1-1-2007

Modelling of methoprene concentration at storm sewer outfall

Cynthia Tam
Ryerson University

Follow this and additional works at: <http://digitalcommons.ryerson.ca/dissertations>

Part of the [Civil Engineering Commons](#)

Recommended Citation

Tam, Cynthia, "Modelling of methoprene concentration at storm sewer outfall" (2007). *Theses and dissertations*. Paper 274.

This Thesis Project is brought to you for free and open access by Digital Commons @ Ryerson. It has been accepted for inclusion in Theses and dissertations by an authorized administrator of Digital Commons @ Ryerson. For more information, please contact bcameron@ryerson.ca.

NOTE TO USERS

This reproduction is the best copy available.

UMI[®]

b17758/05

RA
640
T36
2007

Modelling of Methoprene Concentration at Storm Sewer Outfall

By

Cynthia Tam

B.A.Sc., University of Waterloo, Waterloo, Ontario, 2000

A project

presented to Ryerson University

in partial fulfillment of the
requirement for the degree of

Master of Engineering

in the Program of

Civil Engineering

Toronto, Ontario, Canada, 2007

© Cynthia Tam 2007

PROPERTY OF
RYERSON UNIVERSITY LIBRARY

UMI Number: EC53671

INFORMATION TO USERS

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleed-through, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

UMI Microform EC53671
Copyright 2009 by ProQuest LLC
All rights reserved. This microform edition is protected against
unauthorized copying under Title 17, United States Code.

ProQuest LLC
789 East Eisenhower Parkway
P.O. Box 1346
Ann Arbor, MI 48106-1346

AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this project.

I authorize Ryerson University to lend this project to other institutions or individuals for the purpose of scholarly research.

(Cynthia Tam)

I further authorize Ryerson University to reproduce this project by photocopying or by other means, in total or in part, at the request of other institutions or individuals for the purpose of scholarly research.

(Cynthia Tam)

ABSTRACT

Title: Modelling of Methoprene Concentration at Storm Sewer Outfall

Author: Cynthia Tam, Master of Engineering in Civil Engineering, Ryerson University 2007

The objective of this report is to compare the predicted concentration of methoprene, a larvicide used in the City of Toronto to control the widespread of West Nile Virus by suppressing mosquito growth, at storm sewer outfall during a typical year rainfalls (1980 rainfalls) with the Interim Provincial Water Quality Objectives (IPWQO). The methoprene that is under investigation in this report is in form of ingot. Extending from an existing spreadsheet-based model that simulates the methoprene concentration within two monitored catch basins in the Newtonbrook sewershed of North York, methoprene concentration at the sewer outfall during the 1980 rainfalls is predicted by linear projection upon calibration of the model with the methoprene mass at the outfall measured in year 2005. Results show that predicted methoprene concentration at outfall exceeds the IPWQO in six days out of the one-hundred-day period. It is recommended that to better mimic the actual situation, traveling time effect and sensitivity analysis on catch basin sump volume be included in future study.

ACKNOWLEDGMENTS

The author would like to thank Dr. James Li of Ryerson University for his patient guidance throughout this project. Appreciation is also extended to Kevin Sze for his kind support during analysis process.

TABLE OF CONTENT

AUTHOR'S DECLARATION	III
ABSTRACT	IV
ACKNOWLEDGMENTS.....	V
CHAPTER 1 : INTRODUCTION	1
1.1 BACKGROUND.....	1
1.2 OBJECTIVE AND SCOPE	1
CHAPTER 2 : LITERATURE REVIEW	2
2.1 WEST NILE VIRUS.....	2
2.1.1 <i>History</i>	2
2.1.2 <i>Larviciding Activities</i>	4
2.2 METHOPRENE.....	7
2.2.1 <i>Effects to Human Health</i>	9
2.2.2 <i>Environmental Toxicity</i>	9
2.3 PROVINCIAL WATER QUALITY OBJECTIVES (PWQOs).....	12
2.4 HYDROLOGY MODELLING.....	13
CHAPTER 3 : METHODOLOGY	16
3.1 DATA MEASUREMENTS.....	16
3.2 CATCH BASIN MASS BALANCED MODEL	19
3.2.1 <i>Dry Weather Condition</i>	20
3.2.2 <i>Wet Weather Condition</i>	20
3.2.3 <i>Model Description</i>	23
3.3 CALIBRATION WITH RUNOFF VOLUME.....	24
3.4 CALIBRATION WITH OUTFALL MASS.....	31
3.4.1 <i>Unit Catch Basin Approach</i>	32
3.4.2 <i>Distribution Approach</i>	32
CHAPTER 4 : CASE STUDY	34
4.2 GENERIC CATCH BASIN MODEL.....	40
4.3 TYPICAL YEAR RAINFALLS WATER QUALITY MODEL.....	41
CHAPTER 5 : CONCLUSIONS AND RECOMMENDATIONS.....	44
5.1 CONCLUSIONS.....	44
5.2 RECOMMENDATIONS.....	45

REFERENCES.....	46
------------------------	-----------

LIST OF TABLES

TABLE 2-1: HUMAN SURVEILLANCE IN CANADA (2002 TO 2006)	4
TABLE 2-2: WNV HUMAN CASES IN TORONTO (2002 TO 2006)	4
TABLE 2-3: PROPERTIES OF METHOPRENE	8
TABLE 2-4: ACUTE AQUATIC ECOTOXICITY SUMMARIES FOR METHOPRENE.....	11
TABLE 2-5: MOE BENCHMARKS AND DRAFT IPWQO FOR METHOPRENE.....	13
TABLE 2-6: FREQUENTLY USED URBAN STORMWATER SIMULATION MODELS.....	14
TABLE 3-1: DRAINAGE AREA AND PERCENTAGE OF IMPERVIOUSNESS	16
TABLE 3-2: VISUAL OTTHYMO IMPERVIOUSNESS CALIBRATION	29
TABLE 3-3: PERVIOUS RUNOFF COEFFICIENT CALIBRATION.....	31
TABLE 3-4: MODEL PARAMETERS CALIBRATION.....	32
TABLE 4-1: MODEL PARAMETERS AND RELEASE DAY OF CATCH BASIN S1	38
TABLE 4-2: MODEL PARAMETERS AND RELEASE DAY OF CATCH BASIN S2.....	38

LIST OF FIGURES

FIGURE 2-1: MOSQUITO LIFE CYCLE.....	5
FIGURE 2-2: LARVICIDING MAP OF CITY OF TORONTO	6
FIGURE 2-3: STRUCTURAL FORMULA OF METHOPRENE	7
FIGURE 3-1: NEWTONBROOK SEWERSHED	17
FIGURE 3-2: LAB TANK.....	19
FIGURE 3-3: RELEASE OF METHOPRENE FROM CATCH BASIN	21
FIGURE 3-4: VISUAL OTTHYMO SCHEMATIC	26
FIGURE 3-5: TRIBUTARY AREAS OF SUBCATCHMENTS.....	27
FIGURE 3-6: CATCH BASINS DISTRIBUTION WITHIN NEWTONBROOK SEWERSHED	30
FIGURE 4-1: METHOPRENE CONCENTRATIONS AT LAB TANK MT1	35
FIGURE 4-2: METHOPRENE CONCENTRATIONS AT LAB TANK MT2	35
FIGURE 4-3: METHOPRENE CONCENTRATIONS AT LAB TANK (2004 AND 2005)	36
FIGURE 4-4: METHOPRENE CONCENTRATION AT CATCH BASIN S1.....	37
FIGURE 4-5: METHOPRENE CONCENTRATION AT CATCH BASIN S2.....	37
FIGURE 4-6: OVERALL RELEASE TIME AND RAINFALL RELATIONSHIP	38
FIGURE 4-7: METHOPRENE CONCENTRATION MEASUREMENTS AT OUTFALL - JULY 17, 2005.....	39

FIGURE 4-8: METHOPRENE CONCENTRATION MEASUREMENTS AT OUTFALL - AUGUST 2, 2005	39
FIGURE 4-9: METHOPRENE CONCENTRATION MEASUREMENTS AT OUTFALL - AUGUST 10, 2005 ..	40
FIGURE 4-10: METHOPRENE CONCENTRATION MEASUREMENTS AT OUTFALL - AUGUST 19, 2005	40
FIGURE 4-11: METHOPRENE CONCENTRATION AT A GENERIC CATCH BASIN	41
FIGURE 4-12: METHOPRENE CONCENTRATIONS AT CATCH BASIN DURING TYPICAL YEAR RAINFALLS	42
FIGURE 4-13: METHOPRENE CONCENTRATIONS TO OUTFALL DURING TYPICAL YEAR RAINFALLS	42

APPENDIX A: VISUAL OTTHYMO MODEL

APPENDIX B: MASS BALANCE MODELS

CHAPTER 1 : INTRODUCTION

1.1 Background

Methoprene is a larvicide that is used to control the widespread of West Nile Virus in Toronto, whereas West Nile Virus is a mosquito-borne virus that is threatening human and animal life in recent years. The first case of West Nile Virus in North America occurred in 1999 in New York City, while the virus spreads out across the North America since then. In 2002, West Nile Virus attacked Toronto and caused 11 human deaths. A West Nile Virus program, including the larviciding activities, was established in that year to control the widespread of the virus.

