AVOIDING THE PITFALLS OF DYNAMIC HYDRAULIC CONDITIONS WITH REAL-TIME DATA

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ABSTRACT

Thames Water Utilities Limited (TWUL), together with the UK entities OFWAT, DEFRA, the UK Environment Agency and the Greater London Council, have embarked on the project of to improve water quality in the River Thames. In particular, the plan is to improve the quality of the river by examining the impact of storm flows on the receiving waters. To do this, it was decided that a program be undertaken to study the flows in the London sewers and CSOs that had direct impact on the river.

Although the project is more concerned with total flow volumes and the characteristic movement of these flows under external influences such as rain events, additional data has come to light. In particular, what was found is a series of sites that behave in a most irregular manner. The hydraulic regime of any given site is far from predictable. In fact, the hydraulics are so complicated, it is hard to see how a standard sewer flow model will be able to accurately predict the reaction of any given site to a series of either external (e.g., rainfall) or internal (e.g., local pumping conditions) influences. The data presented here show that by employing the data in a real-time mode, procedures can be set and implemented for further control and understanding of the sewer system.

KEY WORDS – flow, monitoring, real-time

INTRODUCTION

TWUL is currently developing the strategy for improving the quality of storm flows from large London CSOs that discharge into the Thames River tideway. To do so, detailed data relating to the nature and volume of the storm flows in the Trunk Sewers and Storm Sewers in London is required. To acquire the necessary data, TWUL commissioned a long term sewer flow survey, of which there are 18 initial monitoring locations. TWUL selected ADFM flow instruments from MGD Technologies Inc. for use upon the project.

The main objectives of the survey are:

- Provide flow data to +/- 2% accuracy every 24 hours

- To relate flow data to rainfall and Thames tide level
- Use these data to extend and verify the existing catchment models
- Combined use of monitored flow data and model to assess storage and screening options for the design requirements of the CSOs discharging to the River Thames
- Optimise design solutions to reduce cost and environmental impact
- Provide a data system which can be developed into a real time sewer management tool

The project is extremely ambitious. The key to obtaining good data for this wide range of parameters is accuracy under a wide range of hydraulic conditions. Varying performance will increase the variation in modelling results, leading to poor understanding of problem sites, improper estimations of capacity, and improper allocation of capital improvement funds.

PROJECT EQUIPMENT AND DATA RETRIEVAL

TWUL chose the ADFM because of its ability to operate accurately despite varying hydraulic conditions. The system is based on pulse-Doppler signal processing with range-gating. Figure 1 shows a typical installation for measuring open channel flow in a pipe. A transducer assembly is mounted on the invert of a pipe or channel. Piezoelectric ceramics emit short pulses along acoustic beams pointing in different directions. Echoes of these pulses are backscattered from material suspended in the flow. As this material has motion relative to the transducer, the echoes are Doppler shifted in frequency. Measurement of this frequency enables the calculation of the flow speed. A fifth ceramic mounted in the centre of the transducer assembly, and aimed vertically, is used to measure the depth.

For large sewers, it is likely that the flow velocity profile will vary for different flow conditions. Dealing with these can be addressed in several ways. The ADFM uses multiple, narrow acoustic beams and a range gating process to gather very precise measurement of the vertical and transverse distribution of flow velocities within small volumes known as depth cells. The velocity data from the measured profiles are entered into an algorithm to determine a mathematical description of the flow velocities throughout the entire cross-section of the flow – the Flow Profile. These results are integrated over the cross-sectional area to determine the discharge.

The key benefit to this technological approach, and why TWUL selected it, is that the system will operate accurately under different hydraulic conditions without site calibration. As hydraulic conditions change, the change will manifest itself in the distribution of velocity throughout the depth of flow. As the instrument is measuring the velocity distribution directly, it will adapt to the changes in hydraulics, and generate a flow pattern that is representative of the new hydraulic conditions, ensuring an accurate estimate of flow rate.

To retrieve the data on a regular basis, SIMNET (Sewer Information Management Network) was specified and installed. The previous day’s data is posted onto the TWUL data server at 10:00 a.m. each working day. The data set contains flow volume, flow velocity (averaged), and depth of sewer flow. Peak, average and minimum values for each parameter and totalled daily flow volume are tabulated for each parameter. Data collection is managed by OnSite’s parent South Staffordshire

Group Plc, at Walsall, using their OPUS telemetry system. The control room is manned 24-hours a day throughout the year and the operators receive alarms direct from the sites in London. Each instrument is currently automatically polled on an hourly basis and the OnSite database updated.

