Beyond the Guidebook Seminar
November 2007

Beyond the Guidebook: Why the Water Balance Model Powered by QUALHYMO

Incorporating all the lessons we have learned to date...

Beyond the Guidebook connects the dots between source controls at the site scale and stream health protection at the watershed scale

A Presentation
By
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An initiative under the umbrella of the Water Sustainability Action Plan for British Columbia

Beyond the Guidebook:
Why the Water Balance Model Powered by QUALHYMO

Beyond the Guidebook Seminar

Released in June 2007, **Beyond the Guidebook: Context for Rainwater Management and Green Infrastructure in British Columbia**[1] is a guidance document that describes a runoff-based approach to drainage modeling. Co-sponsored by the Green Infrastructure Partnership[2] and the Water Balance Model Inter-Governmental Partnership,[3] the goal is to advance implementation of green infrastructure policies and practices throughout British Columbia. The mantra for this provincial initiative is: **Today's Expectations are Tomorrow's Standards**.[4]

The Beyond the Guidebook Seminar held in November 2007[5] provided a timely opportunity to inform local government and land use practitioners regarding an emerging policy framework for land development and watershed management; and foreshadow how application of the Water Balance Model powered by QUALHYMO[6] will influence the greening of the built environment. The latter is a web-based decision support tool that connects the dots between source control evaluation and stream health assessment. It underpins **Beyond the Guidebook**.

Two rainfall-runoff simulation models are being merged to create a tool that integrates the site with the stream and watershed. The original **Water Balance Model** decision support tool was developed in 2003 as an extension of **Stormwater Planning: A Guidebook for British Columbia**[7]. The new Water Balance Model integrates the powerful continuous hydrologic simulation capabilities of **QUALHYMO,** a tool developed in the early 1980s for the Ontario Ministry of Environment.

Jim Dumont, designated by the Inter-Governmental Partnership as its **Engineering Applications Authority**, provided a technical overview of the considerations shaping model integration. His presentation, titled Beyond the Guidebook: Why the Water Balance Model Powered by QUALHYMO[8], was organized in four parts as shown below. He explained why the models are being integrated, and what this integration will accomplish.

Presentation Outline

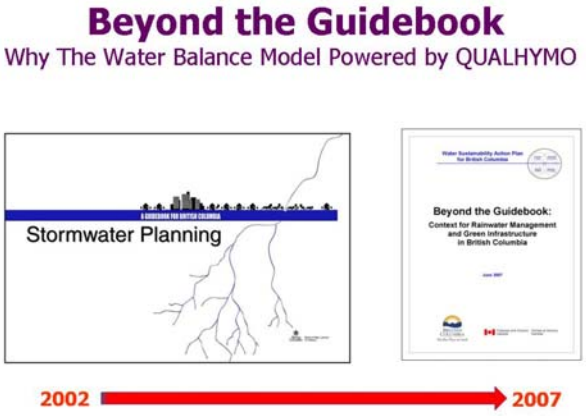
- ❑ Beyond the Guidebook Explained
- ❑ The science behind the Stream Health Methodology
- ❑ So, what is QUALHYMO?
- ❑ What integration of QUALHYMO and the Water Balance Model will achieve

[1] http://www.waterbucket.ca/rm/index.asp?sid=44&id=330&type=single
[2] http://www.waterbucket.ca/gi/index.asp?sid=0&id=13&type=single
[3] http://www.waterbucket.ca/rm/index.asp?sid=12&id=246&type=single
[4] http://www.waterbucket.ca/gi/index.asp?sid=10&id=330&type=single
[5] http://www.waterbucket.ca/gi/index.asp?sid=49&id=319&type=single
[6] http://www.waterbucket.ca/gi/index.asp?sid=23&id=96&type=single
[7] http://www.env.gov.bc.ca/epd/epdpa/mpp/stormwater/stormwater.html
[8] http://www.waterbucket.ca/gi/sites/wbcgi/documents/media/162.pdf

Beyond the Guidebook Explained

Jim Dumont began his presentation by introducing the British Columbia Guidebook, published in 2002, and noted that the purpose in going **Beyond the Guidebook** is to incorporate the lessons learned over the past five years.