The larviciding activities in Toronto involve the addition of Methoprene to catch basins. The characteristic of methoprene will be discussed, and the concern related to the methoprene application to catch basins will be covered in this report. As methoprene is a chemical with a certain level of toxicity, modeling of methoprene concentration at storm sewer outfall is performed and compared to the Interim Provincial Water Quality Objectives.

1.2 Objective and Scope

The objective of this research project is to predict the concentration of methoprene released from catchments when methoprene in form of ingot is used as larviciding agent in a sewershed. For the purpose of this study, methoprene concentrations were measured at two catch basins and at the storm sewer outfall within the Newtonbrook sewershed in North York, Toronto.

CHAPTER 2 : LITERATURE REVIEW

2.1 West Nile Virus

West Nile Virus is a vector-borne virus in which mosquito is the media of transmitting the virus. There are 74 known species of mosquitoes in Canada. West Nile virus infection has been found in 10 of these, but it is more common in species that feed on birds such as *Culex pipiens*, *Culex restuans* and *Culex tarsalis* (PHAC, 2006). The virus is transmitted to human by a bite of an infected mosquito which breeds on birds that carry the virus, while *culex pipiens* is the most common type of mosquito that feeds on bird in Canada. Most people infected with West Nile Virus shows no symptoms, or only have mild flu-like symptoms. However for some individuals that have weaker immune systems, serious symptoms such as meningitis, encephalitis, and acute flaccid paralysis might occur. Studies to date show that some people with serious symptoms and health effects recover completely, while others experience prolonged health problems, in which scientists do not know the reason (Health Canada, 2004).

2.1.1 History

West Nile Virus was first isolated in the West Nile District of Uganda in 1937. The outbreak of West Nile Virus happened in Israel in 1957, while the virus spread to Egypt and France in the early 1960s. Outbreaks of West Nile Virus encephalitis in humans have occurred in Algeria in 1994, Romania in 1996-1997, the Czech Republic in 1997, the Democratic Republic of the Congo in 1998, Russia in 1999, the United States in 1999-2003, Israel in 2000 (CDC, 2004), and Canada in 2002-2003. The virus first appeared in North America in 1999 in New York City and widely spread across North America since then. The first reports of West Nile virus activity in Canada came in August 2001, when the virus was found in dead birds and mosquito pools in southern Ontario.

Canada had its first confirmed human cases in 2002, after people tested positive for West Nile virus in parts of Quebec and Ontario. The virus was also found in

birds, horses or mosquitoes in Nova Scotia, Quebec, Ontario, Manitoba and Saskatchewan. In 2003, over 1400 clinical cases were reported from Nova Scotia, New Brunswick, Quebec, Ontario, Manitoba, Saskatchewan, Alberta, British Columbia and the Yukon, while only 26 cases were reported in Quebec, Manitoba and Saskatchewan in 2004. In 2005, more than 200 Canadians were diagnosed with West Nile virus, whereas almost half of these were in Ontario, with Manitoba and Saskatchewan equally sharing most of the remainder (PHAC, 2006). Table 2-1 shows the cases of human surveillances in Canada from 2002 to 2006.

The first human case of West Nile Virus in Toronto occurred in 2002 when 11 deaths were reported to Toronto Public Health (City of Toronto, 2004). Table 2-2 shows the number of human cases from 2002 to 2006. Since the first occurrence of West Nile Virus human case in 2002, the City of Toronto established a West Nile Virus Control Program. The program includes a public education and community outreach, West Nile Virus surveillance, and mosquito control:

1. Public education and community outreach is provided through a campaign involving information sessions, publications, online information, paid advertising, and circulation of materials to libraries and civic and recreation centres. An information line is also available for general information and for residents to report stagnant water, dead birds, or dead bird pick-up (TPH, 2004).
2. West Nile surveillance involves the surveillance and pick-up of dead birds, surveillance of adult mosquitoes, larval mosquitoes, and human West Nile Virus cases.
3. Mosquito control includes source reduction and larviciding. For source control purpose, standing water and stagnant water are identified and eliminated to reduce mosquito breeding. Larvicide is applied to storm water catch basins in City of Toronto during larviciding activities, as a 2002 study confirmed that there are larvae existing in virtually all of the catch basins being sampled (TPH, 2004).

Table 2-1: Human Surveillance in Canada (2002 to 2006)

Total ² Reported West Nile Virus Clinical Cases and Asymptomatic Infections (WNAI ⁴) in Canada: 2002-2006										
Province/Territory	2002 ⁵		2003 ⁵		2004 ⁵		2005		2006	
	Total ²	WNAI ⁴	Total ²	WNAI ⁴	Total ²	WNAI ⁴	Total ²	WNAI ⁴	Total ²	WNAI ⁴
Newfoundland and Labrador	0	0	0	0	0	0	0	0	0	0
Prince Edward Island	0	0	0	0	0	0	1 ⁵	0	0	0
Nova Scotia	0	0	2 ⁵	0	0	0	1 ⁵	0	0	0
New Brunswick	0	0	1 ⁵	0	0	0	1 ⁵	0	0	0
Quebec	20	0	17	0	3 ³	0	4	1	1	0
Ontario ¹	394 ³	0	89 ³	0	13 ³	1	95 ³	6	42 ³	0
Manitoba	0	0	142 ³	1	3	0	55	3	50	1
Saskatchewan	0	0	937 ³	10	5 ³	0	58 ³	3	19 ³	1
Alberta ¹	0	0	272 ³	3	1 ⁵	0	10 ³	0	39 ³	1
British Columbia	0	0	20 ⁵	0	0	0	0	0	0	0
Yukon	0	0	1 ⁵	0	0	0	0	0	0	0
Northwest Territories	0	0	0	0	0	0	0	0	0	0
Nunavut	0	0	0	0	0	0	0	0	0	0
Total²	414	0	1481	14	25	1	225	13	151	3

¹ These totals include both probable and confirmed WNV cases.

² Total clinical cases is the sum of WNV Neurological Syndrome + WNV Non-Neurological Syndrome + WNV Unclassified/Unspecified.

³ These totals include some cases related to travel outside the province/ territory.

⁴ Satisfies West Nile virus diagnostic test criteria IN THE ABSENCE of clinical criteria. This category could include asymptomatic blood donors whose blood is screened using a Nucleic Acid Amplification Test (NAT), by Blood Operators (i.e. Canadian Blood Services or Hema-Quebec) and is subsequently brought to the attention of public health officials. Blood Operators in Canada perform a supplementary WN virus-specific NAT following any positive donor test result.

⁵ All related to travel outside the province/ territory.

⁶ In 2002-2004, WNV Non-Neurological Syndrome was called West Nile Fever (WNF). In 2002, WNV Neurological Syndrome was called WNV encephalitis including aseptic meningitis and encephalitis.

Source: PHAC, 2006

Table 2-2: WNV Human Cases in Toronto (2002 to 2006)

Year	2002	2003	2004	2005	2006
# of Cases	129	44	6	38	6

Sources: York Region, 2006; City of Toronto, 2006

2.1.2 Larviciding Activities

Mosquito has a four-stage life cycle: eggs, larva, pupa, to adult mosquitoes. Figure 2-1 illustrates the life cycle of mosquito. It takes around 8 to 12 days for

mosquito eggs to turn to adult mosquitoes, while adult mosquitoes can live for a period of 4 to 8 weeks.