FLOW DATA RESULTS

The importance of being able to deal with varying flow conditions, by what ever means, was immediately illustrated by the flow data obtained. Figure 2 is a hydrograph of flow rate and depth at the Lupus Street Low Level Sewer (LL) site. This site is affected by Western Pumping Station. The hydrograph shows rapidly varying flow rates and depths due to the pump station influence. Figure 3 is a graph of the data from the 13th of May, a single day's worth of data showing three distinct events of a sudden rise in depth.

Aside from a time series, a scattergraphs of flow rate versus depth can be very informative as to the hydraulic conditions present at a site, as well as the quality of the data. Free flow conditions will reveal a set of points that follow a standard Manning type curve. A tight scatter curve, meaning the points heavily overlap each other, is created by two factors. The first is that the site flows within the same hydraulic regime at all times. The second factor is the measurement accuracy of the meter used. A meter that is not accurate in its flow measurement (measurement error on the order of 5-20% is typical for most other flow meters) will produce a great deal of artificial scatter. Measurement error will cause the scattergraph to appear random. The definitive example of this effect is the "shot-gun blast" pattern that is familiar to any data analyst.

Figure 4 is the scatter pattern for the single day's worth of data at the Lupus Street site. Although it is tempting to ascribe the term shot-gun blast as described above, clumps of data in certain places and apparent trends in others bears deeper examination. Figure 5 is the same data but with the filling and draining portions of the events on the hydrograph illuminated. It is clear that, as you work through the filling and draining cycles of the three events, the pipe does not have a single hydraulic regime under which it operates. In fact, the hydraulic regime is not only dependent on whether the pipe is in either the fill or drain cycle, but also what the initial conditions (depth, flow rate) were at the beginning of a particular cycle.

Figure 6 is the 13 May, 2002 scattergraph of the Grosvenor Road site for the Western Pumping Station. This is the same day as the Lupus Street site above, with evidence of the same three events. If we again highlight filling and draining portions of the hydraulic record, we see a similar result to the Lupus Street site as shown in Figure 7. The filling and draining portions of the curve always occupy different hydraulic regimes. In Figure 5, the pipe always fills "high" and drains "low", meaning the flow rates are higher on the filling end of the cycle. Figure 7 shows the opposite. The question is, is one tendency preferred over the other?

Figure 8 is an example from the North Western Storm Relief Sewer. This site tends to run dry or nearly dry until it is "needed". At that point, flows are routed through the site to relieve the main collection system during storm events. As seen in Figure 8, this site fills high and drains low. A number of events from this site were examined and all displayed the same characteristic. Figure 9 is from the Walham Green Storm

Relief Sewer, which displays the opposite characteristics – filling low and draining high. Another site, the Hammersmith Storm Relief Sewer, showed both trends, and varied as to when a given trend would appear.

CONCLUSIONS

Several observations have arisen from review of this data. The first is that when modelling systems with difficult sites, accurate data is critical. Accurate data can only be obtained by utilising proper field techniques, making intelligent site selections, and most importantly, selecting the proper technology for a given installation. Despite the nature of the sites reported here, the ADFM provided system data, with confidence and to the accuracy required for the engineering purposes that lay behind this project. The ADFM's ability to accurately measure flow rate in large dimension pipes and channels, without requiring extensive in-situ calibration, is crucial to obtaining the high quality data that is required.

A second observation is that although modelling can certainly solve overview problems, it is very difficult to use a model to accurately predict the behaviour of a single site. The data presented here clearly shows that sites will behave according to a number of variables, and the complexity of these variables would preclude a model from being able to accurately represent the changing flow rates through a site.

This brings us to out final observation, and that is the only way to truly see how a site behaves is by direct observation – in-situ flow monitoring. Real-time tie-in of flow meters and ancillary measurements to a central monitoring station is gaining more and more acceptance as the foremost way to monitor collection system status. The next step is to build, or utilise existing control structures within the system, and use the real-time data to maximise the performance of the system. Existing large sewers can be controlled with gates, for example, to increase storage capacity and prevent the over burdening of treatment plants. In order to do this properly, one must have reliable technology that is suited for the specific site in which it is installed. Real-time control demands the most accurate data possible. The intent is to take the initial monitoring system presented here, and create a truly real-time network.

