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Technical Memorandum

Phase 1 Part 2 CSO Control Plan
Wellington Avenue CSO Facility

Hydraulic Modeling Software Selection

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INTRODUCTION

In the Phase I Part I Wellington Avenue CSO Facility CSO Control Plan Report, Earth Tech recommended the city or Earth Tech, on behalf of the city, develop a hydraulic model of the City's entire collection system, including the sewers, pump stations, combined sewer overflows, and CSO facilities, to accurately establish the system's baseline flow conditions and response to wet weather with regard to CSO events at each of the CSO facilities. A model would also provide a tool to assess the effectiveness of CSO control alternatives with regard to the frequency and volume of CSO using both historical long term rainfall data and design storms such as the 1-year 6-hour storm required by RIDEM CSO Policy. As a first step for the development of a system wide hydraulic model for the city, Earth Tech conducted a comparison of various commercially available hydraulic modeling software packages. This Technical Memorandum (TM) presents the results of Earth Tech's comparison and recommends the most appropriate hydraulic modeling software package, based on the conditions encountered, to the city of Newport. This TM is designed to assist the city in selecting a model that meets their technical needs and is cost effective.

REQUIREMENTS FOR MODELING SOFTWARE

The following general requirements were considered to determine which hydraulic models were selected for evaluation:

Hydrologic and hydraulic analysis – The model must have a hydrologic component that will allow: simulating the time varying physical process of rainfall onto land of varying land use characteristics; conversion of the rainfall to runoff; and routing of the runoff through the collection system. The model must be capable of simulating flows under both free surface and surcharged conditions. The model must also be capable of simulating hydraulic elements such as orifices, weirs, pumps, and flap gates.

Ability to perform combined sewer overflow analysis – The model must have the ability to perform both single event and long term continuous simulations to allow predictions of the frequency, volume, and flow rate of combined sewer overflows under existing and future planned conditions. Both types of simulation are key to understanding the behavior of a combined sewer system, analyzing controls (elimination of infiltration/inflow sources, storage tanks, consolidation conduits, etc.), and projecting CSO impacts to receiving waters.

GIS Integration – The model must allow sewer data from the city's GIS to be imported into the model.

Capacity Analysis – The model must have the capability to determine the capacity requirements for existing, new, replacement, and rehabilitated sewers and storm drains.

Development Reviews – The model must have the capability to perform flow and capacity evaluations in response to development proposals for new residential, commercial or industrial developments.

MODELS EVALUATED

Four models were selected for evaluation; each meeting the above referenced general criteria: INFOWORKS, XPSWMM, DHI MOUSE and EPA's Storm Water Management Model (SWMM). These models were selected because each can simulate sanitary, storm and combined sewer systems, using either static or dynamic analyses. All of the models can accept either fixed inflows or input hydrographs, or they can generate flows based on rainfall data and standard hydrologic parameters (i.e., catchment area, land use, and time of concentration). Each of the models has the ability to simulate a single event (either an actual rainfall event or a design storm) and continuous simulation of a long period of rainfall data such that predictions of the flow rate, volume and frequency of combined sewer overflows can be analyzed.

With regard to hydrologic calculations, each of the models can simulate the various processes that produce runoff from urban areas, including:

- time-varying rainfall
- evaporation of standing surface water
- snow accumulation and melting
- rainfall interception from depression storage
- infiltration of rainfall into unsaturated soil layers
- percolation of infiltrated water into groundwater layers
- interflow between groundwater and the drainage system
- non-linear reservoir routing of overland flow.

In each model, spatial variability in all of these processes is achieved by dividing the study area into a collection of smaller, sub-catchment areas, each containing its own fraction of pervious and impervious sub-areas. Overland flow can be routed between sub-areas, between sub-catchments, or between entry points of a drainage system.

