The Water Balance Model (WBM): A Tool for Stormwater Source Control Modeling in a Watershed Context

Preliminary Work Plan for WBM Upgrade

> *Most natural hydrologic phenomena are so complex that they are beyond comprehension, or exact laws governing such phenomena have not been fully discovered. Before such laws can ever be found, complicated hydrologic phenomena (the prototype) can only be approximated by modeling.*
>
> —Ven Te Chow

1. Overview of the Model

To support several complementary efforts in the Province of British Columbia, CH2M HILL developed a decision support tool for volume-based analysis of stormwater strategies. The tool is named the ***Water Balance Model*** (WBM) and is versatile in meeting educational, watershed planning and site design needs and objectives.

The WBM provides an interactive means for local governments to integrate land use planning with stormwater management, and to evaluate the potential for developing or re-developing *communities that function hydrologically like naturally forested or vegetated systems.* The tool creates an understanding of *how*, and *how well*, stormwater source control strategies would be expected to achieve watershed protection and / or restoration objectives.

The WBM incorporates algorithms that simulate how runoff is generated at the site level, and has a wide range of application possibilities:

- **Design of volume-based stormwater controls**
- **Site performance assessment**
- **Evaluating opportunities for urban retrofits**
- **Volume-based watershed trading for urban stormwater management**
- **Watershed management optimization**
- **Analysis of global climate change impacts**
- **Public education and outreach**

The hydrologic modeling tools that are commonly used by stormwater practitioners originated in an era when 'peak flow-based thinking' dominated urban stormwater management and surface water modeling. Therefore, not one of these models is suitable for modeling water balance volumes at the site level. This gap in modeling technology was the trigger for development of the WBM.

Model Inputs and Outputs

The power of the WBM is in the 'engine' that instantly, interactively, and transparently models hydrologic processes at the site level, including the processes that govern the movement of water through soil and vegetation. This engine provides a continuous simulation of runoff from individual sub-catchments or neighbourhoods (also simulates other hydrologic pathways – infiltration and evapo-transpiration).

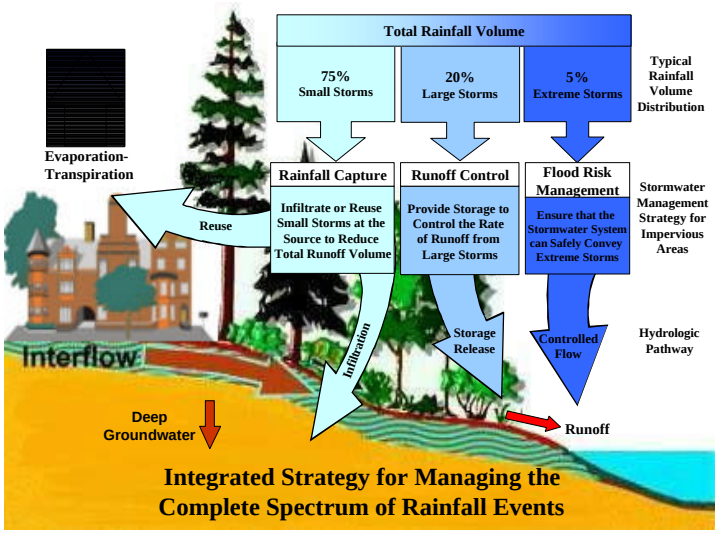
The WBM can be applied to evaluate the hydrologic performance of stormwater source controls (e.g. bioretention, infiltration facilities, rainwater capture and re-use, green roofs) and stormwater detention. It provides a continuous simulation of the runoff from a development (or re-development) area, or from a watershed (or sub-catchment) with multiple land uses, given these inputs:

- **Continuous rainfall data** (any time increment) and **evapotranspiration data**
- **Extent and distribution of land use types**
- **Site design parameters for each land use type (**e.g. road width, rooftop coverage, parking coverage, population density)
- **Soil and groundwater information** (e.g. vegetation rooting depth, porosity, hydraulic conductivity, water table level)
- **Information on stormwater controls** (location and design parameters for stormwater source controls and detention facilities).