"The Guidebook established the framework for rainfall capture and a performance target way-of-thinking and designing. *Beyond the Guidebook* will take the Guidebook to the next level of evolution", stated **Jim Dumont**, "Now that practitioners are becoming comfortable with what 'rainfall capture' means in practice, local governments and the development community are in a position to turn their attention to what is an achievable outcome that makes sense and results in net environmental benefits at a watershed scale."



Founded on British Columbia case study experience, the Guidebook formalized a science-based understanding[9] to set performance targets at the site scale for reducing rainwater runoff volumes and rates. These targets represent the synthesis of biological and hydrological understanding.

The Guidebook is structured to meet the information needs of different audiences: from senior managers and elected officials...to professional planning and engineering staff...to land developers and the consulting community.

Recognition outside British Columbia: The Guidebook set in motion a chain of outcomes that has resulted in British Columbia being recognized internationally as a leader in implementing a natural systems approach to rainwater management in the urban environment.

Tom Schueler, co-founder of the Center for Watershed Protection in the United States, has praised the Guidebook[10] because of its innovation. "I really like what Kim Stephens and his British Columbia team did in developing the water balance methodology, and I told him that when he pinch-hit for me as keynote speaker at a conference in Chicago in February 2003. In the United States, too often we see a cookie-cutter approach when guidebooks and manuals are replicated across the country. Not so with the British Columbia Guidebook - it is unique and it is innovative."

Why Beyond the Guidebook: "Publication of the Guidebook in 2002 was a turning point in how we view rainwater and stormwater management", observed Jim Dumont at the **Beyond the Guidebook Seminar**, "The Guidebook pushed British Columbia in a direction. But it is a guidance document, not a design manual; and this was an early criticism of some engineers who were expecting something along the lines of the cookie-cutter approach described by Tom Schueler. In their minds, the Guidebook wasn't specific enough for their how-do-we-do-it needs."

"To help engineers in particular go *Beyond the Guidebook*, we have developed an analytical methodology that connects source control evaluation with stream health assessment", Jim Dumont informed his audience, "Through implementation of 'green infrastructure' policies and practices, the desired outcome in going *Beyond the Guidebook* is to apply what we have learned at the site scale over the past five years…so that we can truly protect and/or restore stream health in urban watersheds."

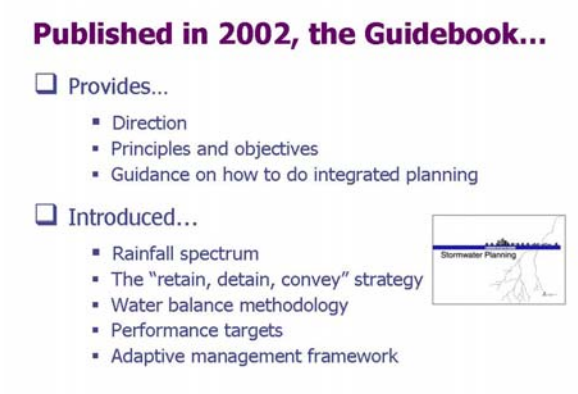
[9] http://www.waterbucket.ca/rm/index.asp?sid=49&id=229&type=single

[10] http://www.waterbucket.ca/gi/index.asp?sid=16&id=53&type=single

The Goal: After first introducing the Guidebook and setting the stage for Beyond the Guidebook, Jim Dumont then addressed the question: so, why are we doing this? According to Dumont, "The goal of land development is to take rural areas, overlay places where people will live and work, and ultimately have no impact on the environment, right?" He employed the collage of images below to underscore his message.

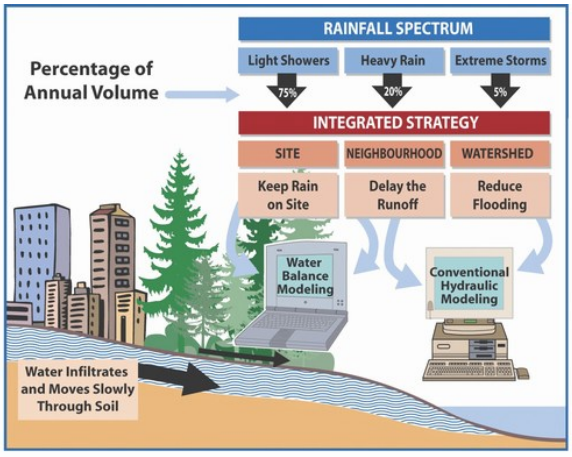
"Giving the goal of 'No Impact', my part in this Beyond the Guidebook Seminar is to provide the technical background and explain how we have applied a science-based rationale to develop the **Stream Health Methodology**", continued Jim Dumont. He then elaborated on the distinguishing aspects of the Guidebook, and how the thinking behind the Guidebook goes to the heart of reconciling competing objectives vis-à-vis land development and watershed protection.

