Brown Hill Keswick Creek STORMWATER PROJECT

APPENDIX 7

MIKE-Flood model technical summary

Background on Brown Hill and Keswick Creek Floodplain Modelling Process

Comparison of One and Two-dimensional Modelling Approaches

In general, one-dimensional models are applicable when flow paths are well defined and the length of the flow path in one direction is much greater than the width. This is typically the case for long lengths of channels and rivers with well defined floodplains or river systems with steep longitudinal grades.

Two-dimensional models are applicable when flow paths are poorly defined (typically in areas with flat terrain), the floodplain width and stream length are of similar magnitude or the hydraulic details of the direction of flood flows across a floodplain are of interest.

Another other main distinction between one and a two-dimensional modeling is the definition of hydraulic structures such as weirs and culverts. These are more commonly implemented in a one-dimensional context, however these can generally be nested within either a one or two-dimensional model and hence should not greatly affect the selection of which approach is most appropriate for a given application.

For higher accuracy and greater spatial extents, a fully two dimensional model will be appropriate. However this will in turn increase run times, data processing time and data storage requirements. Conversely if less accuracy is needed and faster run times are appropriate, a one-dimensional approach will be better. The table that follows provides a summary of 2D vs 1D model characteristics

Hydraulic Model Characteristics

Model Type	Features	Requirements/Characteristics
One-dimensional model	• Series of linked channels with discrete cross-sections at regular intervals (eg 100 - 1000m) • Output at each cross-section can include average water level, depth and velocity.	• Cross-sections input to model, based on field survey or DTM • Time consuming to build - quick to modify • Quick to run (minutes – hours) • Result files are relatively small (MBs) • Requires more interpolation and interpretation of results
Two-dimensional model	• Regular grid-based topography with cell sizes typically ranging from 10 – 100 m • Output at each grid cell can include water level, depth and velocity	• Requires detailed grid to be interpolated from aerial and/or field survey based DTM • Time consuming to build, not a easy to modify as in 1-d • Relatively slow to run (hours to days) • Result files are relatively large (100‟s MB per simulation) • Less interpolation of results required and more easily linked to GIS

MIKE Flood

MIKE-Flood has been used for the floodplain modelling in Brown Hill and Keswick Creeks.

MIKE-Flood is an integrated 1-dimensional/2-dimensional software package developed by DHI Software in Denmark. This package enables control structures such as bridges and culverts to be included in the 2-dimensional model, which facilitates more accurate modelling, particularly for smaller flows.

DHI"s MIKE suite of models are well recognised "industry standard" models. They are used worldwide and by many companies in Australia.

MIKE-Flood couples together two other DHI Software products – MIKE-11 and MIKE-21.

- MIKE-11 is a quasi-1-dimensional unsteady flow modelling tool that has been used in the Brown Hill Keswick Creek catchment to model the flow in the channel sections and in the closed conduits deemed to affect the hydraulics of the floodplain. The channels and conduits are linked to MIKE-21 by the MIKE-Flood Software.
- MIKE-21 is a 2-dimensional modelling system for free surface flows where stratification can be neglected. It was initially developed for the simulation of hydraulic and related phenomena in lakes, estuaries, bays, coastal areas and seas. It has been developed and improved through the experience gained from applications both overseas and in Australia. The software simulates the variation in water level and flow on a rectangular grid covering the area of interest when provided with topographic data, ground surface resistance coefficients and hydrographic boundary conditions.

Evolution of the current MIKE Flood model

Entura (formerly Hydro Tasmania Consulting) has been involved in hydraulic modelling of the Brownhill and Keswick Creeks and their floodplains since the year 2000. The original modelling was carried out using a beta version of DHI"s MIKE Flood software. The original models were essentially MIKE 21 (two-dimensional) hydraulic models with nine key culverts included. The creek channels within the model were modelled in MIKE 21 and no cross sections were included.

A 1984 study by WBCM provided cross section information and culvert/bridge details for each of Brownhill, Keswick, Parklands and Glen Osmond Creeks. During the 2003 study, significant work went into the representation of the channel system and culverts within the MIKE 21 model. This included filed verification of the cross sections and culvert/bridge details. From these cross sections, a HEC-RAS model was built that was used to assess channel capacities. The MIKE-Flood model channels were checked against the HEC-RAS model to ensure that that the capacity of the creek channels represented in the MIKE 21 was reasonable.