The sensitivity of source control performance to any of these model inputs can be tested by comparing modeled scenarios.

The output hydrograph generated by the WBM can become an input to a wide range of hydraulic routing models. WBM hydrographs represent a major improvement over conventional hydrologic simulation of urban runoff.

Model Application



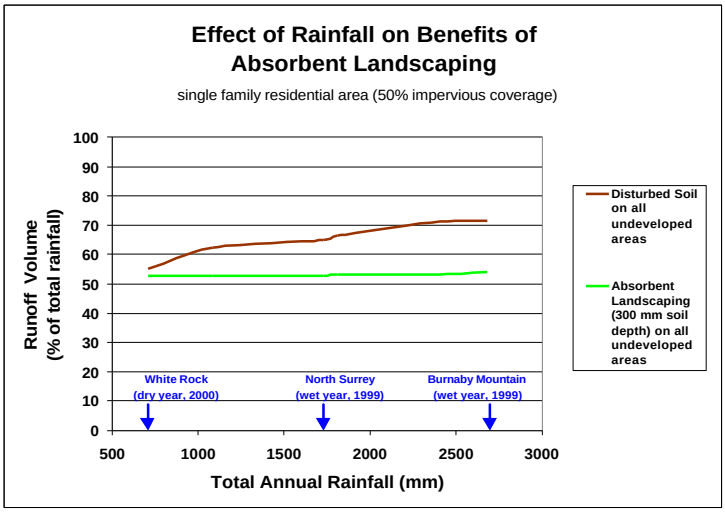
Integrated Strategy for Managing the Complete Spectrum of Rainfall Events

The WBM enables modelling of all three components of the Integrated Strategy for managing the complete rainfall spectrum – that is, *retain* the small frequent events, *detain* the large events, and *convey* the extreme events.

The WBM can be used to evaluate how well alternative strategies (including stormwater source source control and detention) can reduce the runoff from development areas, and how this translates into benefits at the watershed level.

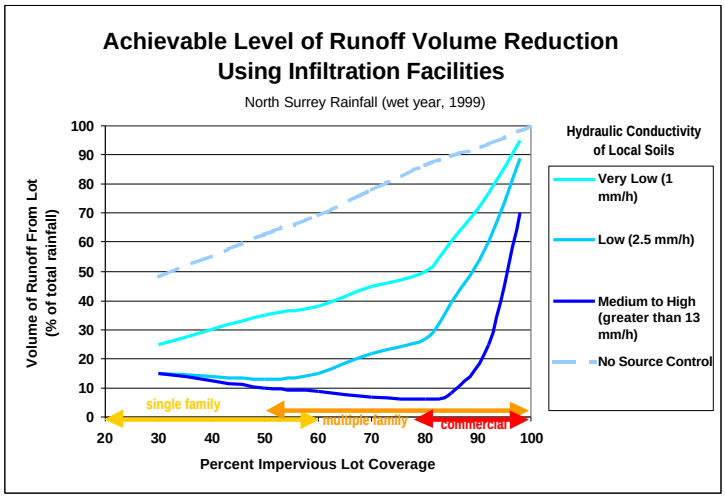
2. Sample Model Output

The following figures illustrate the type of output that the WBM produces:



