been considered as part of the OLFP assessment would have been difficult to practically survey without the use of the modern mapping, data and digital tools. In addition the collected information would have been cumbersome and difficult to analyse and represent practically to other parties.

DISUSSION

Roading Network Impacts

Roads typically convey water to points along their course and spill this water off the road into adjacent land. Using the detailed information describing the OLFP can now be traced from source to discharge point. The survey in NSC has gone a long way to unveiling some of the impacts of roading networks on the OLFP.

For example roading design or the form of a road can divert an OLFP from one natural drainage catchment to another. This process means that the OLFP is artificially intensified. As the flow on the road must eventually discharge off the road or spill, "Spill Points" are thus areas where adjacent land and neighbouring properties can be adversely affected by this discharge.

By using the OLFP model and mapping the locations where they cross roads or discharge from roads the "Spill Points" can be located across an urban area or any other drainage network. Thus providing the opportunity to better plan roads in new subdivisions and investigate, designate and/or schedule works to mitigate the identified adverse affects from uncontrolled (and often unidentified) spill points.

A Tool to better Public Health and Urban Planning

Over recent years it has been widely recognised that the environmental conditions in the home can affect the health and well being of the inhabitants. Moisture, mould and cold damp air are considered some of the negative impacting factors. The course of OLFP's are to a greater or lesser degree associated with areas of cold and moisture. As we search for new places to build houses to accommodate the growing population the more marginal land areas such as gullies and the subdivided urban lot are being developed for urban housing. The location and magnitude of OLFP's is a valuable information resource that can influence the location and design of urban dwellings.

A general "unawareness" was noted throughout the surveyed areas of both the threat to property from free flowing water and measures available to mitigate that threat. It is suspected that "unawareness" stems from a full reliance on the primary piped system and the private on-site systems leading to it. Where a public stormwater system is installed, full reliance on that system has often allowed for inappropriate development of sites. The detailed OLFP now available to Council will support better stormwater planning, design and urban design planning in general. This is in turn will support the more sustainable development of NSC.

Knowledge is Power and Serves Integration

Separate, distinct and often conflicting, too many of the elements that make up our built and natural environment are viewed as separate boxed entities without relationship. This is not surprising given the complexity of these systems. However, with the new and powerful technologies now at our disposal we can assimilate, organise and present multiple data in a way that provides more clarity to the wider inter-complexities of our networks, systems and the environment.

The data collected on the impacts of OLFP has been attached to the NSC Property Layer spatial dataset. This data as well as the locations of the OLFP and their magnitudes is made available on Eview and portions of the collected information are provided to council departments for their use. Eview is an information gateway able to integrate multiple databases and to provide access to their content via a Web browser. Eview allows an organisation to add a spatial dimension to corporate data (via a browser-driven enterprise information portal). This innovative ability to use geography as a data type means that data mapping assumes a new meaning as Council can see their information sets collated and then plotted on a real map integrating information in a meaningful and powerful way.

The OLFP's flow along the lowest points in the surrounding topography. They can impact on the wastewater network by partially draining into the system causing it to overflow and discharge wastewater into the environment. It was not originally anticipated the OLFP modelling or subsequent survey would be of benefit to the operation of the wastewater system. However, the detailed maps of the OLFP that are now available to wastewater network managers are now assisting in the management of overflows.

Conclusion

LIDAR Survey, Modelling and GIS technologies can be used as important sustainability tools in the assessment and management of urban drainage networks. This has been demonstrated in the survey of OLFP in NSC.

OLFP's can and do impact on the way we live and are an integral part of Stormwater Catchment Areas. Runoff along OLFP's can flood the floors of residential dwellings and damage industrial properties. One of the main observations of the survey of OLFP in NSC was that where a public stormwater system is available, full reliance on that system had often allowed inappropriate development of sites often resulting in the flooding of property. The detailed OLFP maps now available to NSC staff will support better stormwater planning, design and urban design planning in general and reduce the incidence of this occurring. This is in turn will support more sustainable development in the City.

Overland flow paths in NSC have been heavily modified. The roading network is the single most significant Council asset type that impacts the overland flow paths. By using the OLFP model and mapping the locations where they cross roads or discharge from roads the "Spill Points" can be located across an urban or any other drainage network. Thus providing the opportunity to better plan roads in new subdivisions and investigate, designate and/or schedule works to mitigate the identified adverse affects from uncontrolled (and often unidentified) spill points.

There is considerable value in being able to assess and make decisions in the field using mobile data capture technologies. By "walking the catchment" in the case of the OLFP assessment, issues such as gully trap compliance, private drainage shortcomings, roof-water capture and disposal etc can be considered where they are often seen in isolation as a side-issue to a site visit. Not until the neighbourhood as a whole is assessed and compared can the scope of such concerns become evident.

The wide range of features that have been considered as part of the OLFP assessment would have been difficult to practically survey without the use of the modern mapping, data and digital tools. The collected information would have been cumbersome and difficult to practically analyse and represent to other parties. These new results can be used to benefit the community, supporting the delivery of sustainable outcomes through better planning process.

By mapping and presenting information in the Eview information gateway and potentially through a public web browser, detailed information about onsite drainage is available to the private landowner and professionals. This raises awareness and gives greater ownership to the wider community.