Maida Vale Flood Alleviation Scheme

tangential vortex drop and passive control to eliminate foul pumping station, incorporated in major project to eliminate property flooding

by Mark Cooper, Hannah Andrew, Stephen Riisnaes & Neil Marples

The Maida Vale area is served by three of the original 'Bazalgette' sewers all about 2m diameter and built in the late 19th century. These sewers are the Ranelagh and Mid Level 2 which run from west to east through the catchment along with the King Scholars Pond which runs from north to south. Whilst these sewers highlight the excellent quality of Victorian design and construction there are a number of areas where they now do not have the capacity to transfer the flows. This is as a result of additional flows brought about by increased permeable areas and changes in climate. The result is that around 200 basement properties predominantly within the shaded areas of Figure 1 *(below right)* now suffer from flooding during severe storm events. The eastern area is referred to as Westbourne Green and the west Tamplin Mews Garden.

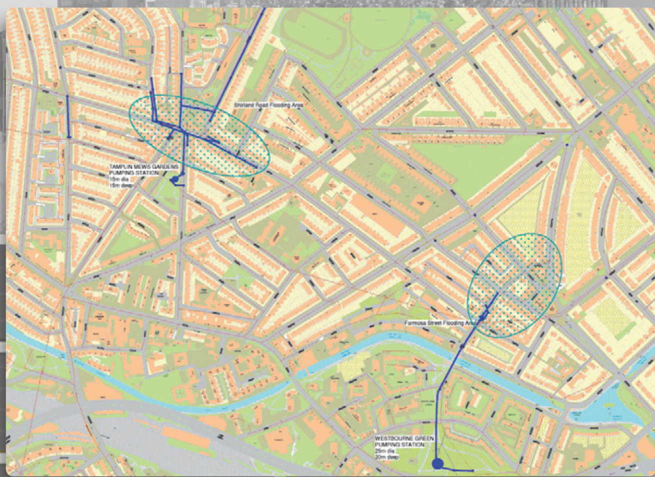

Figure 1: Flooding areas and proposed solutions - Courtesy of Optimise

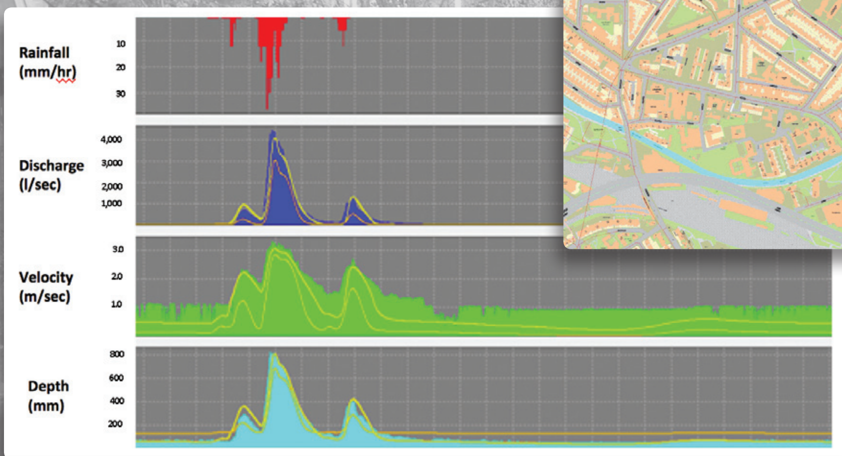

Figure 2: FM 09 Verification Plot - Courtesy of Optimise

Problem Understanding

To understand the problem and subsequently develop an appropriate solution the Beckton hydraulic model has been updated with catchment specific data, verified against existing flow surveys and permanently installed monitors. This has allowed the flooding mechanism to be understood. The graphs in Figure 2 *(above left)* show how the verification improved at a key location from the original data. The orange line represents the original model and the yellow line represents the updated verified model.

Solution Development

In June 2012 Optimise, a joint venture between designers MWH and construction partners Murphy's, Barhale and Clancy Docwra, received an instruction from Thames Water to resolve a flooding problem affecting around 200 properties in the Maida Vale area. The project value is £17.5m and has a demanding contractual deadline of March 2015. The demanding timescale meant that key tasks were run in parallel, including the problem understanding, hydraulic modelling and detailed design. This ensured that the Optimise partners had sufficient time to undertake the construction.

The verified model was a suitable tool for developing an efficient solution. When assessing various solutions it was apparent that upgrading the network was not an option as this would entail re-sewering for 13km across London to Abbey Mills pumping station. Additional storage capacity had to be provided and the required volume was reduced by transferring flows to areas and maximising the capacity of the overall network. There are two parts to the solution, which is currently under construction.

Tamplin Mews Garden

In the west flows in the flooding area are reduced by transferring them from the Ranelagh to the Mid Level 2 trunk sewer. A series of isolation sewers are then provided to disconnect the remaining "at risk" properties from the surcharging trunk sewers, taking all flows to a storage tank sited in the park at Tamplin Mews Garden. The storage tank is 15m diameter and 15m deep. Flows are then pumped back into the sewer network in a controlled manner.