Source: USEPA, 2003

Figure 2-1: Mosquito life cycle

Larviciding refers to the use of larvicide as a pesticide to kill mosquito larvae before they mature to mosquito adult which can reproduce and have the ability to act as carriers of West Nile Virus. Among all the types of mosquito, *culex pipiens* are most likely found to transmit the virus. *Culex pipiens* breed in small, stagnant pools of water but not in open bodies of water such as lake, and catch basins are one of the favorable environments for *culex pipiens* to breed. As supported by the result of the study carried out in 2002, mosquito larvae were presence in virtually all Toronto catch basin that were sampled, while the catch basins in residential areas had a lot more larvae than those in commercial or industrial zone. Therefore, City of Toronto's larviciding activities are focused on the catch basins within residential districts, parks, and laneways that are owned and maintained by the City (TPH, 2004). Figure 2-2 illustrates the City of Toronto's larviciding map. The city is divided into 18 sections for administrative purposes, while approximately 150,000 catch basins within the City are treated with larvicide every summer.

Figure 2-2: Larviciding Map of City of Toronto

Source: TPH, 2004

2.2 Methoprene

Three kinds of larvicides are adopted in City of Toronto – methoprene, Bs (*Bacillus sphaericus*) and Bti (*Bacillus thuringiensis israelensis*). Methoprene and Bs are used to treat catch basins, while Bti is used in other areas to reduce mosquito breeding, in which Bs and Bti are biological pesticides derived from naturally occurring soil bacteria, and methoprene is classified as biochemical pesticide by United States Environmental Protection Agency (USEPA). This research focuses in the study of the fate of methoprene in urban drainage system.

Methoprene, with molecular formula $C_{19}H_{34}O_3$ (Figure 2-3), is an insect growth regulator (IGR) that control mosquito population by interfering mosquito's life cycle and prevent them from reaching adulthood which is the reproductive stage.

Source: PMRA, 2007

Figure 2-3: Structural Formula of Methoprene

Altosid is the name of methoprene products being used in mosquitoes control. Forms of Altosid that are used by the City of Toronto for larviciding activities are pellets, and ingots. Lethal concentration of methoprene has been reported as 0.3 to 2.3 $\mu\text{g/L}$ for *Culex* (Des Lauriers, 2003).

Altosid pellet was approved by the USEPA for use in April 1990, while it contains 4% (wt./wt.) s-methoprene (0.04 lb. active ingredient (AI)/lb), dental plaster (calcium sulphate), and charcoal. Altosid ingot is made of hard dental plaster, 1.8% (wt./wt.) s-methoprene (0.00145 lb. AI/ingot) and charcoal (to retard ultraviolet light degradation). Dental plaster and charcoal are ingredients that slow down the release of methoprene in water, and retard the methoprene degradation in sunlight respectively. A single application of Altosid Pellet can provide mosquito control for up to 30 days under normal weather conditions in

submerged environment, whereas the comparatively harder plaster and larger size of Altosid ingot changes the erosion rate and allows the sustained s-methoprene to release up to 150 days in normal weather (FCCMC, 1998).

Studies demonstrate that methoprene is an unstable substance. It is shown in experimental soil tests that methoprene degrades rapidly in soil, and microbial degradation is the major route of the reaction with soil. Methoprene is unlikely to leach through soil as it is rapidly absorbed by soil. Photolysis also occurs when methoprene is in contact with sunlight, while its half-life under sunlight is very short. Hydrolysis is another reaction that methoprene undergoes when it is submerged in water. Under normal conditions of sunlight and temperature, methoprene degrades rapidly when it is applied to water (PMEP, 2001). Table 2-3 listed the properties of methoprene.

Table 2-3: Properties of Methoprene

Properties	Values
Hydrolysis	$t_{1/2} > 4$ weeks (S-Methoprene)
Photolysis	$t_{1/2} < 10$ hours (S-Methoprene)
Reaction with Soil	$t_{1/2} \sim 10$ days (S-Methoprene)
Water Solubility	< 2 ppm (S-Methoprene)
Specific Gravity	0.9261 g/ml at 20°C
Boiling Point	100°C at 0.05 mm Hg
Vapor Pressure	2.37×10^{-5} mm Hg at 25°C 1.60×10^{-4} mm Hg at 40°C
Solubility in Other Solvents	Soluble in Organic Solvents

Sources: Altosid, 2004; PMEP, 2001

S-methoprene is first registered in Canada in 1982 for the control of insect pests in mushroom culture and stored tobacco, fleas and ticks on dogs, cats and indoor premises, as well as to prevent the emergence of adult mosquitoes from standing water, permanent water sites, storm drain ditches, and roadside ditches (PMRA, 2001).

2.2.1 Effects to Human Health

Studies indicate that methoprene is of low toxicity and poses little risk to human health when used following label instructions. According to USEPA assessment on methoprene, it is not shown to have any significant toxicological effects in the standard battery of toxicity studies used to assess human health effects. It is also shown that methoprene has very low acute oral and inhalation toxicity potential, and is not an eye or skin irritant. Methoprene is also of low acute dermal (skin) toxicity and is not a human skin sensitizer (PMRA, 2001).

2.2.2 Environmental Toxicity

Methoprene has been shown to be practically non-toxic to terrestrial species including mallard ducks and quail and Methoprene had no effect on mallard or quail reproduction (USEPA, 2001). Evaluation of ecological effects of methoprene conducted by USEPA demonstrates that oral LD50 (lethal dosage to 50% of exposed test animal) of methoprene for mallard is greater than 2,250 mg/kg with no mortality or any overt signs of toxicity at any dose level. Furthermore, LC50 (lethal concentration that kills half the exposed test population) in 8-day feeding studies in both, mallard duck and bobwhite quail was more than 10,000 ppm, indicating that methoprene is practically non-toxic to birds (PMEP, 2001).

Ecological effect studies on aquatic species shows that methoprene is moderately toxic to warm water, freshwater fish, and is slightly toxic to cold water, freshwater fish. Exposure of aquatic organisms will be limited by the low solubility (0.51 ppm) of methoprene in water and by its rapid degradation in aquatic environments (PMEP, 2001). Altosid Briquet (ingot) Material Safety Data Sheet (MSDS) states that the LC50 in trout is 760 ppb, in bluegill is greater than 370 ppb, and in aquatic invertebrates such as *Daphnia* is 360 ppb (Altosid, 2004).

Methoprene can be very highly acutely toxic to estuarine and marine invertebrates. However, marine organisms are not likely to be exposed as a result of the use of

methoprene as a mosquito larvicide (USEPA, 2001). The LC50 of methoprene for fresh water shrimp was greater than 100 ppm, and the LC50 for estuarine mud crabs was greater than 0.1 ppm. The effects of methoprene on non-target aquatic crustaceans such as adults and larvae of shrimp, crabs and adult ghost shrimp investigated under controlled conditions indicate that a 96-hour LC50 for adult shrimp or adult crab is 1,050 ppb, whereas the 48-hour LC50 is 260 ppb for larvae. Use of methoprene is not expected to result in exposure to aquatic invertebrates since methoprene is short-lived in aquatic environment and it does not have a high potential for bioaccumulation (PMEP, 2001). Rate of release and data generated under laboratory and field conditions with methoprene mosquito product formulations, including slow release ingot formulations, indicate a maximal rate of release of ≤ 4 ppb. Therefore, exposure to methoprene will not reach levels which are toxic to aquatic non-target species either after acute or chronic exposure (USEPA, 2001).

Methoprene is toxic to amphibians, such as frogs, toads, and salamanders. Reportedly, low application rates and rapid dissipation characteristics of this material should prevent water concentrations from reaching levels that are lethal to most amphibians. Methoprene used as mosquito larvicide poses some hazards to freshwater invertebrates and non-target insects, but major effects are unlikely if applied according to manufacturer's instructions. Methoprene has very little effect, if any, on 35 species of exposed nontarget organisms including earthworms, waterfleas, damselflies, snails, tadpoles, and mosquito fish (PMEP, 2001). Table 2-4 presents a list of acute aquatic ecotoxicity summaries for methoprene from chemical toxicity studies on aquatic organism completed by the Pesticide Action Network. It is shown that the LC50 for all of the non-target species under concern are above 20 ppb, which is greater than the maximum rate of release of ≤ 4 ppb as suggested by USEPA studies.