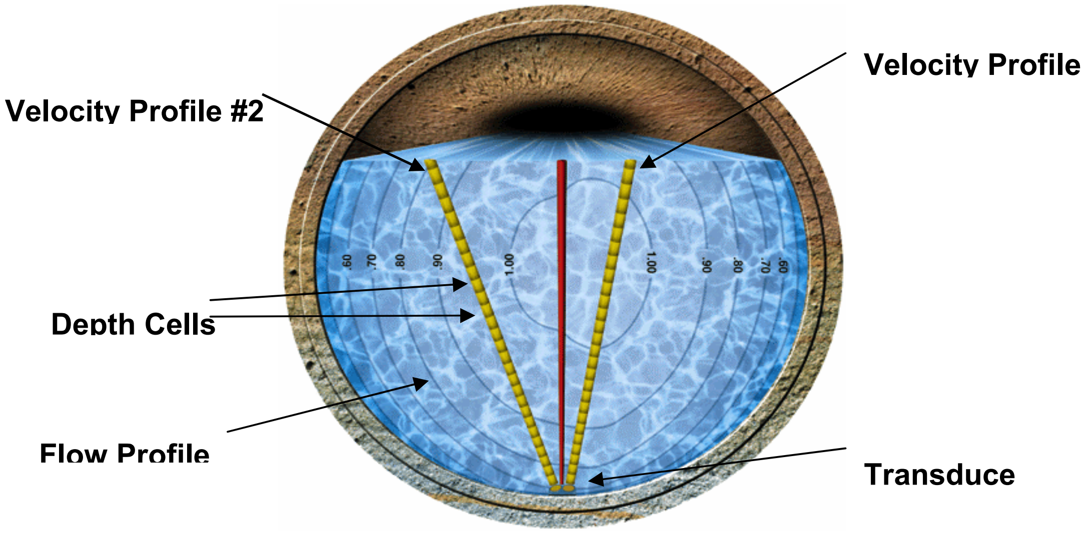

Figure 1 – Typical ADFM installation

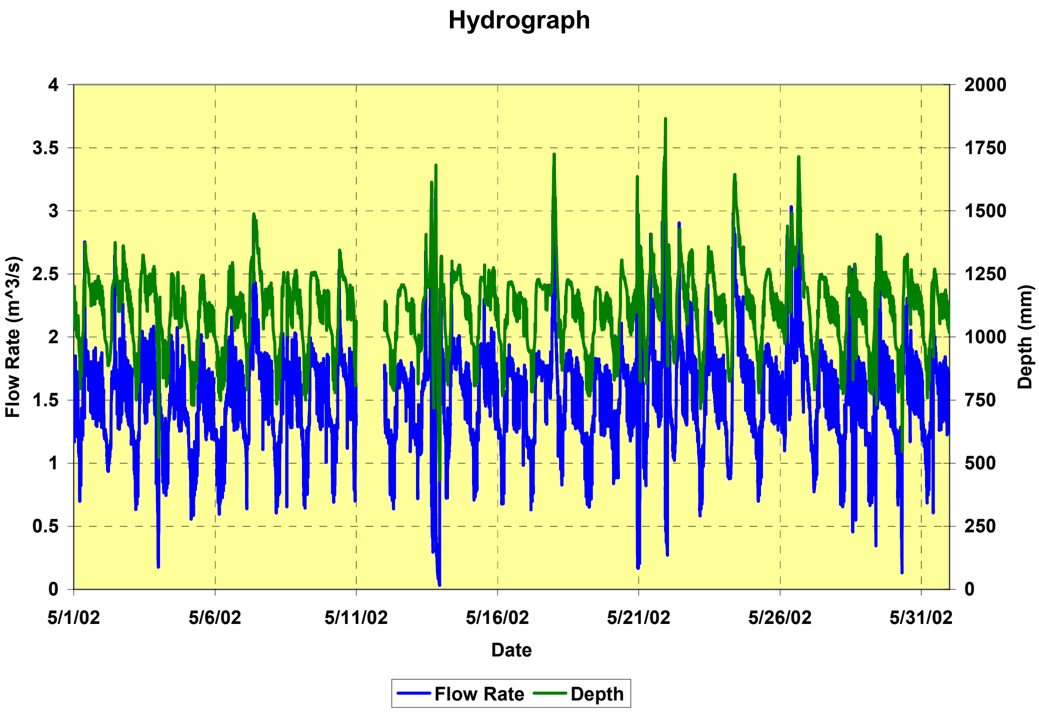

Figure 2 – Lupus Street site flow rate and depth data for the month of May