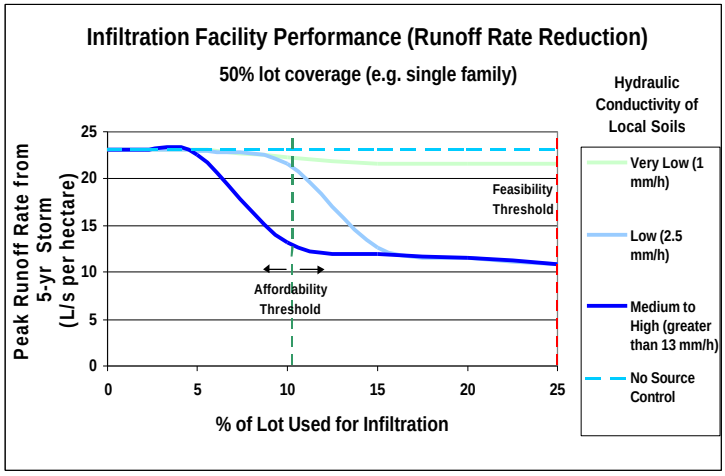
Absorbent landscaping is most beneficial for high rainfall locations, even under conditions where the hydraulic conductivity of the underlying soil is very low.

A 300-mm absorbent soil depth can virtually eliminate surface runoff from undeveloped areas, even in the wettest conditions.



Where soils have medium or better hydraulic conductivity, runoff volume could be reduced to about 10% of total rainfall for all but the highest coverage land uses.

Significant levels of runoff volume reduction can also be achieved in soils with poor conductivity.



Reductions in runoff rates using infiltration facilities depend on the hydraulic conductivity of local soils and the amount of area provided for infiltration.

Affordability thresholds govern infiltration facility sizes for lower coverage land uses, and feasibility thresholds govern for higher coverage land uses.

3. Need for WBM Upgrade

The WBM was initially developed as an spreadsheet application but the number of modules has outgrown this format. At the most basic level, portability is an issue due to the size of the Excel file: over 50 MB. In addition, needed enhancements that would allow the WBM to model multiple land uses and multi-year continuous simulations are simply not possible under the current platform.

The purpose of this document is to establish a vision for the evolution of the WBM and to develop an estimate of the effort require to move the WBM to a more practical version.

An Inter-Governmental Partnership (IGP) has been formed in British Columbia to fund WBM enhancement. The IGP comprises federal, provincial and local government agencies.

4. Vision for the Enhanced WBM

The vision for the WBM is that of a tool that can implement the latest thinking in stormwater management in the United States and Canada. WBM enhancement involves four phases as listed below:

- Phase 1 – Develop the Graphical User Interface (GUI)
- Phase 2 – Test the Model through Case Study Applications
- Phase 3 – Calibrate the Model Engine through Demonstration Projects
- Phase 4 – Convert to an Internet-based Tool

The focus of this document is on the four steps that comprise the Phase 1 Work Plan. The scope of Phase 1 is described below.

Phase 1 – Develop the Graphical User Interface (GUI)

The Phase 1 application will have the 'look and feel' of a web environment. Users will interact with the WBM using a web browser (Internet Explorer or Netscape) much like they would do in a website, except that they would not be connected to the internet.

Information will be supplied through forms and options will be invoked through hyperlinks and buttons. Reports will be delivered in webpages either within the same browser window or in a new window. The data will be stored in Microsoft Access, which is factory-installed in many personal computers.

The new platform will allow for more efficient data storage procedures, faster performance, increased portability, more flexible output options and easier technical enhancement as the state-of-the-science evolves

5. Overview of Phase 1 Work Plan

The Phase 1 Work Plan to upgrade the WBM to a new platform consists of four main steps:

- **Step 1 - Definition of Software Requirements:** This step will establish what users desire from the software and how to fulfill their needs. Much of this work has already been completed by CH2M HILL in developing the current version of the software. Through previous case study applications of the WBM, a wealth of information has become available from potential users and some of it has been incorporated in the spreadsheet version. Step 1 will formalize remaining issues that need to be addressed in the new version of the WBM.
- **Step 2 - Software Design and Specifications Document:** In this step, a blueprint of the software will be developed. This blueprint will define the way the user interacts with the software, software architecture, system requirements, computations to be performed, input/output options, and any other features needed for the programming team to produce the software. The final product of this step is a document that clearly establishes what functions the WBM needs to execute and how to go about programming those functions. Specific elements of this step are further defined in the accompanying Table 1.
- **Step 3 - Software Development:** This step will involve the programming effort, testing of the software, final development, and preparation of a user's manual. This is the main part of the project. Work will be guided by the detailed specifications resulting from Step 2. Software testing will proceed at several stages in the process by the development team and the user community. At a point of substantial completion a "beta" version of the software will be released for field-testing. Software documentation will be prepared once the final version of the software has been defined as a result of testing.
- **Step 4 – Project Implementation**: The main focus of this step will be on training workshops.