Table 2.4: Acute Aquatic Ecotoxicity Summaries for Methoprene

Common Name	Scientific Name	Avg Species LC50 (ug/L)	LC50 Std Dev	Number of Studies	Avg Species Rating
Crustaceans					
Aquatic sowbug	Asellus hilgendorfi	300	-	1	Highly Toxic
Fish					
Mummichog	Fundulus heteroclitus	124950	-	1	Not Acutely Toxic
Channel catfish	Ictalurus punctatus	100000	-	3	Not Acutely Toxic
Bluegill	Lepomis macrochirus	9638	10473	6	Moderately Toxic
Coho salmon, silver salmon	Oncorhynchus kisutch	86000	-	1	Slightly Toxic
Rainbow trout, donaldson trout	Oncorhynchus mykiss	44361	44673	9	Slightly Toxic
Fathead minnow	Pimephales promelas	10000	-	5	Slightly Toxic
Australian blue-eye	Pseudomugil signifer	4000	-	1	Moderately Toxic
Insects					
Southern house mosquito	Culex quinquefasciatus	68.5	70.5	6	Very Highly Toxic
Molluscs					
Bladder snail	Physa fontinalis	10600	-	1	Slightly Toxic
Zooplankton					
Opossum shrimp	Americamysis bahia	106	-	1	Highly Toxic
Copepod	Apocyclops spartinus	4450	3551	4	Moderately Toxic
Water flea	Daphnia sp.	20	-	1	Very Highly Toxic
Scud	Gammarus aequicauda	1473	819.6	3	Moderately Toxic
Water flea	Moina macrocopa	425	85	2	Highly Toxic
Daggerblade grass shrimp	Palaemonetes pugio	10000	-	1	Slightly Toxic

(Source: Pesticide Action Network, 2007)

2.3 Provincial Water Quality Objectives (PWQOs)

PWQOs are numerical and narrative ambient surface water quality criteria which are applicable to all waters of Ontario (e.g. lakes, rivers and streams) except in those areas specifically designated, such as areas influenced by the Ministry of the Environment (MOE) approved point source discharges. In specific instances where groundwater is discharged to surface waters, PWQOs may also be applied to the groundwater. PWQOs represent a desirable level of water quality that the MOE strives to maintain in the surface waters of Ontario to protect all forms of aquatic life and all aspects of the aquatic life cycle during indefinite exposure to the water. PWQOs are set based on the lowest effect concentration for aquatic toxicity, bioaccumulation, and mutagenicity of the subject substances, with an added safety factor. In cases where insufficient toxicological information is available, Interim Provincial Water Quality Objectives (IPWQOs) are established (MOE, 1999).

IPWQO of methoprene is currently under development. Type of effects evaluated for methoprene included LC50s, embryo development, swimming behavior, and fecundity, whereas a safety factor of 10 is applied. In addition to the IPWQO, OMOE established lowest effects levels as benchmarks for fish, amphibians, and aquatic invertebrates. The draft IPWQO for methoprene, 0.2 µg/L, is derived from the amphibian benchmark of 1.6 µg/L for chronic exposure divided by 10. The 1.6 µg/L value comes from a study where significant abnormalities (missing hind limbs and eyes) are produced in Southern leopard frog juveniles exposed to an average methoprene concentration of 1.6 µg/L during a 90-day field exposure (Washington State Department of Ecology, 2006). Table 2-5 lists the MOE benchmarks and draft IPWQO for methoprene.

Table 2-5: MOE Benchmarks and Draft IPWQO for Methoprene

Organism	Benchmark (µg/L)
Fish	84
Invertebrates	10
Amphibians	1.6
draft IPWQO	0.2

(Source: Washington State Department of Ecology, 2006)

2.4 Hydrology Modelling

Hydrologic theory is used in this project to calculate runoff from each catch basin under the study area, while a hydrologic model is built using Visual OTTHYMO v2.0 model to calibrate the overall imperviousness of the subject catchment. Details of the model will be discussed in Chapter 3 and the model is shown in Appendix A of this report.

Hydrologic models are simplified, conceptual simulations of a part of the hydrologic cycle, and are primarily used for hydrologic prediction and for understanding hydrologic processes such as generating flow hydrographs from rainfall and drainage basin data. In other words, hydrologic simulation is the mathematical description of the response of a hydrologic water resource system to a series of events during a selected time period (Viessman and Lewis, 1996).

There are different classifications of simulation models, and one of the most descriptive classification is stochastic vs. deterministic models. Stochastic hydrology models are models based on data. These models adopt mathematical and statistical concepts to link input (e.g. rainfall) to the model output (e.g. runoff). Techniques that are commonly used in stochastic models are regression, transfer functions, neural networks, and system identification (Wikipedia, 2007). Deterministic hydrology models describe the behavior of the hydrologic cycle in terms of mathematical relations outlining the interactions of various phases of the hydrologic cycle. The models are usually structured to simulate streamflows from a given rainfall within watershed boundaries. The model is “verified” or

“calibrated” by comparing results of the simulation with existing records. Once the model is adjusted to fit the known period of data, additional periods of streamflow can be generated (Viessman and Lewis, 1996). Deterministic hydrology models can be subdivided into single-event models and continuous simulation models.

Public-domain stormwater simulation models that are commonly used are shown in Table 2-6. Some of the listed urban runoff simulation models only simulate the urban rainfall-runoff process, while others provide specifics on the type, size, and location of drainage and stormwater handling facilities. Most of them are either single-event models or continuous models that are primarily used in a single-event mode (Viessman and Lewis, 1996).

Table 2-6: Frequently Used Urban Stormwater Simulation Models

Code Name	Model Name	Agency Originating	Year
Rainfall-runoff event-simulation models			
HEC-1	HEC-1 Flood Hydrograph Package	Corps	1973
TR-20	Computer Program for Project Hydrology	SCS	1965
USGS	USGS Rainfall-Runoff Model	USGS	1972
HYMO	Hydrologic Model Computer Language	ARS	1972
SWMM	Storm Water Management Model	EPA	1971
Urban runoff simulation models			
UCURM	U. of Cincinnati Urban Runoff Model	U. of Cincinnati	1972
STORM	Storage, Treatment, Overflow Runoff Model	Corps of Engineers	1974
MITCAT	MIT Catchment Model	MIT	1970
TR-55	SCS Technical Release 55	SCS	1992
DR3M	Distributed Routing Rainfall-Runoff Model	USGS	1978
SWMM	Storm Water Management Model	EPA	1971
ILLUDAS	Illinois Urban Drainage Area Simulator	Ill. Water Survey	1972
PSURM	Pennsylvania State Urban Runoff Model	Pennsylvania State U.	1979

(Source: Viessman and Lewis, 1996)

Visual OTTHYMO v2.0 model that is used in this project is built on the OTTHYMO hydrology model which is an extension of the HYMO model

developed by Williams and Hann in 1972. The HYMO is a unique computer language designed for use by hydrologists who have no conventional computer programming experience. Once the program has been compiled, the user forms a sequence of commands that synthesize, route, store, plot, or add hydrographs for subareas of any watershed. Seventeen commands are available in HYMO to use in any sequence to transform rainfall data into runoff hydrographs and to route these hydrographs through streams and reservoirs (Viessman and Lewis, 1996). In 1983, several new subroutines including URBHYD for the simulation of urban runoff and NASHYD for the simulation of runoff from small to intermediate rural areas were introduced, and the first version of OTTHYMO was developed (JFSA, no date). OTTHYMO is a successful hydrologic management model that has been used for watershed studies, sub-watershed studies, master drainage plans, functional stormwater management plans, site plans, and stormwater management pond design. Like HYMO and OTTHYMO, Visual OTTHYMO v2.0 is a single event hydrologic model which hydrographs generated are based on unit hydrograph theory and common types of unit hydrographs are available for the user (e.g. Nash, William-Hann, SCS). Visual OTTHYMO v2.0 model can give users reliable results without a large number of input parameters as stated in the developer's provided information. It can be used for both uncalibrated or calibrated modelling studies. All routing routines available within the software are based on hydrologic routing principles as Visual OTTHYMO v2.0 is developed based on hydrologic theory but not hydraulic theory (Schaeffers, 2001).

CHAPTER 3 : METHODOLOGY

3.1 Data Measurements

Field monitoring was carried out to investigate the concentration of methoprene released from pellets and ingots over time in catch basins and storm sewer outfall. The field monitoring site is located within the Newtonbrook Sewershed in North York, City of Toronto, with a drainage area measured as 359 ha. Figure 3-1 illustrates the location of Newtonbrook Sewershed. Two catch basins, S1 and S2, are under monitoring in 2005 as shown in Figure 3-1. To allow the study of effect of sump depths on residual methoprene concentration, all sediments in catch basin S2 was removed by a vacuum truck. Drainage areas and imperviousness of S1 and S2 are shown in Table 3-1.