At the time, the method adopted was the best available method for defining the flood inundation extents for Brownhill and Keswick Creeks. This approach is often still used today.

Entura was again engaged to carry out hydraulic modelling of the floodplain for the 2006 study. In the years since the original study, the MIKE-Flood software had evolved into a truly integrated 1D/2D hydraulic modelling package. MIKE-11 cross sections are embedded in the MIKE-21 grid and the links between the two models are controlled by the MIKE-Flood software.

For the 2006 study, the HEC-RAS cross sections that were developed for the 2003 study were again verified then transferred into a MIKE-11 model of the four creeks. The extent of the cross sections stops at the top of bank, where the cross section is linked to the MIKE-21 grid. Some 120 culverts and bridges were also incorporated into the MIKE-11 model.

Current Model Setup

The current MIKE-Flood model is based on the 2006 model and incorporates the full dynamic linkages between MIKE 11 and MIKE 21.

There are some 120 culverts included in the model and 350 channel cross sections (in addition to the culverts sections) represented in the MIKE 11 component of the model.

The floodplain is represented by 5 m grid. The selection of the grid size involves a trade off in model run time and accuracy. The smaller the grid the more accurate but the longer the run times. The final model was completed in two adjoining and overlapping parts - the Upper Brown Hill model consisting of 330,000 cells and the much larger Brown Hill - Keswick model that was made up of 2.2 million cells.

Dynamics of the MIKE 11 and MIKE 21 interface

There are different types of links within MIKE Flood that can be used to couple the MIKE 11 and MIKE 21 hydrodynamic models.

The Brownhill Keswick MIKE FLOOD model utilizes lateral links to facilitate flow between the MIKE 11 channels and MIKE 21 floodplain. A string of MIKE 21 grid cells are laterally linked to a section of a branch or an entire branch in MIKE 11. The lateral link allows transfer of flow between MIKE 11 h points (where water levels are calculated in the MIKE 11 model) and MIKE 21 grid cells. Refer to Figures 1 and 2 for a schematic of this process.

Flow through the lateral link between MIKE 11 and MIKE 21 is through a model boundary which is typically defined using a weir formula with a crest level determined by MIKE 21 grid cell levels, MIKE 11 cross-section markers (or a combination of highest levels from both) or from an external file. The boundary can also be defined a level/depth table in external file or as a headloss based on velocity head.

The model boundary weir formula approach has been used for all links in the Brown Hill Keswick Creek model. The parameters required to define a weir link include:

- Weir Type: Defines the type of weir formula used.
- Source: Determine the definition of the weir crest as described above.
- Depth tolerance: This parameter is used to smooth out the transition when the flow over the lateral link changes direction and model instability may occur if suppression is not applied to the model.
- Weir C: Discharge coefficient adopted for the weir.
- Manning"s n: Roughness value adopted for the weir.