Core Concepts: According to Jim Dumont, "When Kim Stephens wrote the Guidebook, he introduced a number of important concepts, foremost among them being the Integrated Strategy[11] for managing all the 'rainfall-days' that occur each year. In 2002, this represented a major shift in thinking."



"The Guidebook also introduced the concept of Performance Targets[12] to enable implementation of the *Integrated Strategy* for managing the rainfall spectrum", continued Dumont. "In no way did this mean you had to achieve 100% rainfall capture onsite. Too many people have lost sight of the fact that Performance Targets are linked to Adaptive Management[13] - that is, learn by doing, which is the antithesis of a prescriptive approach."

"We are now at a point where we can integrate engineering, planning, biology, geomorphology and recreation to influence the greening of the built environment", added Dumont.



[11] http://www.waterbucket.ca/rm/index.asp?sid=43&id=13&type=single
[12] http://www.waterbucket.ca/rm/index.asp?sid=42&id=259&type=single
[13] http://www.waterbucket.ca/rm/index.asp?sid=16&id=332&type=single

Building on Past Research: Once he had introduced the foregoing core concepts to his audience, Jim Dumont then proceeded to sketch an historical picture that illustrated why one can reasonably conclude that 'the future is the past'….in terms of how we are now picking up where others left off. He referenced the work of Thomas Hammer (1973), Rich Horner and Chris May (1996), Chris Jones (1997) and Craig MacRae (1997).

Documented stream impacts date back to a 1973 research report

Effects of Urbanization on Stream Channels and Stream Flow, Thomas Hammer, 1973

- Streams are impacted by development
- Discharges and width increase
- The width of the buffer strip does not matter when pipes are used to discharge runoff directly into the stream

Looking back, the historical value of **Thomas Hammer's** 1973 report for the US Department of the Interior is the insight it provides regarding the rudimentary nature of practitioner understanding in the early 1970s. At a time when we could put a man on the moon (1969), we had not yet connected the dots between land use changes and stream erosion. One wonders how far Hammer might have advanced the science of hydrology had he not changed careers (i.e. to nuclear engineering) soon after publication of his landmark findings.

In the late 1960s, "…existing knowledge regarding hydrologic effects of urbanization was quite inadequate…It was not known, for example, whether different types of impervious area have different effects on streamflow", wrote **Thomas Hammer**, "This lack of knowledge has apparently existed because of the reluctance of natural scientists, on the one hand, to deal with…complex non-natural phenomena, and the reluctance of planners, on the other hand, to conduct research involving physical rather than social relationships."

According to Jim Dumont, "In BC, we have picked up where Thomas Hammer left off in 1973. His research included the effectiveness of buffer strips. One of the gems buried in his report is that buffer width has no correlation with stream erosion as long as drainage runoff is being piped directly to the receiving stream."

A generation later, Rich Horner and Chris May of the University of Washington facilitated a paradigm-shift when their Puget Sound research established the order-of-priority for the four factors affecting stream health. Their key finding was that *changes in hydrology* due to land development in the surrounding watershed are the #1 cause of in-stream impacts.

In 1996, Horner & May identified factors affecting stream health as…

- ❑ Changes in Hydrology
- ❑ Disturbance and/or Loss of the Riparian Corridor
- ❑ Degradation and/or Loss of Habitat within the Stream
- ❑ Deterioration of Water Quality

According to Jim Dumont, "I fail to understand why more attention has not been paid to the work of **Chris Jones**. A decade ago he clearly demonstrated that state-of-the-practice facilities were not providing the intended biological mitigation."