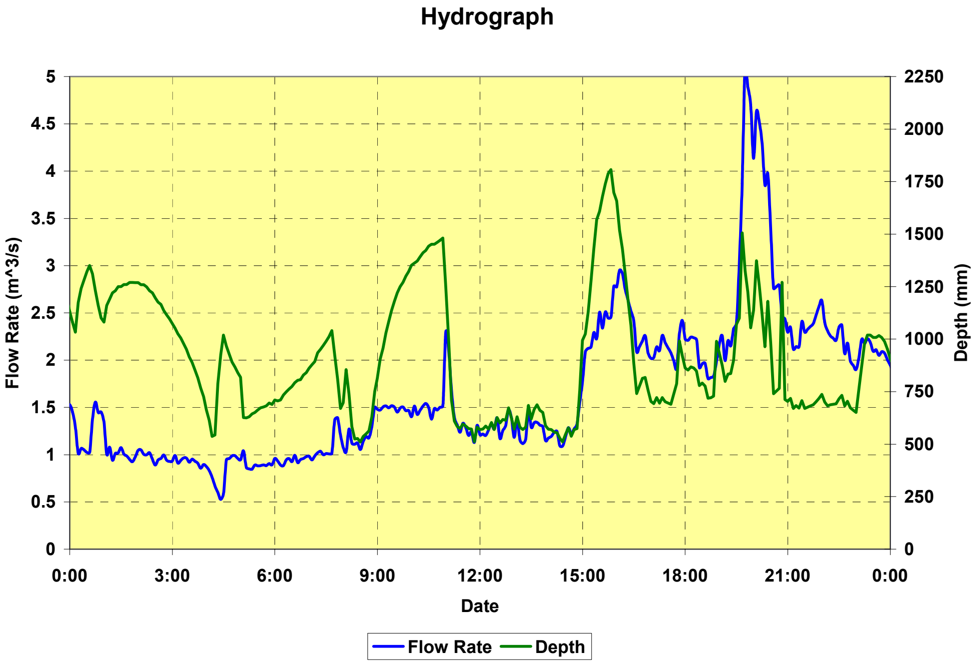

Figure 3 – Lupus Street site flow rate and depth data for 13 May 2002

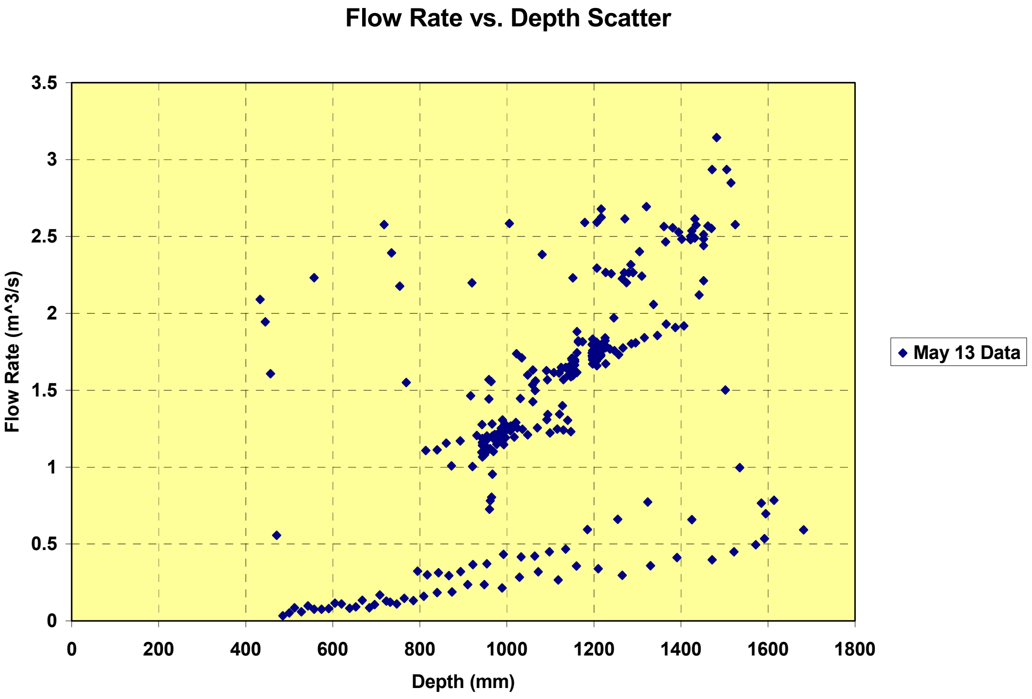