Each model contains hydraulic modeling capabilities used to route runoff and external inflows through the drainage system network of pipes, channels, storage/treatment units and diversion structures. These include the ability to:

- handle drainage networks of unlimited size
- use a wide variety of standard closed and open conduit shapes as well as natural channels
- model special elements such as storage/treatment units, flow dividers, pumps, weirs, and orifices
- apply external flows and water quality inputs from surface runoff, groundwater interflow, rainfall-dependent infiltration/inflow, dry weather sanitary flow, and user-defined inflows
- utilize either kinematic wave or full dynamic wave flow routing methods
- model various flow regimes, such as backwater, surcharging, reverse flow, and surface ponding
- apply user-defined dynamic control rules to simulate the operation of pumps, orifice openings, and weir crest levels

The key component that each of these models has is the ability to simulate free-surface flow, pressure flow and surcharge flow. Each of the models can simulate flows under free surface conditions (i.e., utilizing Manning's Equation where velocity and cross sectional flow area are constant over time). For pressure and surcharge flow conditions, each model utilizes the Saint Venant flow equations (i.e., gradually varied unsteady flow conditions where flow velocity and cross sectional area are not constant over time). By utilizing the Saint Venant equations, each of the models can account for channel storage, backwater effects caused by tidal and non-tidal conditions, entrance and exit losses, flow reversals and surcharge conditions.

The following are brief descriptions of each of the models that were selected for evaluation.

Wallingford Inc.'s InfoWorks

Wallingford Inc.'s InfoWorks and its predecessors have been in use since about 1980. The InfoWorks program was introduced to the United States in 1995. InfoWorks is a dynamic engine designed to model unsteady-state conditions to predict unsteady free-surface flow in pipes. Using the St. Venant equation, InfoWorks solves the finite difference equation implicitly. InfoWorks offers a choice of hydrologic models, including fixed percentage runoff and a variable percentage runoff in which the proportion of runoff is a function of impermeable surface, soil types and antecedent wetness of each sub-catchment. Inflow over the catchment is distributed among the different surfaces using weighting coefficients. InfoWorks can also model sediment transport. InfoWorks is the most expensive modeling software discussed in this TM. The software, with needed add on modules, can exceed $40,000.

XP Software's XP-SWMM

XP-SWMM was developed by XP Software and has been commercially available since 1992. Similar to InfoWorks and MOUSE, XP-SWMM is a fully dynamic modeling software and can solve the St. Venant equation implicitly or explicitly. The XP-SWMM modeling engine tends to use larger time steps causing a longer time requirement to run the model and some instability in the model. XP-SWMM offers 12 different hydrologic options for examining I/I flow. Additionally, external flows can be read into the model and injected into various nodes in the model. Similar to InfoWorks, XP-SWMM's inflow model uses a percentage of runoff from a catchment area proportionate to the impervious area. XP-SWMM can also model sediment transport. XP-SWMM's data management, integration ability, ease of calibration and GIS capability are deficient compared to InfoWorks or MOUSE/MIKE URBAN. The cost for the XP-SWMM modeling software is approximately $16,000.

DHI Inc's MOUSE/MIKE URBAN

DHI Water and Environment's MOUSE modeling software has been commercially available since the late 1970's. DHI's MIKE URBAN is the latest release of DHI's MOUSE software package. MIKE URBAN performs similarly to MOUSE with an improved GIS interface based on ESRI's ArcGIS software. As MIKE URBAN uses the MOUSE system, they are referred to as MOUSE in this TM. Similar to InfoWorks, MOUSE is a fully dynamic model solving the St. Venant equation implicitly. The MOUSE engine is slower than that of InfoWorks, however, it yields similar results given similar input data. MOUSE models inflow and infiltration (I/I) using a rainfall dependent I/I module, which includes a surface runoff model to account for rapid I/I from impervious areas and a hydrologic model to account for slower I/I from the surrounding soil. Because the behavior of I/I coming from the surrounding soil is derived from soil moisture and previous hydrologic activity, the module describes the effects of soil moisture content and evaporation on the I/I flow. MOUSE/MIKE URBAN can cost between $18,000 and $25,000 depending on the add modules included.

EPA's SWMM

The EPA Storm Water Management Model, SWMM, is a fully dynamic model that was first developed in 1971, and has since undergone several major upgrades. It continues to be widely used throughout the world for planning, analysis and design related to storm water runoff, combined sewers, sanitary sewers, and other drainage systems in urban areas, with many applications in non-urban areas as well. The current edition, Version 5, runs under Windows. It provides an integrated environment for editing study area input data, running hydrologic, hydraulic and water quality simulations, and viewing the results in a variety of formats. These include color-coded drainage area and conveyance system maps, time series graphs and tables, profile plots, and statistical frequency analyses. The model is public domain software available for download from USEPA's website at no cost.