Construction of the isolation sewers raised many problems particularly as the starting level for the sewers had to be lower than

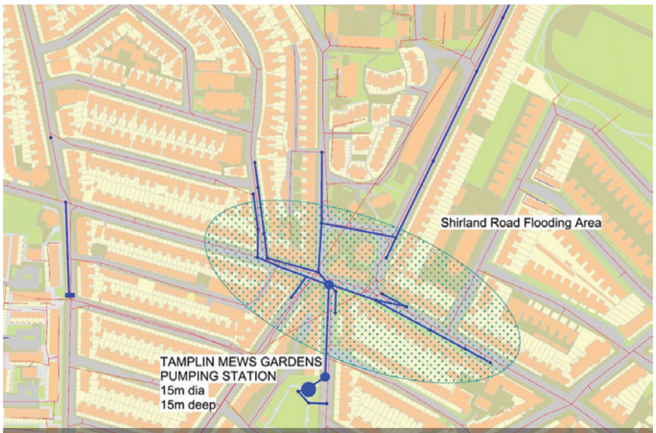

Figure 3: Tamplin Mews Solution - Courtesy of Optimise

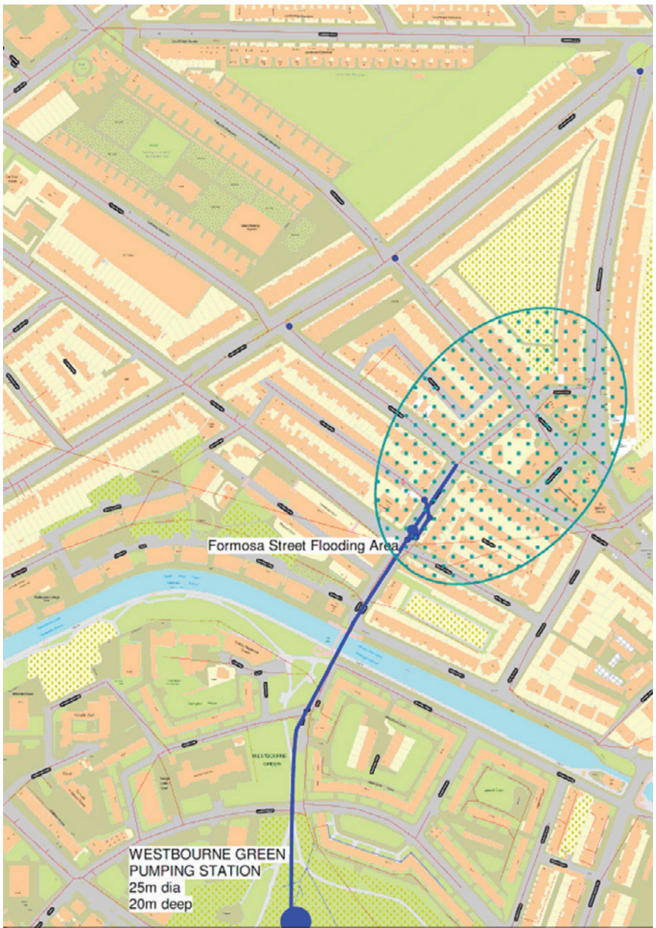

Figure 4: Westbourne green solution - Courtesy of Optimise

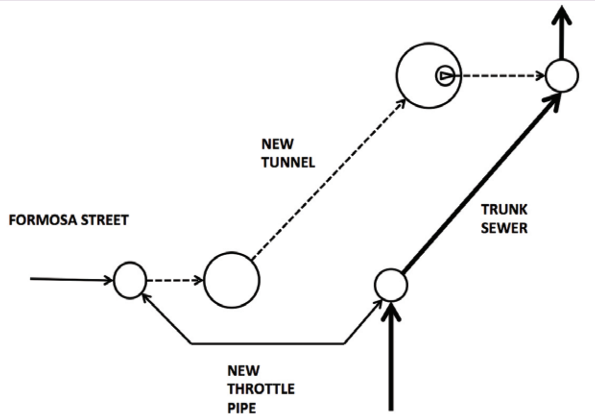

Figure 5: Flows controlled to network and storage tank - Courtesy Optimise

the basement connections, 3.5m below ground level. To pick up all the connection the isolation sewers have to be constructed in open cut and the design is based around a maximum depth of 6m, which is still particularly hazardous in a busy urban environment.

Westbourne Green

Adjusting existing weir settings allows flows entering the flooding area to be better managed by maximising available capacity in the adjacent network; however it is still necessary to provide over 7,000m^3 of storage and there is no available space in the flooding area for this. It is therefore necessary to transfer flows from the flooding area to a nearby park where there is available space to construct a 20m diameter shaft, 26m deep. The flows are transferred through 400m of 2.44m dia tunnel to the tank where it is stored and pumped back into the network in a dynamic manner, balancing the stored volume against the available capacity in the receiving network.