Table 3-1: Drainage Area and Percentage of Imperviousness

Catch Basin	Total Area m ²	Impervious Area m ²	Pervious Area m ²	Percentage of Imperviousness	Percentage of Perviousness
S1	688.17	612.17	76.00	88.96	11.04
S2	1338.50	1338.50	0.00	100.00	0.00

(Source: Sze, 2005)

Two physical plastic tank models were used as control laboratory experiment to observe the residual concentration of methoprene over time in a quiescent condition for ingot in 2005. One of the plastic tanks was filled with tap water to just above the top spout, which was 900mm from the bottom, while the other tank was filled with tap water just half of the first tank, which was about 450mm from the bottom. Methoprene concentrations were monitored daily from each tank. An equal withdrawal amount of tap water was added to the tank after each sampling.

Figure 3-2: Lab Tank

3.2 Catch Basin Mass Balanced Model

An earlier study completed by Sze (2005) covers the development of a water quality model for predicting the fate of methoprene in catch basin and outfall. While the catch basin is conceptualized as a completely well-mixed reactor, the model is developed based on mass balance approach (Sze, 2005). Methoprene loading, methoprene reaction, flushing effect of methoprene, and dilution are processes that are taken into account in the model.

The model takes into consideration of reaction during both the dry weather and wet weather condition. During dry weather condition, reaction is the only process that occurs within the catch basin, whereas during wet weather condition, two scenarios are considered: the first scenario is that dilution and reaction occur within the system, while flushing also occurs in addition of dilution and reaction for the second scenario. To gain the understanding of flushing effect due to various factors such as inflow rates, sump depths, and fall depths, a hydraulics analysis was performed to determine critical flows. The results of the study are used as input for the water quality model to predict the fate of methoprene in catch basins and storm sewer outfall (Sze, 2005). The following sections 3.2.1 to

3.2.3 summarize the theories and assumptions that are adopted in the catch basin mass balanced model.

3.2.1 Dry Weather Condition

The loading rate of methoprene pellet and ingot are considered as exponential loading, while the decay of methoprene is assumed to be a first order reaction. The equation of loading rate, $W(t)$, is as follow:

$$W(t) = W_e e^{-\beta_e t}$$

where W_e = initial rate of mass loading ($\mu\text{g/d}$) at $t = 0$; β_e (or Beta) is the rate of mass decay (d^{-1}); and t is time (d).

Reaction of methoprene is expressed by:

$$\text{Reaction} = KM$$

where K = first order reaction coefficient (d^{-1}) and M = mass of methoprene (μg).

The mass of methoprene over time in dry weather condition is:

$$M = \frac{W_e}{(K - \beta_e)} (e^{-\beta_e t} - e^{-Kt})$$

where K = first order reaction coefficient (d^{-1}) and M = mass of methoprene (μg).

3.2.2 Wet Weather Condition

As mentioned before, two scenarios are covered in wet weather condition. Scenario 1 represents a system with occurrence of dilution and reaction, while scenario 2 represents a system with occurrence of dilution, reaction, and flushing of pellets/ingots.

Scenario 1

Mass equation without flushing effect is:

$$\begin{aligned}
\frac{dM}{dt} &= W(t) - K \left(M - M \times \frac{R_r}{V_T} \right) - \left(M \times \frac{R_r}{V_T} \right) \\
&= W(t) - \left(K - K \times \frac{R_r}{V_T} + \frac{R_r}{V_T} \right) M \\
&= W(t) - K' M
\end{aligned}$$

where R_r = runoff volume (m^3); V_T = runoff and water sump volume (m^3); and K' = net decay coefficient.

The mass of methoprene over time in wet weather condition without flushing effect becomes:

$$M = \frac{W_e}{(K' - \beta_e)} (e^{-\beta_e t} - e^{-K' t})$$

Figure 3-3 illustrates the release of methoprene mass from a catch basin.

(Source: Sze, 2005)

Figure 3-3: Release of Methoprene from Catch Basin

Scenario 2

Mass balance equation with flushing effect is:

$$\begin{aligned}\frac{dM}{dt} &= W'(t) - K \left(M - M \times \frac{R_r}{V_T} \right) - \left(M \times \frac{R_r}{V_T} \right) \\ &= W'(t) - \left(K - K \times \frac{R_r}{V_T} + \frac{R_r}{V_T} \right) M \\ &= W'(t) - K' M\end{aligned}$$

where

$$W'(t) = W_e' e^{-\beta_e t} = R W_e e^{-\beta_e T} e^{-\beta_e t}$$

in which W_e' = new initial rate of mass loading ($\mu\text{g/d}$) at $t = T$ after flushing of methoprene pellets/ingots; T = time of flushing of pellets (d); and R = percent of remaining pellets. Percentage of pellets being flushed is determined by the peak flow and the result from the hydraulics analysis done by Sze (2005) as mentioned at the beginning of this chapter.

The mass of methoprene over time in wet weather condition with flushing effect becomes:

$$M = \frac{W_e'}{(K' - \beta_e)} (e^{-\beta_e t} - e^{-K' t})$$

When pellets/ingots are flushed out, W_e will become W_e' and K will become K' . W_e' will be used for the dry weather condition after the pellets/ingots are flushed out. The general equation for W_e in case of multiple flushing is:

$$W_e^n = R_n \times W_e^{n-1} \times e^{-\beta_e (T_n - T_{n-1})}$$

where n = number of flushing.

3.2.3 Model Description

The water quality model, a spreadsheet model utilizing the equations mentioned above, predicts the mass of methoprene remaining within catch basin and discharged out of the catch basin. Several assumptions are adopted within the model (Sze, 2005):

- the time interval for the model is daily;
- the model is completely well-mixed and mass of methoprene is uniformly distributed within the catch basin;
- the decay constant, rate of release, and loading function do not change with runoff volume;
- there is no interaction between sediment or suspended solids and methoprene;
- the mass of methoprene at time t is the mass available to release from catch basin during a rainfall event at time t ;
- the inflow rate is equal to outflow rate; and
- the runoff is applied at the beginning of time t .

Three mass balance models (see Appendix B) are generated in this project in order to predict the concentration of methoprene being released to the outfall during the typical year rainfalls. The first model is used to calibrate the W_e , β_e , and K parameters with the 2005 measured concentrations at the subject catch basins; the second model is a generic catch basin model that assumes all catch basins within the Newtonbrook sewershed have identical tributary boundary and therefore allows a unit catch basin approach to match the 2005 measured concentration at the storm sewer outfall; and the third model is used to predict concentration of methoprene at outfall during the typical year rainfalls utilizing the W_e , β_e , and K parameters generated from the generic catch basin model.

3.3 Calibration with Runoff Volume

Five-minute continuous daily rainfall measurements are separated into independent rain events for determination of peak flow and runoff volume under each storm event. An interevent time of two hours is chosen for the summer storm as suggested in Sze 2005. The subcatchment is first separated into pervious and impervious portion, and then rainfall-runoff transformation is performed using the following equations:

$$V_r = 0 \quad \text{if } P \leq S_d$$

$$V_r = 0.001 \times C_v \times (P - S_d) \times A \quad \text{if } P > S_d$$

where V_r = runoff volume (m^3); P = rainfall (mm); S_d = depression storage (mm); C_v = volumetric runoff coefficient; and A = drainage area (m^2).

Overall daily runoff generated from the subcatchment is:

$$R_r = \sum V_{rp} + \sum V_{ri}$$

where V_{rp} = pervious area runoff (m^3); and V_{ri} = impervious area runoff (m^3).

In order to calibrate the average imperviousness of the sewershed for the purpose of the generic catch basin model as mentioned in the previous section, a Visual OTTHYMO model (see Appendix A) is built to match the 2005 runoff volume measurements at outfall. The aim of the calibration is to minimize the Root Mean Square (RMS) percentage difference between predicted and measured runoff volume. Definition of RMS percentage difference is the following:

$$RMS \% \text{ difference} = \sqrt{\frac{\sum_{i=1}^n \left(\frac{V_{r_{m,i}} - V_{r_{p,i}}}{V_{r_{m,i}}} \right)^2}{n}} \times 100$$

where $V_{r_{m,i}}$ = measured runoff volume under the i^{th} storm event; $V_{r_{p,i}}$ = predicted runoff volume under the i^{th} storm event; and n = total number of storm events.