Figure 4 – Lupus Street flow rate and depth scatterplot for 13 May 2002

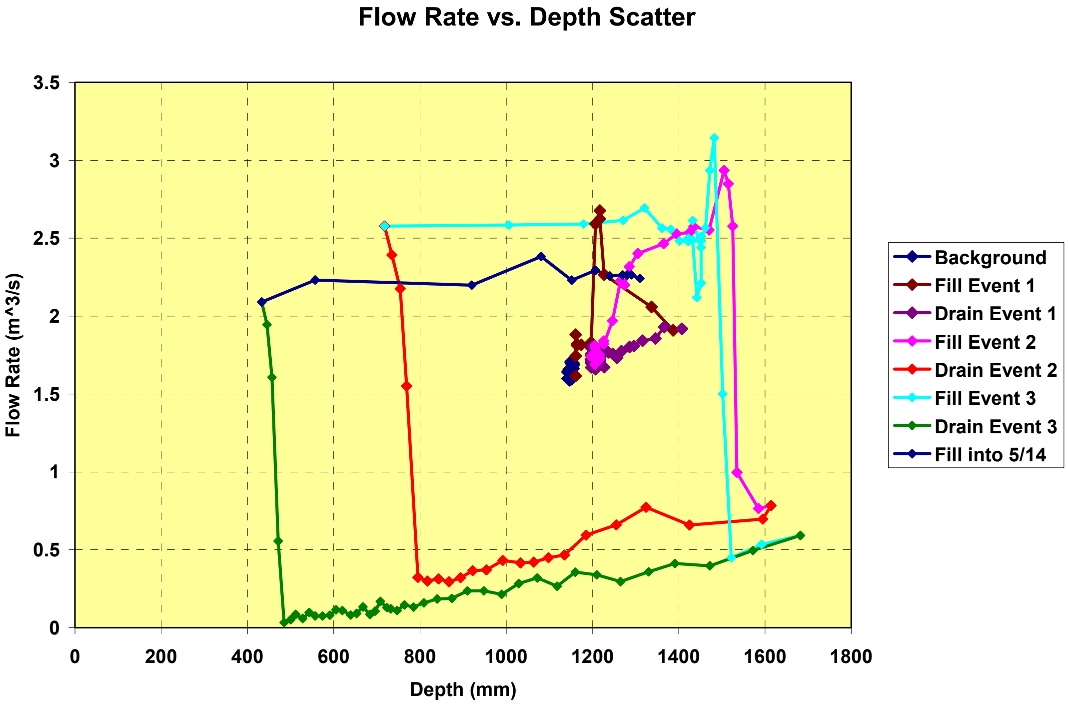

Figure 5 – 13 May 2002 scatterplot highlighting the fill and drain portions of the data

