ABSTRACT

The aim of the “Valve Criticality” project undertaken by Thames Water Utilities, UK is to identify critical valves within the Company’s water supply network, in terms of their potential impact on the customer levels of service, either when they are shut or fail to shut, during planned or emergency work. The consequence of each valve operation can be measured in terms of the number of properties being disconnected or receiving an unacceptable level of service (e.g., low pressure). An additional benefit of the project is increased knowledge on the system operation, which will enable maintenance and replacement work to be prioritised to the most critical valves.

As it is not always obvious which valves are the most critical within a water supply network, the decision was taken to make the assessment using an all mains hydraulic model of each water pressure zone. However, with many thousands of valves to analyse, each requiring separate model runs, even a small zone could take over a week to analyse using conventional modelling software.

A decision was therefore taken to approach MWH Soft to enhance their InfoWater Protector modelling software to automate the process so that thousands of valves could be analysed in one batch of model runs. A careful specification of the output results was required to avoid vast quantities of data being produced.

Network trace techniques were used to identify each section of the network to be closed in, and the next available valve, should the targeted valve fail to close.

The InfoWater Valve Criticality Modeling (VCM) module was released to users on the 13th May, 2006, ahead of schedule. MWH Soft has now successfully provided Thames Water and all InfoWater users with the capability to assess the criticality of the many thousands of valves within major supply networks, enabling maintenance and replacement to be targeted to critical valves. The module will help Utilities
develop an optimal investment regarding infrastructure maintenance, minimising the impact on customer levels of service and improving knowledge on the operation of the network.

The tool is being developed alongside a risk assessment module, also using InfoWater that assesses the impact of valve operation on water quality within the network.

Keywords
Valve operation, maintenance optimization, customer levels of service, hydraulic modeling, asset management.

INTRODUCTION

The supply networks of a large water Utility such as Thames Water, will contain many thousands of valves whose operation are crucial to ensure that activities such as the day to day maintenance of the system, and the capability to respond to incidents, are carried out with a minimum of disruption to the customer. The impact on customers of operating some valves will be larger than others. It is probable that some valves are less likely to be operated successfully than others (e.g., due to age, accessibility, or location). The two main risk factors that determine the criticality of a valve are therefore based on probability and consequence.

The aim of the “Valve Criticality” project current being undertaken by Thames Water Utilities, UK is to identify the most critical valves within the Company’s water supply network, both in terms of the probability and consequence of their operation. The consequence of each valve operation can be measured in terms of the number of properties disconnected or receiving an unacceptable level of service.

Identifying the most critical valves is not always obvious. Some large valves may have less of a customer impact when closed than key smaller valves that are a major feed to an area. On some occasions if a small valve cannot be shut tight to isolate a section of main, the next valve back may have a much larger impact on customers. To make an objective assessment of the consequence of operating a valve or its failure to operate successfully, the decision was taken to use an all mains hydraulic model of each water pressure zone to identify the key valves within each zone. However, with many thousands of valves to assess, each requiring separate model runs, a pilot assessment showed that even a small zone could take over a week to analyse using conventional modeling software.

A decision was therefore taken to approach MWH Soft to enhance their InfoWater Protector modeling software to automate the process so that thousands of valves could be analyzed in one batch of model runs. The powerful network trace techniques available in InfoWater were used to identify each section of the network to be closed in, and the next available valves, should the targeted valve fail to close.

A careful specification of the output results was required to avoid vast quantities of output data being produced from the numerous batch runs. The InfoWater Valve Criticality Modeling (VCM) module provides extensive output options for listing, viewing and evaluating the results of a valve criticality analysis. Users can view, search and sort results from multiple assessments, in order to identify the most critical valves. Affected elements can be color-coded in Map Display to assist understanding the impact of valve closures and identifying areas of the network that will suffer unacceptable levels of service.
METHODOLOGY

The InfoWater VCM module assesses the consequence of valve operation, in terms of the total customers and types of customers affected, and also the consequence of the failure of an individual valve to operate, requiring valves further back to be operated.

Each valve (called the assessed valve – see Figure 1) will form part of set of valves that are required to close a section of the network in an emergency or for maintenance. This isolated section of the network is called a pound (impounded section). If, however, the assessed valve fails to operate or close, then a further section of the network will need to be closed off on the other side of the valve, generating a second pound.

The upstream and downstream pounds shown in Figure 1 indicate the two sections of the network that could be isolated by the operation of the assessed valve in conjunction with other nearest valves, assuming that the assessed valve functions properly. If the assessed valve fails to operate or close properly then the combined pound represents the minimum area of the network that has to be isolated (assuming all other valves function properly).

The consequence of needing to isolate a section of the network (or pound) is that customers within the isolated section of the network will clearly be without water. Customers on dead ends solely supplied by the pound (see Figure 1) will also be isolated. These customers can be identified from a simple GIS trace. However, customers outside the pound that experience low pressure or loss of supply can only be determined by hydraulic modeling.

To assess the customer demand affected it is necessary to simulate the hydraulic performance of the network. InfoWater VCM does this by identifying the valves to be closed, isolating the disconnected network, and running the remaining network in the hydraulic model.

InfoWater VCM is designed to assess multiple valves in a network, enabling Utilities to rapidly evaluate entire water supply systems in one simple batch run. Valve criticality assessments rely on detailed All Mains and/or All Valve network models. In order to generate an accurate assessment the network model should contain all mains and all line valves (gate valves).

