CALIBRATING AN EXISTING STORMWATER ASSET USING THE 2014 EVENT

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ABSTRACT

The establishment of flow gauging and monitoring sites in a stormwater network often requires the installation of new assets, for example, Parshall flumes, weirs, or calibrated culverts. In the majority of cases, this requires a capital budget for the installation of the structure, and results in a new potential obstruction to flow and a new asset that requires cleaning and maintenance. A straightforward and reliable technique for the calibration of existing structures would facilitate the creation of more gauging points in stormwater networks without the need to install new structures. During the 2013 construction season a Type VI USBR energy dissipation structure was established downstream of the Russell Crescent catchment, a 1.1km2 catchment on the side of Mt Ngongotaha. Using construction drawings, verified with structure from motion (SFM) photogrammetry techniques a 3 dimensional model of the outlet has been created and used to create a computation fluid dynamics (CFD) model. This model has been run for various flows and depth metrics taken from the model to establish a hydrograph set for the structure. Photographs of the structure and the downstream channel were taken during the August 2014 (3 - 4 year ARI) event providing sufficient calibration data to extrapolate the flows through the structure for comparison against the calculated hydrographs. This study outlined the techniques, algorithms and software packages used in the calibration of the Russell Crescent structure, thus providing a method for the calibration of existing structures of variable shape.

KEYWORDS

Computational Fluid Dynamics, CFD, structure calibration, structure from motion photogrammetry

PRESENTER PROFILE

Adam is a Principal Civil / Environmental Engineer with Sigma Consultants Ltd in Rotorua. Adam has more than 10 years post-graduate experience and has extensive hydraulic and hydrologic modeling experience, ranging from 1 dimensional overland flow and hydraulic modeling scenarios through to full 3 dimensional CFD models.

1 INTRODUCTION

Within the Central North Island and the Bay of Plenty, specifically within some of the more volcanic soils, there is a dearth of information on runoff values. This is not helped by a lack of monitoring points in the area, relative to some of the other areas in the country.

Monitoring points often require the establishment of one or more of the following:

- Parshall flumes
- Weirs

- Calibrated culverts

as well as the establishment of depth and / or monitoring equipment. In each case, this requires the establishment of a new asset within the stream which needs to be paid for, as well as maintained. It also requires the establishment of a new impediment to flow which can result in increased risk of blockage and resultant flooding within the drainage network.

Through most networks a number of roading culverts, bridges, energy dissipation devices and other structures could, with proper modeling and calibration be easily used as flow measurement devices.

The techniques used to calibrate the structure in this paper are computational fluid dynamics and structure from motion photogrammetry.

1.1 COMPUTATIONAL FLUID DYNAMICS

Computational Fluid Dynamics (CFD) is a modeling method that allows 1:1 scale fluids modeling in three dimensions. Provided a three dimensional model is created, a CFD model can be produced for most attainable flows and can provide information at a very high level of refinement. Computational Fluid Dynamics models can, therefore, be used to calibrate existing structures without the need for either flow testing or physical modeling of the structure.

1.2 STRUCTURE FROM MOTION PHOTOGRAMMETRY

The key in creating an accurate CFD model is the accurate creation of the fluid domain. In this an accurate three dimensional model is a key requirement. Methods of survey that have been readily available are:

- Tape and sketch
- Theodolite / land survey techniques
- Laser scanning

Recently advances in computer vision and modeling have created the ability for computers to be able to interpolate three dimensional point clouds, and by inference solids, from photographs, using only the parallax movement in the photographs. This technique, called structure from motion allows for the creation of fine grained three dimensional point clouds which simply need some scaling measurements taken to provide a 1:1 computer model.

2 CASE STUDY

The Gordon Road / Russel Crescent stormwater works were undertaken in 2013 / 2014. The upstream catchment forms part of the shoulders of Mount Ngongotaha, the dominant mountain in the Rotorua Caldera with an area of approximately 1.1km^2. The catchment is largely native bush and scrub, with the geology being generally recent volcanic soils (ashes, tephras and pumice sands). These catchments fall to a pond which forms a headwater over a stormwater inlet structure. This falls steeply to the outlet which forms the start of the Gordon Road stormwater works. Initial calculations, using the modified rational method indicated that the expected flows could be in the order of 7 - 8 cumec, through the 600 diameter stormwater pipe (in a 50 year event). This amount of flow and energy required the installation of an energy dissipation unit. A type VI USBR unit was designed by Sigma and installed as a part of the contract. The pipe longsection, catchment plan and outlet structure construction details are shown in Figures 1 2 and 3 respectively.