6. Details of Phase 1 Work Plan

Table 1 outlines the proposed actions, with associated timelines and costs, required to complete the Phase 1 WBM upgrade. The table includes both administrative and technical action items. Administrative actions are highlighted in red and technical actions are highlighted in blue. All timelines and costs are tentative.

Step 1 could officially begin as soon as sufficient funding is confirmed. Steps 1 and 2 could be completed within three months of the start date. The target date for completion of Step 3 is May 31st, 2003.

The total estimated cost is $150,000 (Canadian dollars). Note that the budget for Step 3, software development, will only be known with certainty once Step 2, the *Software Design and Specifications Document* is completed. Costs provided for Step 3 are for planning purposes only at this initial stage. Similarly, the budget for Step 4 is a provisional allowance.

Preliminary Budget

The anticipated budget is summarized below. It allows for the cost of one round-trip from Washington, DC, to Vancouver by Dr. Dan Medina during Step 2 to meet with the IGP Steering Committee and to provide input into the software design.

STEP	DESCRIPTION	BUDGET
1	Definition of Software Requirements	$22,000
2	Software Design and Specifications Document	$45,000
3	Software Development	$73,000
4	Project Implementation	$10,000
	TOTAL BUDGET (excluding GST)	**$150,000**

Preliminary Schedule

Subject to funding being in place, the target date for project completion is May 31st 2003. The objective is to complete Steps 1 and 2 by December 31st 2002.

STEP	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
1									
2									
3									
4									

Progress Review Meetings

The budget for Step 1 allows for two Progress Review Meetings with the IGP Steering Committee.

The budget for Step 2 allows for a single Progress Review Workshop once the technical tasks related to preparation of the Software Specifications Document have been completed.

The unit cost for additional Progress Review Meetings, as and when requested by the IGP Steering Committee, would be $1000 per meeting. This allows for the attendance of two representatives from CH2M HILL at either a morning or afternoon session. This unit cost also allows for travel time to and from the GVRD offices, the designated site for IGP meetings.

7. Contact Information

The Inter-Government Partnership (IGP) is a consortium of federal and provincial government agencies, local governments and other funding partners. The BC Ministry of Agriculture, Food and Fisheries and Environment Canada are the lead partners in this venture. The Greater Vancouver Regional District (GVRD) is the host organization for IGP meetings.

For information about the proposed WBM upgrade, please contact

Ted Van der Gulik,
Chair, WBM Inter-Governmental Partnership
(604) 556-3112
Ted.vanderGulik@gems8.gov.bc.ca.

OR

Laura MacLean,
Co-chair, WBM Inter-Governmental Partnership
(604) 666- 2399
Laura.Maclean@ec.gov.ca

For technical issues, please contact

In Canada:

Kim Stephens
CH2M HILL Canada Limited
(604) 684-3282 Ext. 309
kstephe1@ch2m.com.