The subject sewershed is divided into 21 subcatchments according to the location of connections to the trunk sewer. Figure 3-4 presents the schematic of the Visual OTTHYMO model, while Figure 3-5 shows the tributary area of each subcatchment.

Figure 3-4: Visual OTTHYMO Schematic

Figure 3-5: Tributary Areas of Subcatchments

LEGEND:

Tributary Area Boundaries

Trunk Sewer

Tributary Area
Visual OTTHYMO ID

With the input of known properties of subcatchments and pipes such as drainage areas, CN value, and pipe sizes, and the assumption of general pipe slope as 0.5 % and typical depression storage as 1.5 mm and 6.0 mm for impervious and pervious areas, respectively (Viessman and Lewis, 1996), the overall imperviousness of the Newtonbrook sewershed is calibrated. Table 3-2 compares the raw measurements of the selected daily rainfall with the results from Visual OTTHYMO calibration. It is found that the average imperviousness of the sewershed is 15%.

Table 3-2: Visual OTTHYMO Imperviousness Calibration

Raw Measurements

Date	Runoff Volume (m ³)	Qp
17-Jul-05	7439.559	1.698
2-Aug-05	6665.246	3.43
10-Aug-05	3951.232	2.04
19-Aug-05	7030.9	1.12

VO2 Calibration

XIMP	0.08
TIMP	0.15

Date	Runoff Volume (mm)	Runoff Volume (m ³)	Qp	% Error (RV)	% Error (Qp)
17-Jul-05	2.52	9048.564	0.872	-21.63	48.65
2-Aug-05	1.793	6438.1251	1.566	3.41	54.34
10-Aug-05	1.005	3608.6535	1.079	8.67	47.11
19-Aug-05	2.033	7299.8931	0.774	-3.83	30.89
			RMS =	11.93	%

The average imperviousness of the sewershed is then used to calculate the runoff and peak flow from each generic catch basin. To ensure that the runoff volume generated from each catch basin using the rainfall-runoff transformation equation corresponds to the runoff volume at outfall, the runoff coefficient of the pervious area is calibrated by multiplying the calculated runoff volume from each catch basin by the total number of generic catch basins within the sewershed, i.e., 1261 (as counted from Figure 3-6), and compare the value with the outfall runoff volume. Table 3-3 shows the results from the calibration.

Figure 3-6: Catch Basins Distribution within Newtonbrook Sewershed

(Excerpt from City of Toronto, 2007)

Table 3-3: Pervious Runoff Coefficient CalibrationRaw Measurements

Date	Runoff Volume (m ³)
17-Jul-05	7439.559
2-Aug-05	6665.246
10-Aug-05	3951.232
19-Aug-05	7030.9

Runoff Coefficient Calibration

Pervious Cv	0.15
-------------	------

Date	RV per Catch Basin (m ³)	Total RV within Sewershed (m ³)	% Error
17-Jul-05	5.426	6842.19	8.03
2-Aug-05	5.426	6842.19	-2.65
10-Aug-05	3.693	4656.87	-17.86
19-Aug-05	5.865	7395.77	-5.19
RMS =			10.22 %

As the RMS percentage difference between calculations and measurements is less than 15%, the calculations with the calibrated runoff coefficient are considered valid and therefore the peak flow and runoff volume values are ready to be input into the generic catch basin water quality model.

3.4 Calibration with Outfall Mass

The generic catch basin model is used to determine a single set of model parameters that could represent the fate of methoprene. The model assumes model parameters remain constants throughout the 100-day modeling period, and as mentioned in section 3.2.3, the mass of methoprene at time t is the mass available to release from catch basin during a rainfall event at time t . Therefore, mass of methoprene released daily from catch basins should correspond to the mass of methoprene measured at the outfall.

Methoprene concentrations and flows are measured at the storm sewer outfall. As such, the measured methoprene mass for one event (EM) is calculated as:

$$EM = \sum (C_i \times Q_i \times \Delta t_i)$$

where C_i = concentration of sample at time interval i ($\mu\text{g/L}$); Q_i =flow rate at time interval i (L/s); and Δt_i =time interval i (s).

3.4.1 Unit Catch Basin Approach

Model parameters are chosen such that the RMS percentage difference between the resulting methoprene mass released from the catch basins multiplying the total number of catch basins within the Newtonbrook sewershed, i.e., 1261, and the measured methoprene mass at outfall is minimized. Four rainfall events are chosen to carry out the calibration. Table 3-4 shows the calibration results.

Table 3-4: Model Parameters Calibration

Measured Mass at Outfall

Date	Mass (μg)
17-Jul-05	495704.7
2-Aug-05	536906.4
10-Aug-05	1130914
19-Aug-05	889636.6

Model Parameters Calibration

We = 1100	Beta = 0.5	K = 0.83
-----------	------------	----------

Date	Mass (μg)	% Error
17-Jul-05	685631	-38.3144
2-Aug-05	496380	7.548122
10-Aug-05	722477	36.11561
19-Aug-05	889636.6	33.30129
RMS =		31.38 %

3.4.2 Distribution Approach

This alternative approach takes in consideration of the travel time and routing effect of the pipe systems. Making use of the Visual OTTHYMO model for the subject sewershed mentioned in section 3.3, travel time can be determined with some refinements to the model such as the input of actual pipe slopes. Since the model separates the sewershed into 21 subcatchments that contain various numbers of catch basins, the different travel time of each subcatchment would

result in a more realistic methoprene mass distribution at outfall. However, due to time constraints of this project, this approach has not been performed.

With the calibrated set of model parameters from the generic catch basin model, the typical year rainfall water quality model is then used to predict methoprene concentration at outfall.

CHAPTER 4 : CASE STUDY

4.1 Data Measurements

As mentioned in the previous chapter, the area under study is the Newtonbrook Sewershed. In 2005, all catch basins including the two catch basins, S1 and S2 were dosed with one Altosid ingot, and the outfall downstream was monitored. Two laboratory tanks each dosed with one Altosid ingot are set up to allow observation of methoprene concentration under quiescent situation. Measurements from the monitoring activities are used in this study to calibrate the mass balance model parameters, W_c , β_c , and K , and release time for the understanding of methoprene characteristic. Figure 4-1 and Figure 4-2 shows the methoprene concentrations at lab tanks MT1 and MT2, respectively. W_c values that correspond the measured concentration are found to be 1446 $\mu\text{g/d}$ and 964 $\mu\text{g/d}$ for MT1 and MT2, respectively, while β_c , and K values are 0.25d^{-1} and 0.33d^{-1} for both MT1 and MT2. Lab tank measurements demonstrate that the ingot can provide protection with concentration above the minimum lethal concentration of 0.3 $\mu\text{g/L}$ for 16 days.

Figure 4-3 illustrates the comparison of the lab tank measurements between 2004 and 2005 monitoring results. It is shown that peak methoprene concentration of 2004 is much lower than that of 2005, and second release did not occur within 100 days after dosage in 2005. This might due to the different lab settings between 2004 and 2005 monitoring. The lab tank in 2004 is left open without cover, while black plastic bags are used to cover the lab tanks in 2005 to mimic the dark environment in catch basin sump. The results of the measurements suggest that without the reaction with light, methoprene decays in a smaller magnitude, and the release time is delayed.

Figure 4-1: Methoprene Concentrations at Lab Tank MT1

Figure 4-2: Methoprene Concentrations at Lab Tank MT2

Figure 4-3: Methoprene Concentrations at Lab Tank (2004 and 2005)

Figure 4-4 and Figure 4-5 shows the methoprene concentration at catch basins S1 and S2, respectively. Field measurements shows that there are 3 to 10 days when the methoprene concentration is above the minimum lethal concentration of 0.3 µg/L. Different sets of model parameters are chosen to mimic the concentration variation within the 100-day monitoring period as shown in Table 4-1 and Table 4-2. As the model can reproduce the measured concentration in a decent fitment, the catch basin model is a valid tool for simulation.