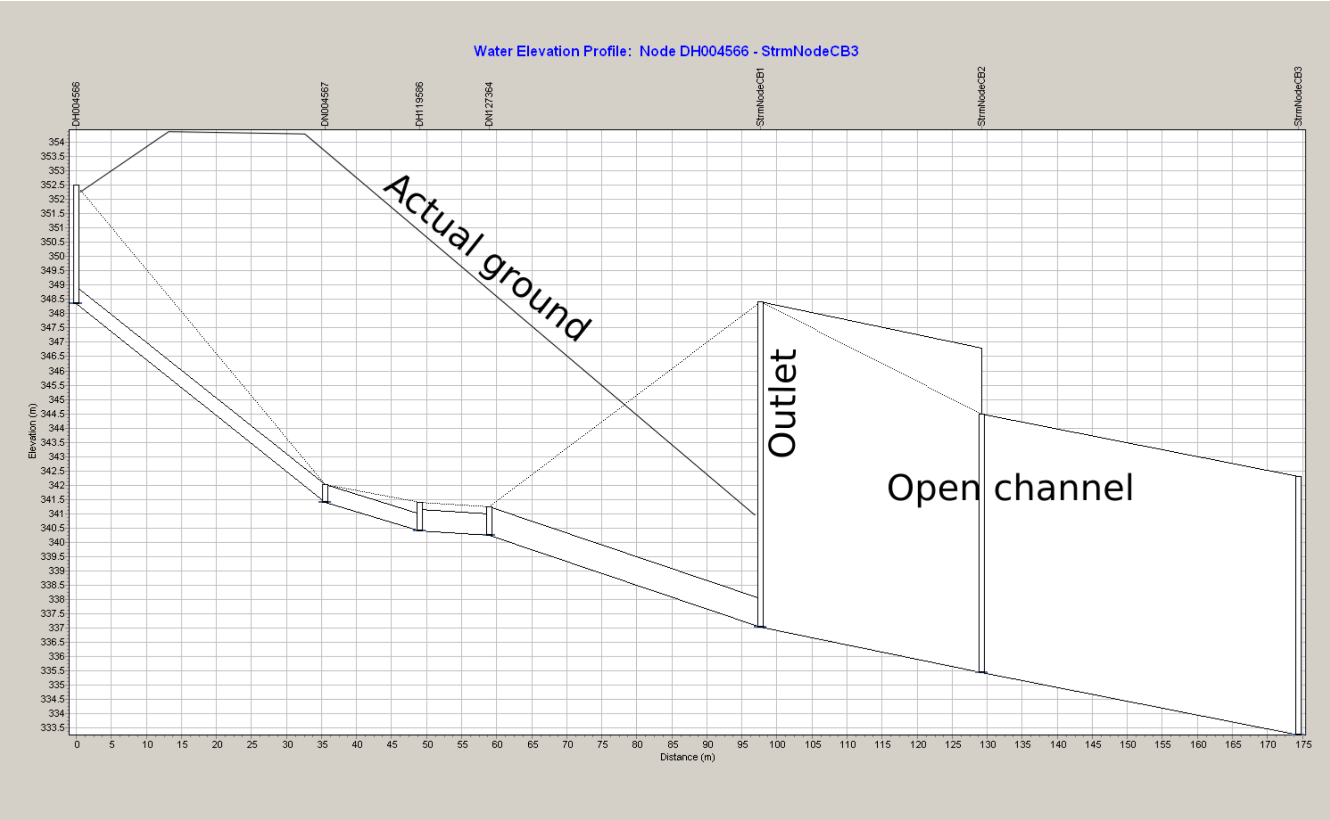

Figure 1: Upstream longsection

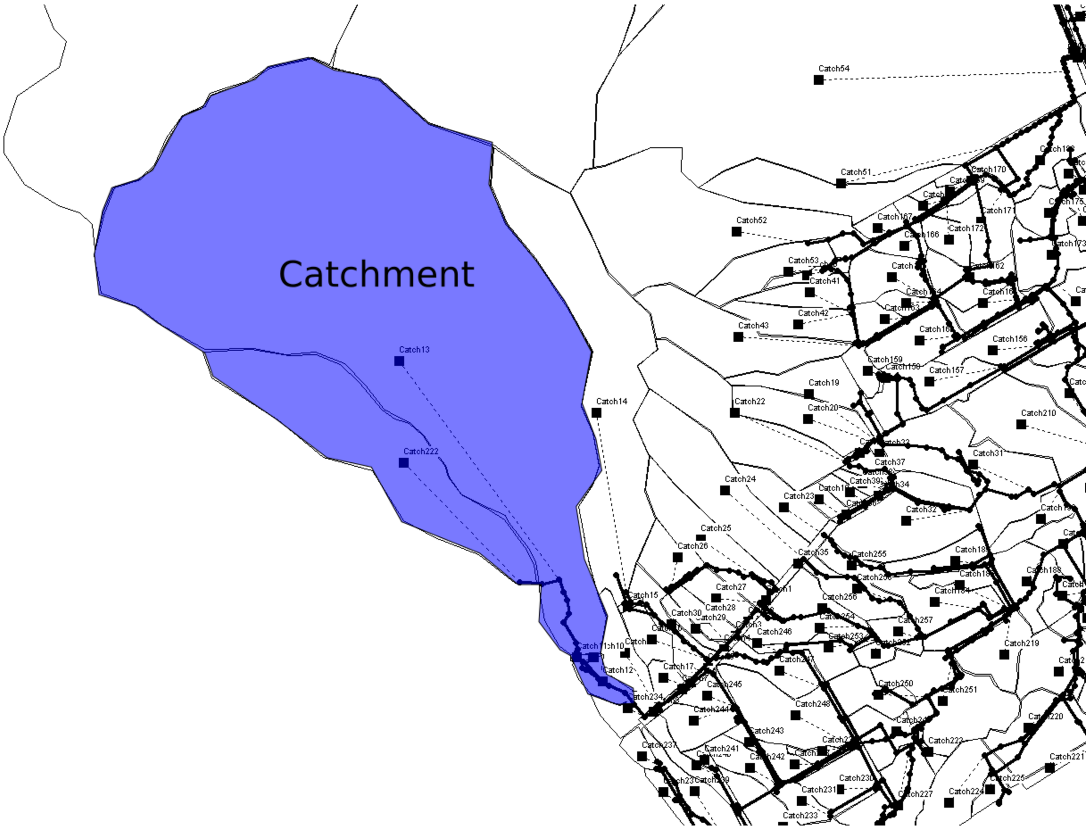

Figure 2: Upstream Catchment

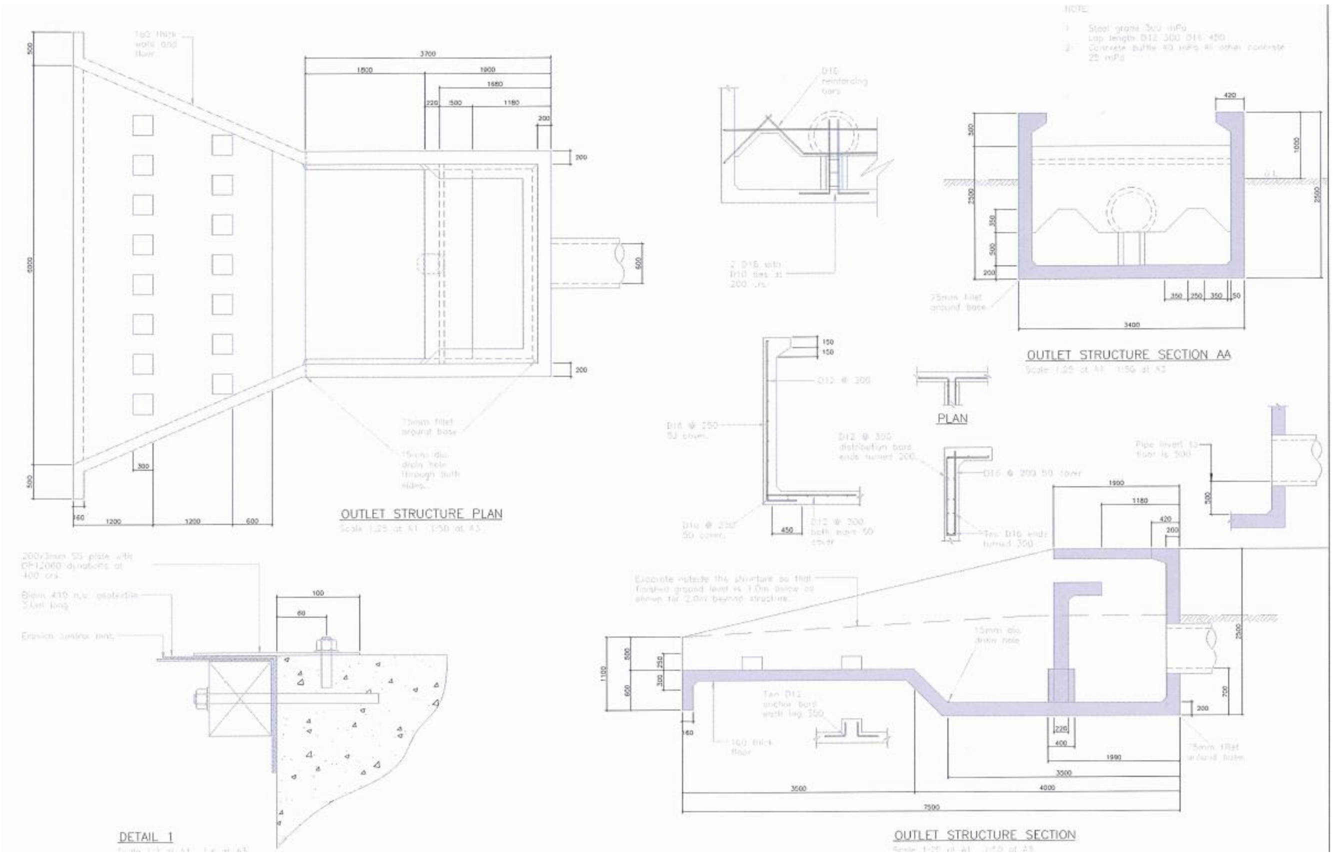

Figure 3: Outlet Structure construction plans

An approximately 3-4 year return period storm struck the Bay of Plenty region on the morning of August 20, 2014. During this storm period, Sigma Consultants representatives visited several sites of interest around the Rotorua