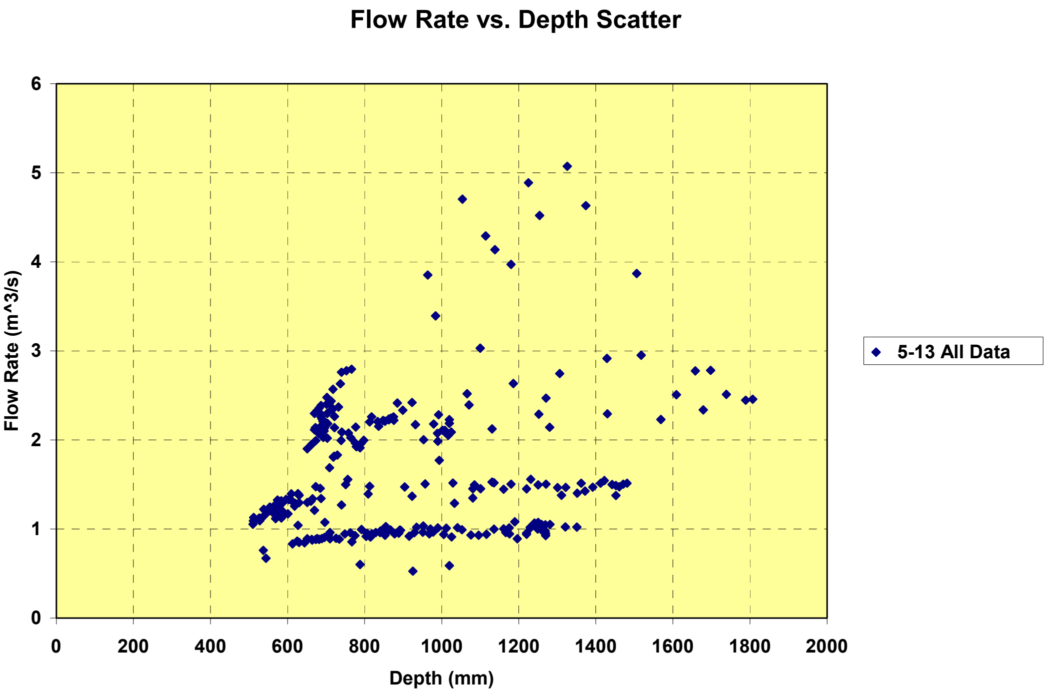

Figure 6 – Grosvenor Road scatterplot for 13 May 2002

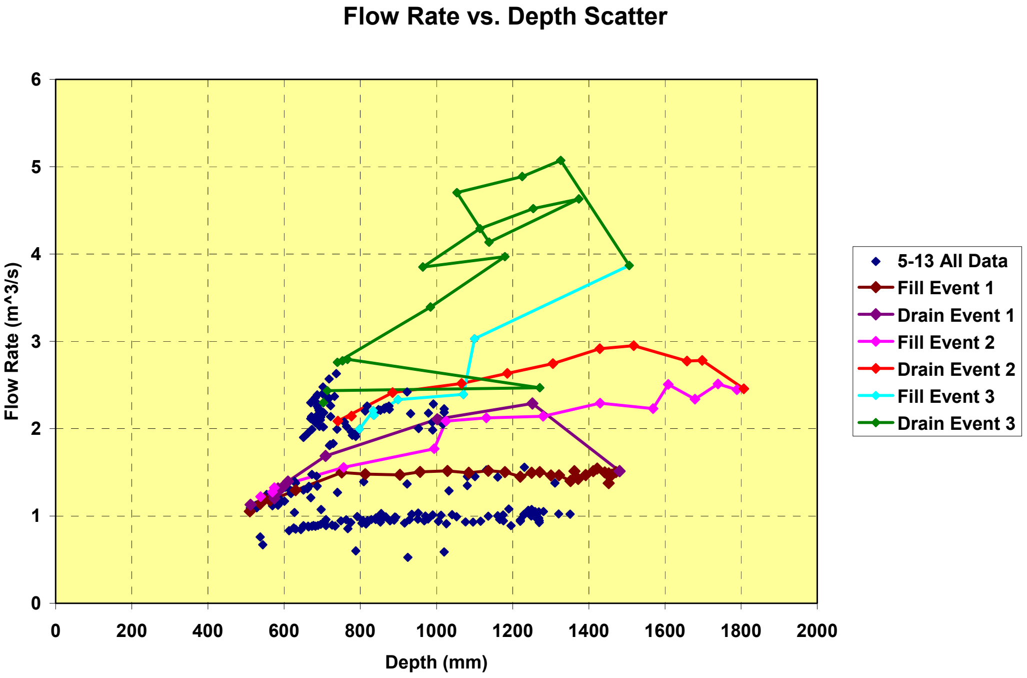

Figure 7 – Grosvenor Road scatterplot for 13 May 2002 highlighting the fill and drain portions of the record