Real World Operation – Example 1

Bioassessment of BMP Effectiveness in Mitigating Stormwater Impacts on Aquatic Biota, Chris Jones, 1997

- Biological communities degraded below Best Management Practices (BMPs) as compared to reference watersheds
- No difference in biological diversity above or below BMPs

"Looking back, major advances in science-based understanding were occurring in the mid-1990s. Yet engineering practice generally did not incorporate this understanding", continued Dumont, "Another prime example is the work of **Craig MacRae**. He looked at the effectiveness of detention ponds, and concluded that the use of the 2-year criterion as a release rate was flawed because it actually accelerated stream erosion."

Real World Operation – Example 2

Experience from Morphological Research on Canadian Streams, Craig MacRae, 1997

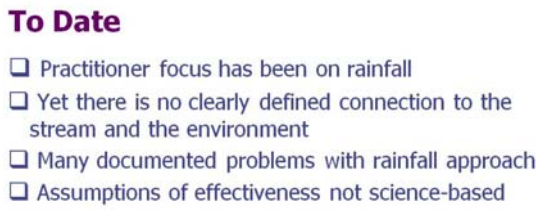
- Stream channels below detention basins designed to control to 2-year discharges experienced accelerated erosion at 3 times the predevelopment rates
- Recommendation - Do not use this criterion to prevent erosion

In British Columbia, the 2-year criterion provided the technical basis for the 1992 Land Development Guidelines.

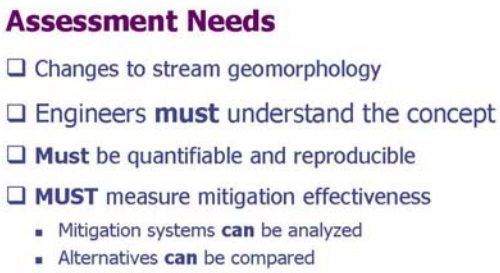
Framework for Moving Forward: Jim Dumont challenged his audience by rhetorically asking: Will we repeat the learning experiences of others a decade ago and wait another decade to move forward; or will we take their lessons learned and advance the state-of-the-practice immediately?

He answered his own question by stating that **Beyond the Guidebook** approach is based on the latter. "In developing the **Stream Health Methodology** that is being incorporated in the **Water Balance Model powered by QUALHYMO**, we have picked up where others left off in the late 1990s", emphasized Dumont.

"Drainage engineers have seemingly forgotten what they learned in Hydrology 101, and have over-emphasized the use of rainfall data to calculate streamflow rates", stated Dumont, "There is no direct connection between rainfall and what we see in the stream. There are a number of processes in between the two. So, when we assess stream health, what we need to analyze is runoff data."

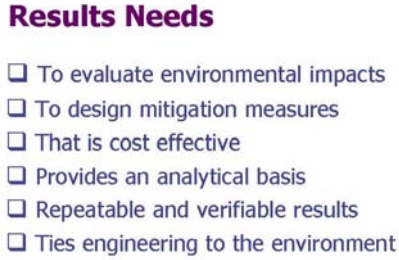


Types of 'Needs: Jim Dumont then described three types of needs: Assessment, Analyses and Results. First, he laid out a mind-map for **Assessment Needs**. This starts with an understanding of stream geomorphology. "Measuring mitigation effectiveness is fundamental to good engineering analysis and implementation", he stressed.



Building on the above theme, Jim Dumont then reviewed the **Analyses Needs** as summarized in the slide below. "From an engineering point-of-view, we need to know how things work; and we need a tool", stated Dumont, "We have chosen to concentrate our efforts on the *Water Balance Model powered by QUALHYMO* because we believe this tool offers us the best opportunity to minimize the risk of failure."

"At the end of the analysis, we need to tie all the pieces together", observed Dumont. This comment led into an overview of **Results Needs** as summarized in the slide below.



A New View: "We need a 'new view'. We have to switch to something that works better, because what we have been doing to date has not been that effective", continued Jim Dumont, "We are at a crossroad in the path defining the methodologies and applications used in rainwater management. In a nutshell, *Beyond the Guidebook* enables us to make a clear distinction between a **rainfall-based approach** and a **runoff-based approach**."

A New View

- ❑ An analytical approach
- ❑ Clearly defines causes and effects
- ❑ Logical and easy to use
- ❑ Includes adaptive management

According to Jim Dumont, "A basic tenet of hydrology is that rainfall and runoff have different return periods. Yet drainage practitioners persist in applying a rainfall-based approach that assumes rainfall will always result in the same magnitude of runoff."