area, including a visit to the Gordon Road energy dissipation structure. Photographs were taken of the structure during this period of moderate flow.

Figure 4: Outlet Structure during 5 year event

3 STRUCTURE FROM MOTION MODELLING

A short movie was taken of the structure and broken into its constituent frames. These were then imported into Visual SFM a structure from motion software by Changchang Wu. (Wu et al, 2011). A point cloud was generated from this dataset and is shown in Figure 5 below.

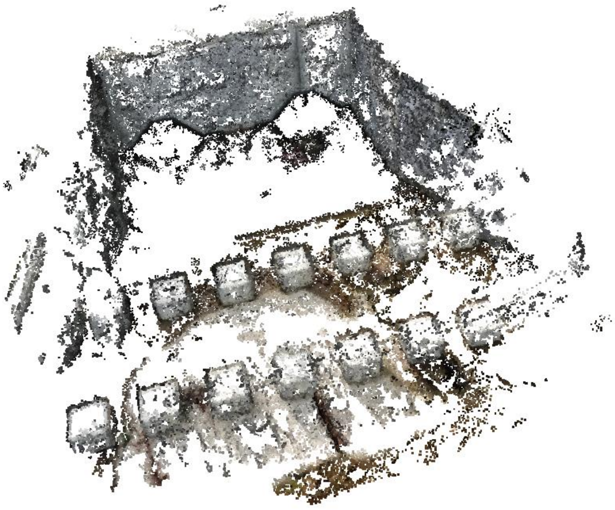

Figure 5: Point Cloud exported from VisualSFM

The point cloud was scaled to verify against CAD / CAM models that the structure had been built according to the plans. In this case, the construction plans were available, so the model was built from these originals. In the event that these were not available then a model would have been built from the volume enclosed in the point cloud.