In the United States:

Dan Medina
CH2M HILL
(703)471-6405 Ext. 4128
dmedina@ch2m.com

TABLE 1 - DETAI LS OF PHASE 1 WORK PLAN

Action	Lead	Timeline	Expected Cost ($ Canadian)
ESTABLISH THE INTER-GOVERNMENTAL PARTNERSHIP			
Project Initiation Meeting	WBM Inter-Governmental Partnership	Mar '02	$0
Define and secure minimum level of funding required to proceed with WBM enhancement	WBM Inter-Governmental Partnership	May '02	$0
Meet with WBM Steering Committee to define project scope and deliverables	WBM Inter-Governmental Partnership	Jul '02	$0
Arrange for third party to manage funds and contracting	WBM Inter-Governmental Partnership	Jul '02	$0
Incorporate deliverables into contract	WBM Inter-Governmental Partnership	Sep '02	$0
Resolve WBM ownership and intellectual property issues and write into contract	WBM Inter-Governmental Partnership	Sep '02	$0
PHASE 1 – DEVELOP THE GRAPHICAL USER INTERFACE (GUI)			
Step 1 - Definition of Software Requirements			
1.1 Develop scope of upgrade program	CH2M Hill	Sep '02	$4,000
1.2 Define software requirements, including Review Meeting #1 with IGP Steering Committee	CH2M Hill	Oct '02	$12,000
1.3 Finalize software requirements, including Review Meeting #2 with IGP Steering Committee	CH2M Hill	Oct '02	$6,000

Action	Lead	Timeline	Expected Cost ($ Canadian)
Step 2 - Software Design and Specifications Document			
2.1 Establish sources and format of input data	CH2M Hill	Oct '02	$2,000
2.2 Define data structures and management procedures	CH2M Hil	Oct '02	$3,000
2.3 Select Graphical User Interface (GUI) platform (HMTL, ASP, Flash , or Director-based navigation)	CH2M Hill	Oct '02	$3,000
2.4 Define issues of access, passwords, ownership and privacy	CH2M Hill	Oct '02	$2,000
2.5 Design GUI screens and prepare prototypes in the selected platform	CH2M Hill	Nov '02	$12,000
2.6 Develop prototype model for "walk through" purposes	CH2M Hill	Nov '02	$2,000
2.7 Prepare sample data set	CH2M Hil	Nov '02	$2,000
2.8 Define software testing and quality control procedures	CH2M Hill	Nov '02	$2,000
2.9 Specify documentation requirements re: user's manual, technical reference manuals, and software administration, support and maintenance	CH2M Hill	Dec '02	$12,000
2.10 Prepare accurate cost estimate and schedule for Step 3 - Software Development	CH2M Hill	Dec '02	$2,000
2.11 Hold interim workshop to review work products and next steps with Inter-Governmental Partnership	CH2M Hill	Dec '02	$3,000

Action	Lead	Timeline	Expected Cost ($ Canadian)
Step 3 - Software Development			
3.1 Program WBM according to specifications from Step 2	Lanarc	Jan '02	$31,000
3.2 Conduct software testing	Lanarc	Mar '02	$6,000
3.3. Complete final software development	Lanarc	Apr '03	$8,000
3.4 Pilot with local government users ("beta" testing)	Lanarc	Apr '03	$6,000
3.5 Make final adjustments as required	Lanarc	Apr '03	$5,000
3.6 Build instructions for use into user interface, or develop user manual	Lanarc	May '03	$14,000
3.7 Present enhanced WBM to Inter-Governmental Partnership and / or GVRD Stormwater Inter-Agency Liaison Group	CH2M Hill	May '03	$3,000
Step 4 – Project Implementation			
4.1 Decide on how to distribute / provide access to enhanced WBM	WBM Inter-Governmental Partnership	May '03	
4.2 Hold training workshops (2) for specific user groups	CH2M Hill	May '03	$10,000 provisional allowance
4.3 Clarify provisions for providing ongoing technical support	WBM Inter-Governmental Partnership	May '03	
TOTAL ESTIMATED COST (excluding GST)			**$150,000**

Action	Lead	Timeline	Expected Cost ($ Canadian)
PHASES 2 through 4			
Develop plan to validate and calibrate model outputs against field data		to be determined	to be determined
Develop internet capability		to be determined	to be determined
Incorporate WBM into the GVRD's ISMP Template		to be determined	to be determined