Design / Assessment Basis

- ❑ Two Paths that initially appear similar
- ❑ Rainfall Based
  - Control of a fixed volume (e.g. 30mm)
  - Control of discharge rates
- ❑ Runoff Based
  - Address impacts on streams
  - Quantifiable and measurable

The *Rainfall-Based Approach* grew out of simple to use methodologies that address the reduction of flood risk for drainage conveyance systems. The R*unoff-Based Approach*, on the other hand, leads to the analysis of runoff and its interaction with the physical aspects considered important to the aquatic environment.

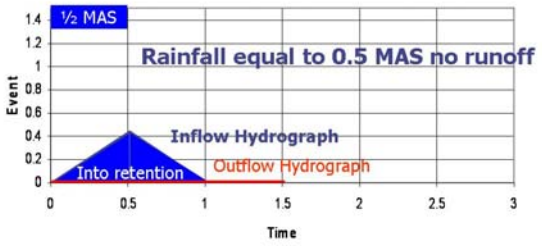
Rainfall-Based Approach: Jim Dumont commented that the rainfall-based approach appeals to drainage modelers because of its simplicity. "It gives them answers and they assume it works", he observed, "But there is no correlation with stream health, which is the Beyond the Guidebook focus."

Rainfall Basis

- ❑ Simple
- ❑ Capture volumes from impervious areas
  - Create some detention / infiltration
- ❑ Maintain predevelopment rates
  - Use design storms
  - Use retention ponds
- ❑ **Assume** (hope) it works to mitigate impacts
  - No way to test before construction

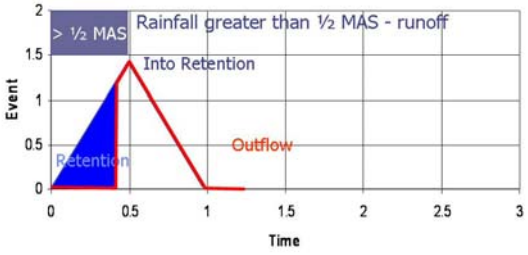
To illustrate an inherent weakness in the rainfall-based approach, he presented an example that goes to the heart of the discharge rate criterion for detention ponds as specified in the **1992 Land Development Guidelines**. The two slides below show two operating conditions. In slide #1, there is no outflow when rainfall matches storage capacity. In slide #2, rainfall exceeds storage and there is no reduction in the outflow hydrograph.

Does 50% of Mean Annual Streamflow (MAS) Criterion Reduce Discharge?



More Rainfall

Events > ½ MAS: no decease in peak discharge



Runoff-Based Approach: "The runoff-based approach provides the analytical foundation for the *Water Balance Model powered by QUALHYMO*", stated Jim Dumont, "A primary benefit of this approach is the use of continuous simulation using long-term records to calculate runoff means that the frequencies and durations of various conditions can be estimated easily."

Runoff Basis

- ❑ Flow duration for habitat availability
- ❑ Tractive force to measure potential erosion
- ❑ Sediment washoff to evaluate water quality
- ❑ Optimize systems to manage the impacts of the altered hydrologic cycle
- ❑ **Test** mitigation works **prior** to construction

"The performance of *rainfall capture* and *runoff control* facilities for volume and flow rate reduction depends not only on the rainfall volume and temporal distribution, but also on antecedent conditions such as soil moisture and the volumes of existing water retained in ponds from previous storms", he elaborated, "All of these factors overlie the physical characteristics of a site or watershed in terms of vegetative cover, imperviousness, connectivity, slope, and the many defining parameters describing the condition of the soils."

Dumont also explained that the use of continuous simulation allows a direct observation of the frequency of the condition of interest from the results of the calibrated models, and therefore accounts for the effect of joint probabilities of occurrence of the large number of variables.

He summarized by stating that the runoff-based approach enables practitioners to focus on the causes of stream impacts, and determine how best to optimize the design of appropriate mitigation measures.