Figures 6 below shows the three dimensional model of the structure.

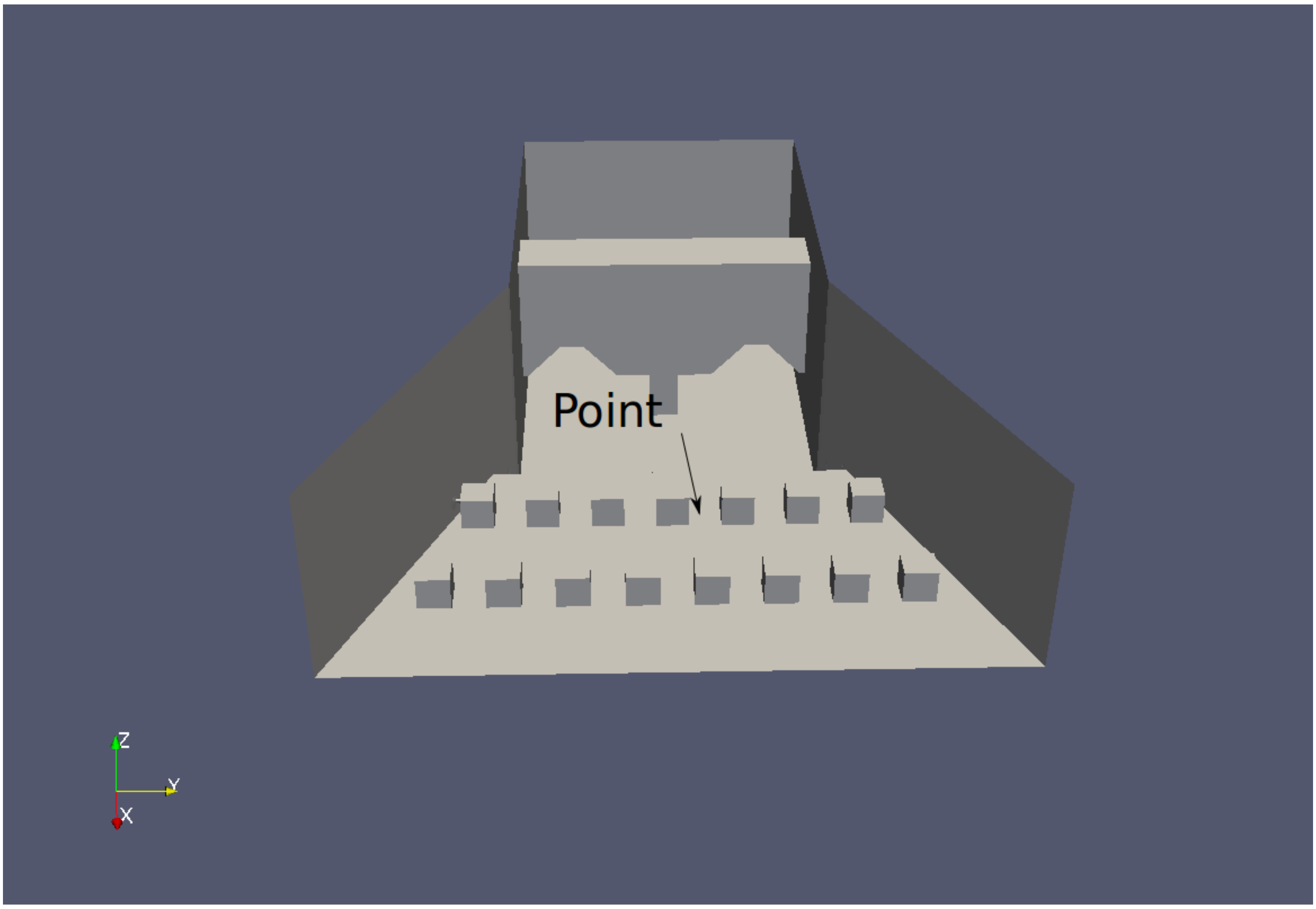

Figure 6: Outlet Structure model domain

These models were translated into a computational fluid dynamics domain.