InfoWater VCM employs a number of terms in the criticality assessment. These terms are shown schematically in the typical model example (see Figure 1) and defined below.
Assessed Valve

The valve selected for criticality assessment. In InfoWater VCM these can be both Valve and Junction Elements.

Closeable Elements

Elements that can be used to isolate sections of the network. In InfoWater VCM these can be Pipe, Valve or Pump Elements

Pound

In InfoWater VCM, a Pound describes the modeled links and nodes isolated (or impounded) by closure of the closest valves (or closeable elements) to the valve being assessed.

NOTE: The Upstream Pound, Downstream Pound and Combined Pound are shown in Figure 1 by a boundary box drawn around the elements in each pound. In reality a pound has no geographic area and merely represents a collection of network elements.

The three pounds are assessed for each valve. These are the Upstream Pound, Downstream Pound and Combined Pound.

Figure 1. An illustration of the terms used in Valve Criticality Modeling
**Upstream Pound**

The Upstream Pound is the pound containing the upstream pipe connected to the assessed valve. In a GIS there is no distinction between upstream and downstream for a typical line valve (gate valve). However, in InfoWater every valve has a direction, determined by the digitized direction of the incoming and outgoing link. Hence it is possible to identify the upstream link for every modeled valve.

In practice the direction of flow is unimportant, but upstream and downstream valve connectivity in InfoWater is used to identify which pounds have been evaluated during the criticality assessment.

**Downstream Pound**

The Downstream Pound is the pound containing the link connected to the downstream side of the valve being assessed.

**Combined Pound**

The Combined Pound comprises both the Upstream and Downstream Pounds. It represents the pound that would be formed if the assessed valve were inoperable.

**Isolated Junctions**

Junctions are isolated by the formation of a pound and by geographical or hydraulic disconnection.

NOTE: InfoWater VCM will report unsatisfied demand for all Isolated Junction Elements. Isolated Junctions do not contribute to the total System Demand for the network.

**Low Pressure Junctions**

Junctions that have a predicted pressure less than the Low Pressure Threshold but above the No Water Threshold. Typically the Low Pressure Threshold would be the minimum level for pressure set by “levels of service” regulations.

**No Water Junctions**

All hydraulically connected junctions that have a predicted pressure less than the No Water Threshold. In practice, the No Water Threshold is the pressure at which customers are assumed to be unable to receive water at the tap. This may be greater than zero pressure in the mains due to the height of a customer’s internal tank or fittings.

NOTE: InfoWater VCM is designed to report affected demand for Junction Elements with pressure below the Low Pressure or No Water Threshold. It does not evaluate pressure dependent supply to such Elements. Hence, Low Pressure or No Water Junctions continue to contribute to the total System Demand for the network.

**Affected Demand**

The sum of instantaneous demands in each of the three hydraulic consequences: Isolated, Low Pressure and No Water expressed as gpm (or liters/second).
Instantaneous Demand is determined by:
{(DEMAND1 x PATTERN1) + (DEMAND2 x PATTERN2) +…+ (DEMAND10 x PATTERN10)} x GLOBAL MULTIPLIER
for the selected simulation time.

**Affected Category Demand**

The sum of base demands for each InfoWater demand category (i.e. DEMAND1 through DEMAND10) expressed in the user’s defined units for each demand category. This enables the impact on various types of users (e.g. domestic, hospitals, etc.) to be analyzed if they are listed as a specific demand category.

Affected Category Demand is reported for each of the three hydraulic consequences: Isolated, Low Pressure and No Water.

**OUTPUT REPORTING**

The InfoWater Valve Criticality Modeling Reports menu provides multiple options for listing, viewing and evaluating the results of a InfoWater VCM analysis. Users can view, search and sort results from multiple assessments, in order to identify the most critical valves. Affected elements can be color-coded in InfoWater to assist understanding the impact of valve closures and identify areas of the network that will suffer unacceptable levels of service.

The dialog box shown in Figure 2 appears when the InfoWater VCM module is launched. Figure 3 illustrates a typical summary report output showing the total demand of areas affected by isolation, low pressure, and no water for valve combined pounds.

In Figure 4 the number of domestic properties isolated, affected by low pressure, and no water are listed for each valve closure. This can be viewed when the number of properties are used as the base unit of domestic demand.

Figure 5 shows the estimated area of the network likely to receive no water due a specific valve operation. Note when large numbers of no water are generated it is likely that the actual performance of the network may vary as pipes are no longer full. However, the VCM module still gives a good indication of the impact relative to other valves for the criticality assessment.

As well as the ability to view the results interactively and graphically, users can also save the results of specific runs to view them at a later date. The summary lists can also be easily downloaded into Excel for further processing.
Figure 2. Launching a run of the InfoWater VCM module
Figure 3. A typical summary output report

Figure 4. Output report sorted by domestic properties without water
SUMMARY

The InfoWater Valve Criticality Modeling (VCM) module was released to users on the 13th May, 2006, ahead of schedule. MWH Soft has now successfully provided Thames Water and all InfoWater users with the capability to assess the criticality of the many thousands of valves within their major supply networks, enabling water Utilities to automatically carry out a wide ranging assessment of the resulting hydraulic impact of valve operations on customer service levels. This information greatly improves knowledge allowing Utilities to optimize future expenditure on maintaining the serviceability of key infrastructure assets.