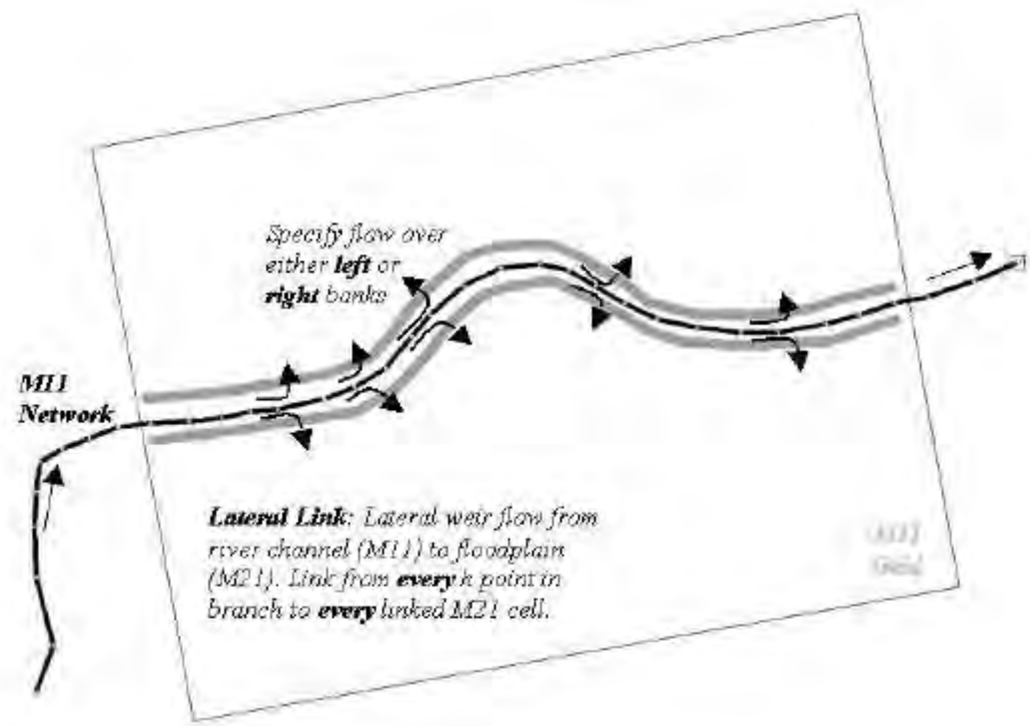

Figure 1: MIKE FLOOD 1D-2D Modelling Schematic (Source Fig 2.2 user Manual, DHI 2009).

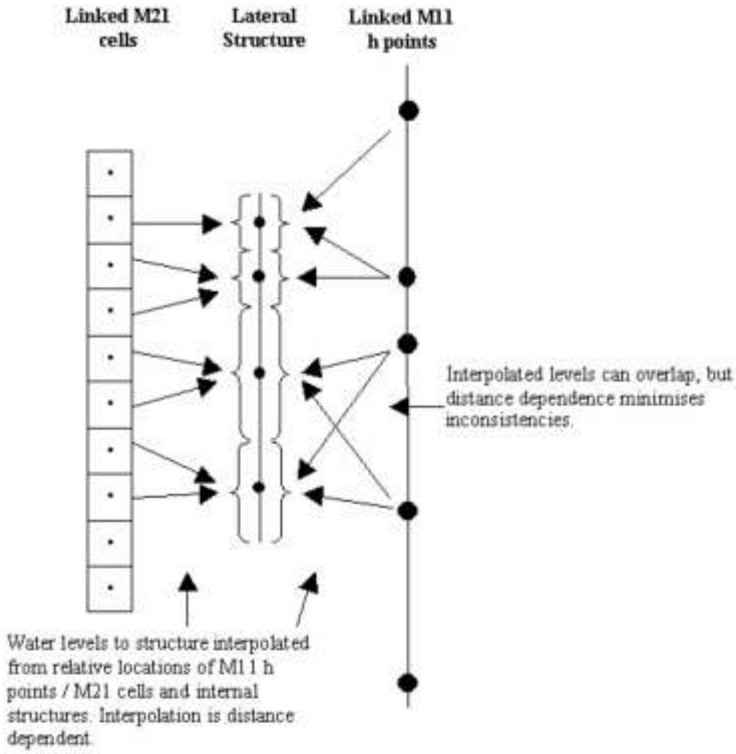

Figure 2: MIKE FLOOD 1D-2D Lateral Links Schematic (Source Fig 8.2 Modelling user Manual, DHI 2009).

The parameters adopted for the Brownhill Keswick model are provided in Table 1 below.

Table 1: Brown Hill Keswick Creek Model 1D-2D Lateral Weir Interface Description

Parameter	Value	Comment
Type	Weir 1	$Q = W \cdot C \cdot (H_{us} - H_w)^k \cdot \left[1 - \left(\frac{H_{ds} - H_w}{H_{us} - H_w}\right)^k\right]^{0,385}$ Refer to MIKE 11 reference manual for details.
Source	HGH	HGH adopted for model stability (highest of MIKE 21 grid cell and MIKE 11 overbank levels).
Depth Tolerance	0.1m	For model stability.
Weir C	1.838	Default discharge coefficient.
Manning‟s n	0.05	Adopted value.

The calculation process for flow transfer through a lateral link is summarised below:

- Water levels at MIKE 11 h points and MIKE 21 grid cells are calculated.
- Where required water levels are interpolated between MIKE 11 h points and MIKE 21 grid cells to provide water levels either side of the lateral link at the locations of the link structures. Refer to Figure 2 for a schematic diagram for this process.

- The width of link structure engaged for flow transfer based on the interpolated water levels is calculated.