4 CFD MODELLING

A free surface CFD model was run, using OpenFOAM 2.1 at various flows with water depths taken at the point shown in Figure 6. The model was constructed using the k-Omega turbulence modeling technique. The models were run on the Amazon EC2 cloud, using the 32 core 60 gigabyte instances (c3.8xlarge running CAELinux 2013).

Flow depths were plotted against the flow and produced the calibration graph below:

This graph can then be read to estimate the flow through the unit.

Assessing the photographs taken on August 2014, the approximate depth is 175 mm, giving an expected flow of 0.30 m^3/s.

5 COMPARISON OF FLOWS TO GIVE A SCS C VALUE

These photographs were taken at 14h00 on the 20th. The peak of the storm was at approximately 09h00. Taking the flows as being on the descending limb of the hyetograph, we can extrapolate that the SCS 'C' value for the catchment is approximately 30. If a longer record of the flows could be obtained, then a more accurate number could be obtained.

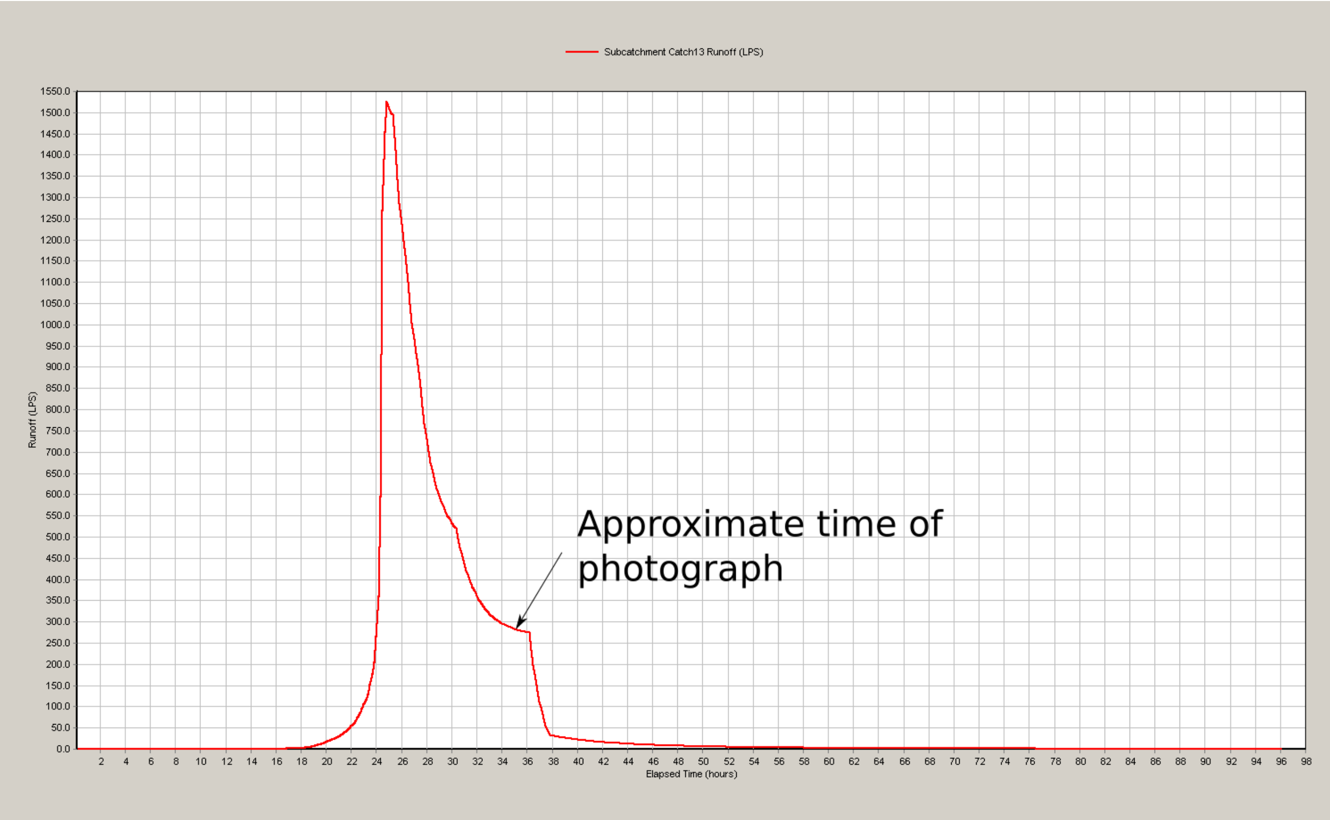

Figure 6: Outlet Structure model domain

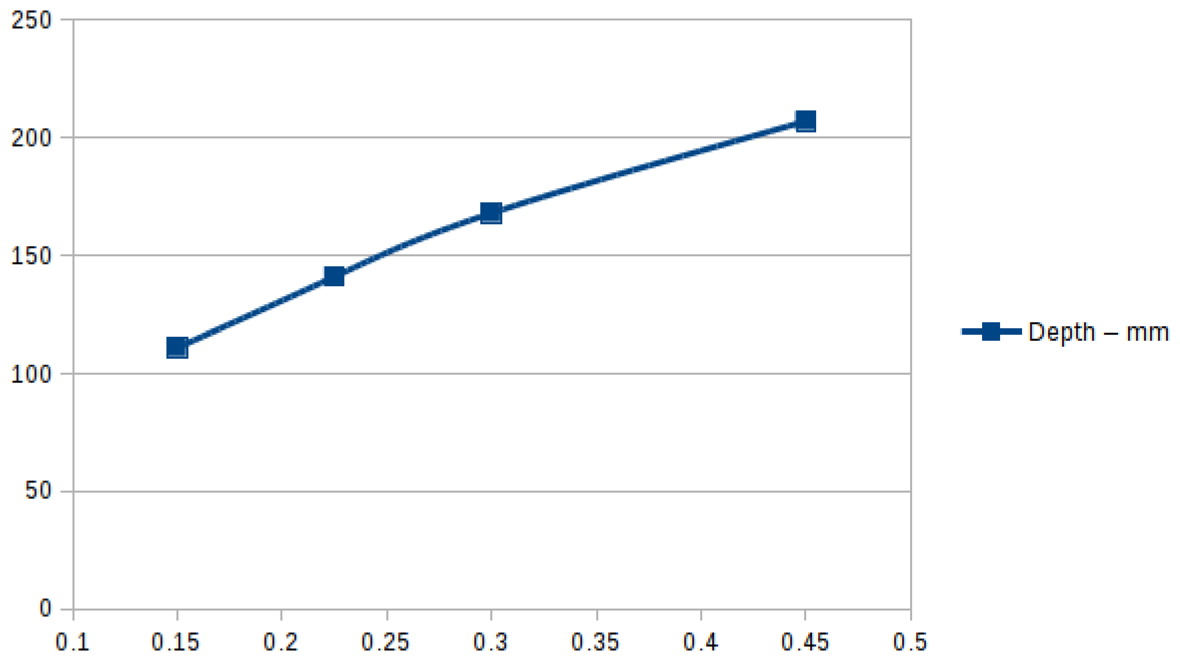

Figure 7: Depth – flow graph

6 RECOMMENDATIONS FOR FUTURE INSTALLATIONS

As outlined above, there is a significant dearth of flow information, particularly in the Rotorua Caldera. The calibration of existing structures could be achieved for a relatively modest cost. A simple camera / pair of cameras could be set up for a modest cost using off the shelf parts. These could be set up to record only when rainfall levels exceed a certain level. If more than 1 camera was set up and these timed to take simultaneous photographs then these photographs could be used in the structure from Motion software above to develop a water surface. This could easily be matched against three dimensional CFD models.

ACKNOWLEDGEMENTS

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