Figure 4-4: Methoprene Concentration at Catch Basin S1

Figure 4-5: Methoprene Concentration at Catch Basin S2

Table 4-1: Model Parameters and Release Day of Catch Basin S1

Release Day	Day 2	Day 13	Day 21, 28	Day 40	Day 59	Day 72
We	1592.55	184.40	27.40	115.09	213.74	30.95
Beta	0.5	0.5	0.5	0.5	0.5	0.5
K	0.83	0.83	0.83	0.83	0.83	0.83

Table 4-2: Model Parameters and Release Day of Catch Basin S2

Release Day	Day 2	Day 9	Day 23	Day 34
We	301.75	55.01	80.47	79.60
Beta	0.5	0.2	0.5	2
K	0.83	0.83	0.83	0.83

In combination with the release day fitment of the 2004 ingot field measurements analyzed by Sze (2005), an overall release time and rainfall relationship is generated as shown in Figure 4-6. This relationship is used in the generic catch basin model and the typical year rainfalls model to predict the release time in response to rainfall.

Figure 4-6: Overall Release Time and Rainfall Relationship

Methoprene concentration measurements at the outfall for rain events occurred on July 17, August 2, August 10, and August 19 of 2005 are shown in Figure 4-7, Figure 4-8, Figure 4-9, and Figure 4-10, respectively. Measurements show that each of the rain events has readings above the iPWQO of $0.2 \mu\text{g/L}$.

Figure 4-7: Methoprene Concentration Measurements at Outfall - July 17, 2005

Figure 4-8: Methoprene Concentration Measurements at Outfall - August 2, 2005

Figure 4-9: Methoprene Concentration Measurements at Outfall - August 10, 2005

Figure 4-10: Methoprene Concentration Measurements at Outfall - August 19, 2005

4.2 Generic Catch Basin Model

After the calibration exercises with the runoff volume and methoprene mass as described in the previous chapter, a set of model parameter is established:

$W_c=1100 \mu\text{g/d}$, $\beta_c=0.5 \text{ d}^{-1}$, and $K=0.83 \text{ d}^{-1}$. This single set of model parameter represents the average characteristic of inlet. Figure 4-11 illustrates the methoprene concentration within the generic catch basin corresponding to the calibrated model parameters.

Figure 4-11: Methoprene Concentration at a Generic Catch Basin

4.3 Typical Year Rainfalls Water Quality Model

With the set of model parameters calibrated from the generic catch basin model, the 1980 typical year peak flows and runoff volumes calculated from the equations shown in section 3.3 of this report, as well as the release day derived from the release time and rainfall relationship, the methoprene concentration expected at outfall is predicted. Figure 4-12 illustrates the methoprene concentration at catch basin during typical year rainfalls, while Figure 4-13 is a prediction of methoprene concentration at outfall during typical year rainfalls.

As expected, the methoprene concentration at catch basin during typical year rainfall has a similar magnitude and pattern as the generic catch basin model of 2005 since the same set of model parameters is adopted. From Figure 4-13, it is

shown that methoprene concentration at outfall exceeds the iPWQO of $0.2 \mu\text{g/L}$ in 6 days out of the 100-day modeling period, while none of them exceeds the USEPA environmental concentration of $10 \mu\text{g/L}$.

Figure 4-12: Methoprene Concentrations at Catch Basin during Typical Year Rainfalls

Figure 4-13: Methoprene Concentrations to Outfall during Typical Year Rainfalls

The high methoprene concentration at the outfall occurs at the later time of the rainy season, after September 9 to be specific, when the runoff volumes are small. The methoprene concentrations prediction is found valid as it agrees with the outfall measurements recorded in 2005 which demonstrates that iPWQO exceedances do exist in all the observed rain events as shown in section 4.1.

CHAPTER 5 : CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The widespread of the West Nile Virus is threatening North America in recent years. A West Nile Virus program is established in Toronto in 2002, which includes public education and community outreach, West Nile Virus surveillance, and mosquito control. Larviciding activities are performed in catch basins within City of Toronto, while methoprene pellets and ingots are used as the larvicide. As there are arguments that methoprene might cause adverse effect to the aquatic life, modelling of methoprene concentration in the urban system is necessary.

Lethal concentration of methoprene has been reported as 0.3 to 2.3 $\mu\text{g/L}$ for *Culex*, and the iPWQO of methoprene is 0.2 $\mu\text{g/L}$. Lab tank monitoring demonstrates that light has a major role in the decay of methoprene, and might affect its release time. It is shown that under quiescent situation, ingot can maintain a minimum lethal concentration of 0.3 $\mu\text{g/L}$ for 16 days. Field measurements in selected catch basins shows that there are 3 to 10 days when the methoprene concentration is above the minimum lethal concentration of 0.3 $\mu\text{g/L}$. On the other hand, concentration measurements at the storm sewer outfall during selected storm events show that each of the storm events has readings above the iPWQO of 0.2 $\mu\text{g/L}$.

Water quality model prediction demonstrates that during typical year rainfalls, methoprene concentrations exceed the iPWQO of 0.2 $\mu\text{g/L}$ in 6 days out of the 100-day modeling period. All the predicted concentrations are within the USEPA environmental concentration of 10 $\mu\text{g/L}$. The prediction is found valid as it agrees with the 2005 outfall measurements that exceedances do occur when runoff volumes are small.

5.2 Recommendations

The calibration with outfall mass exercise adopted in this project is based on a unit catch basin approach, i.e., linear multiplication of mass with total number of catch basin within the sewershed. To better mimic the actual situation, a non-linear approach that takes into consideration the travel time and routing effect of the pipe system is recommended. The non-linear approach involves the refinements of the Visual OTTHYMO model built for the subject sewershed mentioned in section 3.3. Since the model separates the sewershed into 21 subcatchments that contain various numbers of catch basins, the different travel time of each subcatchment would result in a more realistic methoprene mass distribution at outfall.

More field data is required. The availability of more field data can allow researchers to have a better understanding of the relationship between model parameters and rainfall characteristic. A statistic analysis can then be performed with the collected data and leads to a better prediction of methoprene concentration at catch basins and outfalls.

A sensitivity analysis on sump volume towards methoprene concentration is suggested in future study. The sump volume that is adopted in the generic catch basin model of this project is an average between the sump volumes of catch basins S1 and S2. Sensitivity analysis on sump volume towards methoprene concentration can allow researchers to better understand the necessity of having accurate measurements of sump pump volume in order to gain a better prediction of methoprene concentration at catch basins and outfalls.

REFERENCES

Adams, Barry J. and Papa, Fabian. 2000. Urban Stormwater Management Planning with Analytical Probabilistic Models. John Wiley & Sons, New York.

Altosid. 2004. Material Safety Data Sheet: Altosid Pellets. Altosid Website. http://www.altosid.com/PDF_3_02/Zoecon_Altosid_Pellets.pdf [Accessed: December 12, 2004].

Centers for Disease Control and Prevention (CDC) . 2004. West Nile Virus - Background: Virus History and Distribution. CDC Webpage. <http://www.cdc.gov/ncidod/dvbid/westnile/background.htm> [Accessed: December 18, 2004].

Chapra, S. C. and Canale, R. P. 1988. Numerical Methods for Engineers 2^d ed. McGraw-Hill, New York.

Chapra, Steven C. 1997. Surface Water Quality Modelling. WCB/McGraw Hill. United States.

City of Toronto. 2004. West Nile Virus: City of Toronto West Nile Virus Program. City of Toronto Website. http://www.city.toronto.on.ca/health/westnile/wnv_factsheet_2004_backgrounder.htm [Accessed: December 10, 2004].

City of Toronto. 2007. Personal Communication. Works and Emergency Services, City of Toronto.

Csondes, Angela. 2004. Environmental Fate of Methoprene. California Department of Pesticide Regulation Website. <http://www.cdpr.ca.gov/docs/emprm/pubs/methofate.pdf> [Accessed: December 10, 2004].

Des Lauriers, A. 2003. The Fate and Transport of Methoprene in an Urban West Nile Virus Mosquito Control Program. M.A.Sc. Thesis, Ryerson University. Toronto, Canada.

Florida Coordinating Council on Mosquito Control (FCCMC). 1998. Florida Mosquito Control: Larvicides and Larviciding. FCCMC Website. <http://fmel.ifas.ufl.edu/whitep/ch5.htm> [Accessed: December 9, 2004].

GreenConsumer. 2004. Pesticide Product: Methoprene. GreenConsumer Website. <http://www.greenconsumer.cc/managers/methoprene.html> [Accessed: December 9, 2004].