METHODOLOGY FOR COMPARING MODELING SOFTWARE

The following criteria were established to evaluate the five models:

- Technical Requirements (applicability to the Newport system and project requirements) 60%
- Cost to Purchase Software Package 20%
- Ease of Use 10%
- Technical Support 10%

Each of the categories was assigned a numeric rating from 1 to 10, with 10 indicating the best fit of the criteria. The features of each model were evaluated with respect to each of these categories.

A summary of the results of the comparison is shown in Table 1. A description of each of the criteria is described on the table.

TABLE 1
Software Selection - Evaluation Matrix

TOPIC		Weighting	Wallingford Inc. Info Works		XP-Software XP-SWMM		DHI Inc MOUSE		EPA SWMM	
TECHNICAL REQUIREMENTS	**Hydraulics**	**10**	**9**	Dynamic model - will assess average and peak sanitary flows for sanitary system sizing and optimization using a dynamic approach. Fastest and most stable fully dynamic engine.	**7**	Dynamic model - will assess average and peak sanitary flows for sanitary system sizing and optimization using a dynamic approach. Tends to be unstable with longer step times.	**9**	Dynamic model - will assess average and peak sanitary flows for sanitary system sizing and optimization using a dynamic approach. Slightly slower engine than InfoWorks.	**7**	Dynamic model - will assess average and peak sanitary flows for sanitary system sizing and optimization using a dynamic approach.
	Hydrology Simulation (Storm Water Modeling)	**10**	**9**	InfoWorks uses a groundwater infiltration module to simulate the influence of groundwater table on infiltration flow. Info Works provides an advance analyses to model flow control structures, pumps and siphons.	**9**	XPSWMM uses a groundwater infiltration module to simulate the influence of groundwater table on infiltration flow. Also it could evaluate any infrastructure like sewer siphon, gate, and weirs.	**9**	MOUSE most closely simulates the true physical processes of inflow and infiltration. It could also evaluate any new infrastructure like siphon, pipe with different sections	**9**	EPA SWMM uses a groundwater infiltration module to simulate the influence of groundwater table on infiltration flow. Also it can evaluate any infrastructure like sewer siphon, gate, and weirs.
	Data Management	**10**	**9**	All data is maintained within the program, changes are tracked and displayed by each user. Scenario Manager allows tracking of each scenario through parent/child concept to track system modifications between scenarios.	**5**	Project (Scenario Management) is available and multiple files can be solved using Multi-Run Command. Modeling parameters can be updated directly through the project database.	**8**	MOUSE 2002 is capable for handling multiple "What-If" scenarios and examines an unlimited number of alternative modeling scenarios. MOUSE also has a Scenario Manager, which aids in the management of files, alternatives and calibration runs.	**0**	Data can not be managed under SWMM Application.
	Integration Ability	**10**	**7**	Imported data is contained within the .iwm file. Rigorous data management and tracking tools including data flags, which allow the modeler to track the source and validity of the data or changes to the data.	**5**	XP-SWMM uses mapping functionality to import GIS database files into the software and does not work directly with GIS layers. User needs to map the necessary database fields in the software to the corresponding fields in the GIS data.	**7**	Can import/edit GIS files in MOUSE. Converts imported data into a binary file format MOUSE can read. Allows import through an Open Database Connection (ODBC) connection as a database file. MIKE URBAN- user interface similar to ArcGIS maintaining ODBC.	**0**	No Integration ability at all.
	Ease of Calibration	**10**	**9**	In InfoWorks, the amount and speed of flow is adjusted to match the graphs for predicted vs. observed flows. This response is achieved through adjustments to runoff surfaces and the groundwater infiltration module.	**6**	XPSWMM has a sensitivity analysis tool that identifies which factors influence storm events and allows for adjustment of these factors. Calibrating to wet-weather events in XP-SWMM can be difficult due to its inability to graph rainfall with the simulated and measured flow.	**8**	MOUSE's calibration tool is more physically based than the other models and is better suited for calibration where the individual flow components can be identified and tracked. Longer calibration time and extensive data required due to increased precision and accuracy.	**0**	No Calibration tool
	GIS Capability	**10**	**9**	InfoWorks has the most extensive and comprehensive GIS interface. Software allows overlaying with background images, import/export shape files.	**5**	XP-SWMM imports data using a mapping tool instead of directly importing GIS data. Software allows overlaying with background images and exporting modeling networks to image file (e.g. dxf)	**8**	Not as extensive and comprehensive as InfoWorks. MOUSE GM can be used to clean, fix and import GIS data. Software allows overlaying with background images, import/export shape files	**2**	EPA SWMM is capable of accepting a metafile from the GIS system, but no vertical data.
PRICE (Based on Unlimited Node Version)		**20**	**10**	$42,000	**15**	$16,000.00	**15**	$18,000	**20**	Free
Ease of Use		**10**	**9**	A user friendly program with good graphic features. Stable engine using variable time step. Many additional graphic and reporting components. Includes flagging and data management tools.	**5**	3000 pipe system requires 1hr per 1 day of simulation with above computer settings. A sophisticated program with lots of features and good graphic features. However, XPSWMM uses the SWMM engine and has slow run times and is not as stable as the other nominees	**8**	A sophisticated program with lots of features. It uses a variable time step and has many graphical features. It is more stable that the SWMM engine.	**0**	Extremely difficult to understand, learn and use the code to model a large network.
Technical Support		**10**	**8**	Can provide on site and on-line training. Technical support and Software Maintenance is 15% of the software cost annually. It includes unlimited phone, fax, email and WEBEX support as well as software upgrades during the year.	**8**	Annual Support which includes a full year of program upgrades and technical support, including our new online support is free for the first year after purchase.	**8**	Including one year maintenance which include model update and telephone\email support. Used in 120 countries with over 1,000 licenses. WEBEX, email and telephone support is provided whenever required.	**0**	The only support to the SWMM Modeling tool is from the SWMM user listserver or other SWMM User's personal web sites
OVERALL EVALUATION		**100**	**79**		**65**		**80**		**38**	