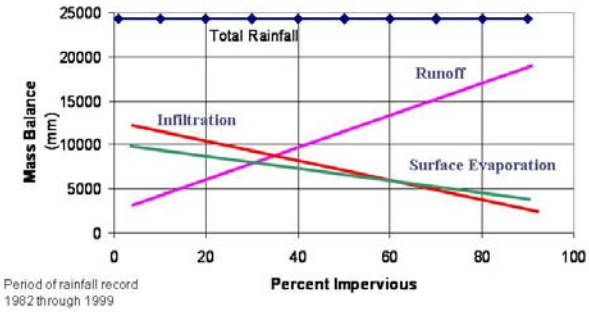
In wrapping up this segment of the presentation, Jim Dumont's key message was that the runoff-based approach enables the drainage modeller to test proposed mitigation works prior to construction.

The Science behind the Stream Health Methodology

Jim Dumont has built on the foundation provided by others in developing the science-based stream health methodology that is at the heart of the **Water Balance Model powered by QUALHYMO**. "The methodology is runoff-based and connects the dots between source controls at the site scale and stream health protection at the watershed scale", he stated.

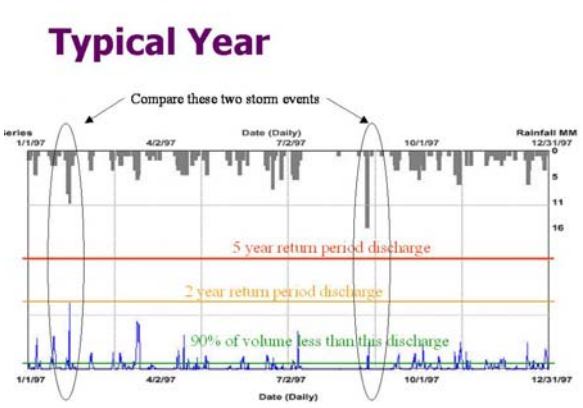
Elements of the Mass Balance: Dumont used the graphic below to highlight both the obvious and not so obvious vis-à-vis the mass balance. "Infiltration obviously decreases while runoff increases with increasing impervious cover", he pointed out, "What most people overlook is that evaporation is almost equal to infiltration. This means there is increasingly more volume to manage as the landscape is built over."

Hydrologic Change



In providing the audience with modelling context, Dumont stressed that evaporation is critical and typically gets overlooked in conventional drainage modelling. "To maintain the mass balance would require more and more infiltration as development intensifies, but is that a good or bad thing", he asked rhetorically. He then drew attention to regional examples of slope destabilization and high groundwater to underscore why too much infiltration could cause problems.

Variable Watershed Response to Rainfall: Jim Dumont then presented the hydrograph for a 'typical year' to illustrate the variable response of a watershed to rainfall. Two events are highlighted in the graphic below. The larger of the two rainfall events resulted in much less runoff. As can be seen from the hydrograph, the smaller of the two rainfall events was preceded by a period of wet weather such that more runoff resulted.



"The hydrograph also shows that 90% of the total annual runoff volume corresponds to a very small runoff rate", continued Dumont, "The implication of this finding is that it we can easily manage 90% through rainfall capture measures. For the other 10%, it is a matter of detaining and conveying in accordance with the integrated strategy for managing the complete rainfall spectrum.

In again highlighting the inherent weaknesses in design storm approaches, he emphasized that drainage engineers need to turn their minds to rainwater runoff reduction through means other than infiltration. "Design storm tools are inadequate to deal with runoff volume, stream erosion and water quality", stated Dumont emphatically.

"To deal with these other issues, we are expanding the capabilities of the Water Balance Model by integrating QUALHYMO, which is an engineering tool", added Dumont.

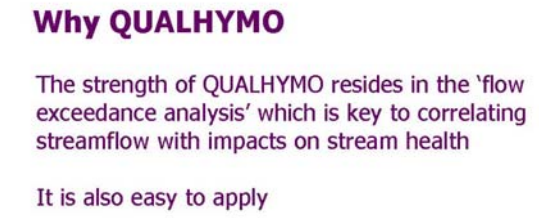
So, What is QUALYMO?

The **QUALHYMO** (QUality HYdrologic MOdel) continuous hydrologic simulation model was developed in the early 1980s by Dr. Charles Rowney for the Ontario Ministry of Environment. He is one of the pioneers of hydrologic modelling in Canada, and has had a hands-on role in the merging of the two models.