- Flow over the link structure is calculated based on the length of link structure engaged, upstream and downstream water levels and the hydraulic equation for the lateral weir interface.

- Flow over the structure is then distributed to the relevant MIKE 11 h points and MIKE 21 cells.

Flow Over the Floodplain

MIKE 21 calculates water depth over a model (floodplain) based on the shear stress (resistance to flow). While the values may be specified as either a Manning"s M number, (where M = 1/n and n = Manning"s „n" value) or a Chezy number, Manning"s M numbers have been adopted for Brown Hill and Keswick Creeks because more resistance data is available and the model developers were more familiar with its use.

In MIKE-Flood, resistance can be specified as a constant value for the whole model or as a value for each grid cell. Normally for such a large model (over 2 million cells) it would be time consuming and costly to define the various land usages and prepare the data given the nature of the floodplain (residential, parkland, road, river, etc). However, as cadastral information was available it was possible to prepare a two-dimensional data file of resistance parameters (Manning M) for the various land uses.

The modelling process assumes that buildings are permeable but that flows are retarded or diverted by structures (buildings) on the floodplain. This is simulated in the model by increasing the roughness parameter.

The resistance parameters given in Table 2 were adopted for the various land uses. They were chosen from literature and Hydro Tasmania"s previous modelling experience. No sensitivity analysis was undertaken as the adopted parameters were considered to be the best estimate.

Table 2: Adopted Resistance Parameters

Land Use	Manning’s n	Manning’s M
Recreational, parkland	0.055	20
Road pavement	0.018	55.6
Residential, commercial	0.17	6

Boundary Conditions

In MIKE Flood, model boundaries can be either open or closed. For open boundaries, it is possible to specify water level or flow with each being either constant or varying with time. In floodplain situations where flow extends overland beyond a boundary, it is customary to class define an open boundary. The boundary can be conceptualised as a wide “excavated trench” and a constant water level set below that of the adjacent topography. This allows the overland flow to discharge into the trench before it is lost to the system. The results on the floodplain are therefore not affected in the vicinity of the trench (boundary condition).

For the Upper Brown Hill model, open boundaries were identified at two locations along the four model boundaries. All boundaries, except for those locations specified below, were considered closed due to topographical features. The open boundaries were located on the northern and western boundaries in the northwest corner of the model. The northern boundary was defined as a constant water level of 43.5 m AHD, while the western boundary was defined as a constant water level of 47.0 m AHD. These constant water levels are set below the adjacent ground levels.

In the main Brown Hill – Keswick model, only one open boundary was defined. It was located on the western boundary of the model where the Brown Hill Creek channel drains into the Patawalonga Lake. A constant water level boundary was adopted and set at a level of 0.5 m AHD for all flood scenarios.

Model Calibration and Verification

The model calibration process can involve the adjustment of:

- Hydraulic roughness – in river channels and floodplain areas
- Configuration of structures - critical levels and operation or head-loss characteristics.
- Model topography/structure – in terms of any identified inconsistencies between the survey and observed behaviour.

Roughness parameters are usually derived in the first instance based on field observations, past experience and interpretation of aerial photographs and satellite imagery as available.

As there is limited history of floodplain inundation in the Brown Hill Keswick Creek catchments it was not possible to calibrate the floodplain model in 2003. More recently the flood event in November 2005 was used to verify model performance for the 2006 upgrade of the model.

Experience with detailed hydraulic models of this type has shown that once the model structure is correct, often only small adjustments are required in calibration, with major inconsistencies usually associated with errors in structures.

Key Assumptions of Computer Model

A range of assumptions are normally required to construct and use a complex floodplain model. These assumptions are all simplifying assumptions necessary to represent complex natural processes in way that can be effectively represented in a numerical model. Key assumptions made in the Brown Hill and Keswick Creek model are as follows:

- All channels are clean with nothing in or around them that could possibly be washed into the channel causing blockages of the channel or of the culverts or bridges through which water flows.

- Floodplain roughness values were based solely on cadastral information. House footprints were not taken into account so water can flow “through” houses. Also, due to the high roughness value assigned to residential and commercial areas, water may be restricted in flowing through open areas where it may be expected to flow.

- The ground and channel geometry is assumed to be stable. Neither the MIKE 11 nor MIKE 21 models provide for dynamic changes to the landscape during the simulation process due to water cutting new channels and altering the distribution of flow.