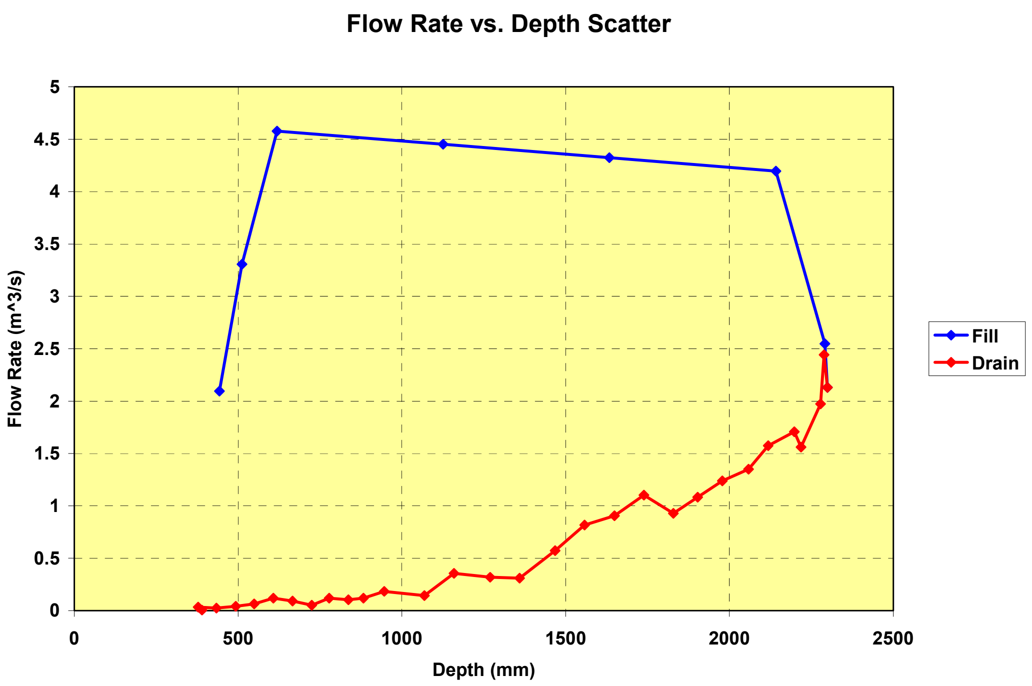

Figure 8 – North Western Storm Relief Sewer fill and drain cycle. This site fills at a faster pace than it drains.

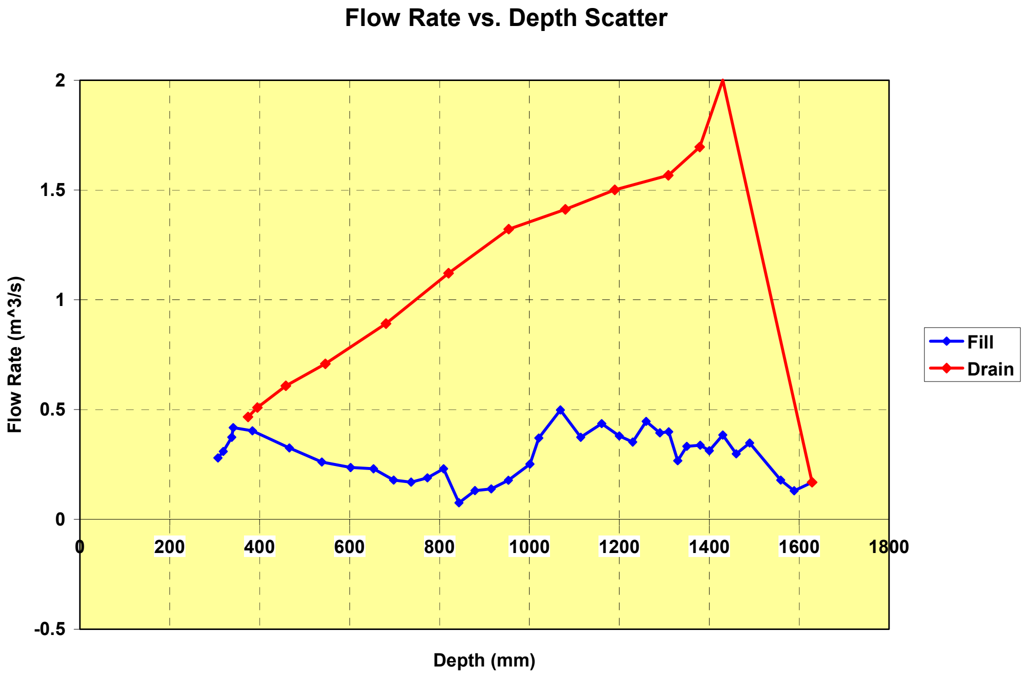

Figure 9 – Walham Green Storm Relief Sewer fill and drain cycle. This site drains at a faster pace than it fills, the opposite of the North Western SRS site