QUALHYMO has gone through numerous verification and testing processes. The validation of the engine has already been done and the model is a proven piece of software. "Charles produced a really nice tool that has stood the test of time", stated Jim Dumont, "The advantage in merging the Water Balance Mode with QUALHYMO lies in the access to the output and reporting and how much effort would be expended in extracting the information that is important."

"QUALHYMO provides the desired information without having to write too much new code to extract the information" continued Dumont, "This is what facilitates merging of the two tools, from both the timing and cost perspectives. This is in sharp contrast to a tool such as SWMM which requires considerable time and effort to obtain results."

"We have been able to readily adapt QUALHYMO



to meet our needs in developing an integrated tool that can be applied by planners and engineers", concluded Dumont, "The QUALHYMO model is the hydrologic calculation engine that will provide consistent delivery of reliable results; the web-based decision support tool will manage data so that users and reviewers can compare multiple development and land use scenarios."

Why QUALHYMO: According to Jim Dumont, "The strength of QUALHYMO resides in the flow exceedance analysis. This capability leads directly into the Stream Health Methodology which is a function of flow duration, and hence stream erosion."

Duration of Discharge

- Critical to aquatic health
  - Discharge is linked to stream health
- It can be measured and verified
- Computer simulations for duration of:
  - Flood discharges
  - Base flows
  - Fish habitat availability (depth vs duration)

Stream Erosion: "Several qualitative indicators can be utilized in assessing the potential for erosion or sediment accumulation within a watershed", explained Jim Dumont, "The methodology is based upon shear stress as applied to the stream banks over time. This is a measure of the energy available to cause erosion in a stream. Continuous simulation is the key to generating scenario comparisons. "

Stream Erosion

- Calculate stream power
- Estimate potential erosion
- Identify critical stream reaches for protection and enhancement
- Create watershed / stream specific plans

QUALHYMO can simulate water and can add sediments and dissolved constituents to the analysis process. "Because we can calculate how much energy is available in a stream, we can then compare scenarios to determine the most effective combination of rainfall capture measures on development sites", continued Dumont.

Water Quality: "Normal sediment loading from a stable urban watershed is in the range of 0.10 to 0.61 tonnes per year per hectare of watershed. It is therefore normal and expected that a stream will carry some sediment on a regular basis. Because sediment transport is a natural process, it should not be disrupted without anticipating some consequences", explained Jim Dumont, "So, when simulating the build-up and wash-off of sediment and first-order decay contaminants from a watershed, the general objective is to identify what combination of rainfall capture measures will maintain a natural level of annual suspended sediment loading**."**

Water Quality

- What do we mean?
  - No consistent answer
  - No consistent expectations
  - Regulations vary greatly
- Models use sediment as a surrogate

"Right now everyone has a different concept of water quality and how to model it. It is not easy. So we need a surrogate. Sediment meets that need; and this is what is unique about QUALHYMO", concluded Jim Dumont.

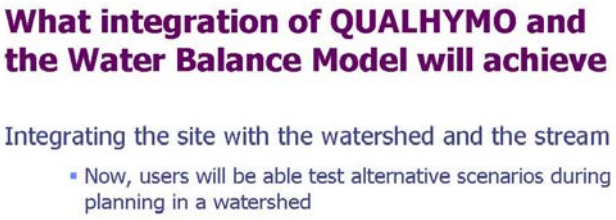
What integration of QUALHYMO and the Water Balance Model will achieve

"The significant benefit of the new Water Balance Model is the resulting emphasis on strategy and alternative implementation methodologies, as well as the focus on a multitude of design details available to achieve the desired objectives", noted Dumont, "It will allow users to input different scenarios and compare them."

"The Water Balance Model website will be a place to get dependable answers, a place where efficient and secure access to data, tools and methods is consolidated on an agreed common platform", he continued.

"Rather than expending effort re-inventing calculation methods and chasing routine data, stakeholders will focus on developing the results they seek in an accessible, flexible and proven environment that has been delivered with the features they have specified", he explained.

"This tool is the professional computational and communication backbone that will take us towards the sustainable reality of a greening of the built environment", concluded Jim Dumont.



Suggested reading:

Stormwater Management: A Discipline in Transition, article by Jim Dumont, published by the Association of Professional Engineers and Geoscientists of British Columbia in **Innovation Magazine**, September/October 2006.