There were two parts to this solution that offered real challenges, these being; managing the flows to the storage tank and how to drop flows 18m below existing structures whilst in a very tight urban environment.

Managing flow to the storage tank

It was identified that a traditional approach of transferring and pumping back all flows from the flooding area would result in a total of 241,500m^3 of flow being pumped in a typical year, of which only 21,500m^3 is the storm flow which causes the flooding problem, the remainder being the continuous foul flow.

The benefits of not transferring the foul flow are significant. A standard approach for achieving this would be to have an activated penstock whereby flows continue to the existing network until a storm arrives at which point the penstock would close and all flows would be transferred to the tank. However this would require planning permission for a control kiosk in a sensitive area and it would always carry the risk that in the event of a power failure the penstock could remain open and properties would again suffer flooding, so the scheme would fail.

The trunk sewer network, developed by Bazalgette in the late 19th century, is complex with many deep large sewers. To understand the cause of the overall flooding problem it had been necessary to develop a very detailed hydraulic model. In addition to being able to understand the flooding problem and develop an appropriate solution, using the hydraulic model and specialist MWH software *'HADES'* provided the tool to look in more detail at the hydraulic characteristics of the network and to develop options that would reduce construction and operational risk.

Understanding these characteristics allowed the design team to identify what would happen if we simply allowed the foul sewer to continue to be connected to the existing trunk sewer that causes the flooding problem. Understanding that reverse flow would occur in extreme events, we were able to develop a design with a 'passive' control which would allow flow to pass in two directions, as shown in Figure 5 *(bottom left)*. In exceptional events reverse flow is passed to the storage tank.

The throttle pipe controlling the flow between the existing network and the tank is designed to be 200mm dia, which minimises the flow passed to the storm pumps; it is maintenance free and most importantly protects properties from flooding.

This approach eliminates the need for pumping the foul flow, a saving of 3,400 pump hours per annum. It has significantly reduced capital and operational costs and the approach can be reused particularly on other inner city projects where space is critical. It is though dependant on understanding the flows within the sewer network.

Dropping 3.8 cumecs of flow 18m

To transfer flow from the flooding area to the storage tank it is necessary to drop the flow 18m to be able to cross safely below the Ranelagh and Mid Level 2, the Bazelgette trunk sewers, and the Grand Union Canal. Because of the topography and layout of the area the drop shaft needed to be located in Formosa Street. This is a relatively small street in a residential area. It became evident at an early stage in the design progress that the standard means of dropping flow by this distance, the *'Ackers & Crump'* scroll vortex generator, would require a large construction area taking up the full width of the available highway with extensive service diversions.

At this stage, a literature review was undertaken by the designers to investigate possible alternative options for drop shaft designs. Although a number of different approaches have been used in various places, the main constraining factor at Formosa Street - limited space - generally proved to be prohibitive. The exception to this was the tangential vortex generator, a simple and compact design whereby flow is directed to enter the drop pipe tangentially, thus inducing a vortex.

However, unlike the scroll vortex generator, whose depth-discharge relationship is well known for a range of scales and geometries, the characteristics of the tangential vortex generator were less well-understood, and examples of their use were limited.

The water depth upstream of a tangential vortex intake is controlled either by the approach channel (or pipe) or the slot at the point where the intake meets the drop pipe. The hydraulic control point is determined by the flow. For small discharges, the water depth is controlled at the approach channel; the flow within the vortex generator itself being supercritical. For large discharges, the control is at the slot downstream of the vortex generator. Flow stability, which is crucial to the operation of the structure, depends on the geometry of the vortex generator.

Using a methodology introduced by *D Yu and J Lee* , a conceptual design was developed for the Formosa Street drop shaft. This methodology allows for a tangential vortex generator to be designed to comply with a number of geometry and flow conditions which, if met, should ensure stability of hydraulic operation.

Because of the lack of industry precedents for this design and a number of additional features specific to Formosa Street, including supercritical approach flow and limited available space, a scale physical model of the vortex generator and drop shaft was commissioned. This model, provided by Hydrotec Consultants Ltd, allowed the design to be verified and optimised further.

The use of this alternative approach enabled the following savings to be made:

- Reduction in drop shaft diameter from 7.5 to 6m.
- Elimination of need to provide a 2.4 x 1.4m culvert with a cascade as inlet.
- Two large gas and one water main diversions avoided.
- Large scale overpumping avoided.

Since completing the design of the Formosa Street drop shaft, which is currently under construction, the general design has been adopted and standardised by MWH. As part of this process, several further modifications are under investigation to improve the performance of the device.

The Maida vale project is half way through the construction phase and it is programmed to be fully commissioned by March 2015.

Future MWH designs will benefit from the development that has taken place on the project so the tangential drop and the means of controlling pump flows by means of a passive control will be used more frequently contributing to more efficient and cost effective solutions being developed.

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Formosa St location of vortex drop - Courtesy of Optimise