Note: All prices are exclusive of and other taxes and duties.

RECOMMENDATIONS

Earth Tech performed an evaluation of five hydraulic models currently being utilized for hydrologic and hydraulic analysis of combined and separated wastewater collection systems, similar to the city of Newport's system. Earth Tech has extensive experience with each of the modeling software packages. Based on the review of the features of each of these models, Earth Tech recommends that the MOUSE model be utilized to perform the analysis of the city's sanitary sewer system, storm drains and combined sewer overflows

The DHI MOUSE model is recommended for use based on the following:

- DHI is an established name in hydraulic modeling. Their Mouse product has a very stable hydraulic engine.
- DHI MOUSE/MIKE URBAN's ease of use is nearly equal to InfoWorks and far exceeds that of XP-SWMM and EPA SWMM.
- DHI MOUSE is faster and more stable than XP-SWMM.
- DHI MOUSE's RDII module (dealing with rainfall-derived inflow and infiltration) seems to have the most well developed and explicit approach to modeling wastewater high flow events. It directly simulates the actual physical driving forces.
- New MIKE URBAN interface module will close the gap between MOUSE and competitor InfoWorks in the GIS capability, integration ability, and ease of use categories. MIKE URBAN's ability to work well with ESRI's ARCGIS products would permit the city to manipulate the model simply by importing existing or updated GIS mapping.
- Pricing for MOUSE/MIKE URBAN is much more attractive than its main competitor InfoWorks.
- Technical support for DHI is comparable or better than all of the other model software packages.

Considering all of the above, DHI MOUSE is the recommended choice for modeling the city of Newport's sanitary sewer system, particularly with the wet weather inflow conditions that the system has exhibited. It is noted that Wallingford Inc.'s Info Works is rated favorably as well. Earth Tech has used InfoWorks to perform hydraulic analysis for several municipal clients. While InfoWorks is marginally better than DHI's MOUSE in some evaluation categories, it's high price and high maintenance and support fees don't justify spending the additional money at more than double the cost of DHI MOUSE. DHI's MOUSE/MIKE URBAN is the most cost effective software package to meet the city's needs at a lower cost.