Health Canada. 2004. West Nile Virus. Health Canada Website. <http://www.hc-sc.gc.ca/english/westnile/symptoms.html> [Accessed: December 18, 2004].

J.F. Sabourin and Associates (JFSA). no date. StormWater Management Hydrologic Model (SWMHYMO) Brochure. <http://www.jfsa.com/download/SWMHYMOv402.PDF> [Accessed: May 2, 2007].

Ontario Ministry of the Environment (MOE). 1999. Provincial Water Quality Objectives. <http://www.ene.gov.on.ca/envision/gp/3303e.htm> [Accessed: April 28, 2007].

Ontario Ministry of the Environment (MOE). 2003. Permit Applicant Guide: Controlling Mosquito Larvae for Prevention and/or Control of West Nile Virus. MOE Website. <http://www.ene.gov.on.ca/envision/gp/4319.htm> [Accessed: December 12, 2004].

Pesticide Action Network, 2007. PAN Pesticide Database. http://www.pesticideinfo.org/Detail_Chemical.jsp?Rec_Id=PC32837 [Accessed: April 27, 2007].

Pest Management Regulatory Agency (PMRA). 2001. Fact Sheet on the Use of Methoprene in Mosquito Control Programs. http://www.pmr-arla.gc.ca/english/pdf/fact/fs_methoprene-e.pdf. [Accessed: April 26, 2007].

Pest Management Regulatory Agency (PMRA). 2007. Proposed Acceptability for Continuing Registration: Re-evaluation of S-Methoprene. <http://www.pmr-arla.gc.ca/english/pdf/pacr/pacr2007-01-e.pdf> [Accessed: April 26, 2007].

Public Health Agency of Canada (PHAC). 2006, West Nile Virus. PHAC Website. http://www.phac-aspc.gc.ca/wn-no/hist_e.html [Accessed: April 28, 2007].

Schaeffers and Associates. 2001. Visual OTTHYMO v2.0 Users' Manual. Schaeffers and Associates, Ontario.

Sze, Kevin. 2005. Modelling the Fate of a Larviciding Chemical, Methoprene, at Drainage Systems. M.A.Sc. Thesis, Ryerson University. Toronto, Canada.

The Pesticide Management Education Program (PMEP). 2001. EXTTOXNET. Pesticide Information Profile: Methoprene. PMEP Website. <http://pmep.cce.cornell.edu/profiles/exttoxnet/haloxyp-methylparathion/methoprene-ext.html>. Cornell University, New York. [Accessed: December 12, 2004].

Toronto Public Health (TPH). 2004. West Nile Virus in the City of Toronto 2003. A Summary of the Toronto Public Health West Nile Virus Program for

2003.

<http://www.toronto.ca/legdocs/2004/agendas/committees/h1/h1040614/it002.pdf>
[Accessed: December 9, 2004].

USEPA. 2001. Methoprene Fact Sheet Update. USEPA Website.

http://www.epa.gov/oppbopd1/biopesticides/ingredients/factsheets/factsheet_105401.pdf [Accessed: April 26, 2007].

USEPA. 2002. Post-Construction Storm Water Management in New Development & Redevelopment. USEPA Website.

http://cfpub2.epa.gov/npdes/stormwater/menuofbmps/post_17.cfm [Accessed: December 15, 2004].

USEPA. 2003. Pesticides: Topical and Chemical Fact Sheets. USEPA Website.

<http://www.epa.gov/pesticides/factsheets/mosquitojoint.htm> [Accessed: December 9, 2004].

Viessman, Warren, Jr. and Lewis, Gary L. 1996. Introduction to Hydrology 4th Edition. HarperCollins College Publishers, New York.

Washington State Department of Ecology. 2006. Methoprene Concentrations in Surface Water Samples from Grant County - Mosquito Control District No.1.

<http://ecystage.ecy.wa.gov/pubs/0603001.pdf> [Accessed: April 26, 2007].

Westchester County Department of Health. 2004. Mosquito's Life Cycle. Westchester Government Website.

http://www.westchestergov.com/health/WNVmosquito_life_cycle.htm#life%20cycle [Accessed: December 19, 2004].

Wikipedia. 2007. Hydrology. <http://en.wikipedia.org/wiki/Hydrology> [Accessed: May 2, 2007].

World Health Organization (WHO). 2007. Methoprene in Drinking-water: Use for Vector Control in Drinking-water Sources and Containers.

http://www.who.int/water_sanitation_health/gdwqrevision/methoprene2ndadd.pdf [Accessed: April 27, 2007].

York Region. 2006. Report No. 2 of the Health and Emergency Medical Services Committee - Regional Council Meeting of March 23, 2006. Ontario, Canada.

APPENDIX A

VISUAL OTTHYMO MODEL

```

V   V   I   SSSSS U   U   A   L
V   V   I   SS   U   U   A A  L
V   V   I   SS   U   U   AAAAA L
V   V   I   SS   U   U   A   A  L
VV    I   SSSSS UUUUU A   A  LLLLL

```

```

OOO   TTTT   TTTT   H   H   Y   Y   M   M   OOO   TM, Version 2.0
O   O   T   T   H   H   Y   Y   MM MM   O   O
O   O   T   T   H   H   Y   M   M   O   O   Licensed To:
OOO   T   T   H   H   Y   M   M   OOO

```

Developed and Distributed by Greenland International Consulting Inc.
 Copyright 1996, 2001 Schaeffer & Associates Ltd.
 All rights reserved.

***** S U M M A R Y O U T P U T *****

Input filename: C:\Program Files\Visual OTTHYMO v2.0\voin.dat
 Output filename: D:\School\METHOP-1\VO2200-1\Newtonbrook Sewershed.out
 Summary filename: D:\School\METHOP-1\VO2200-1\Newtonbrook Sewershed.sum

DATE: 5/6/2007 TIME: 8:54:40 AM

USER:

COMMENTS: _____

```

*****
** SIMULATION NUMBER: 2 **
*****

```

W/E COMMAND	HYD ID	DT min	AREA ha	Qpeak cms	Tpeak hrs	R.V. mm	R.C.	Qbase cms
START @ .00 hrs								

READ STORM 5.0								
[Ptot= 15.40 mm]								
fname : D:\School\Methoprene Model\20050717.stm								
remark: Newtonbrook 2005 July 17 Rainfall								
* CALIB STANDHYD	0102	1	5.0	15.22	.06	5.25	2.49	.16
[I%= 8.0:S%= 2.00]								
* DUHYD	0132	1	5.0	15.22	.06	5.25	2.49	n/a
MAJOR SYSTEM: 0132 2 5.0 .00 .00 .00 n/a .000								
MINOR SYSTEM: 0132 3 5.0 15.22 .06 5.25 2.49 n/a .000								
* PIPE [2 : 0132]	0008	1	5.0	15.22	.05	5.42	2.49	n/a
* CALIB STANDHYD	0107	1	5.0	2.70	.01	5.17	2.48	.16
[I%= 8.0:S%= 2.00]								
* DUHYD	0130	1	5.0	2.70	.01	5.17	2.48	n/a
MAJOR SYSTEM: 0130 2 5.0 .00 .00 .00 n/a .000								
MINOR SYSTEM: 0130 3 5.0 2.70 .01 5.17 2.48 n/a .000								
* CALIB STANDHYD	0112	1	5.0	1.09	.01	5.17	3.75	.24
[I%= 8.0:S%= 2.00]								
* DUHYD	0127	1	5.0	1.09	.01	5.17	3.75	n/a
MAJOR SYSTEM: 0127 2 5.0 .00 .00 .00 n/a .000								
MINOR SYSTEM: 0127 3 5.0 1.09 .01 5.17 3.75 n/a .000								
* CALIB STANDHYD	0113	1	5.0	6.24	.03	5.17	2.48	.16
[I%= 8.0:S%= 2.00]								
* DUHYD	0143	1	5.0	6.24	.03	5.17	2.48	n/a
MAJOR SYSTEM: 0143 2 5.0 .00 .00 .00 n/a .000								
MINOR SYSTEM: 0143 3 5.0 6.24 .03 5.17 2.48 n/a .000								
* PIPE [2 : 0143]	0047	1	5.0	6.24	.02	5.33	2.48	n/a

*	ADD [0127 + 0047]	0070	3	5.0	7.33	.03	5.33	2.67	n/a	.000
*	CALIB STANDHYD	0121	1	5.0	57.22	.19	5.33	2.49	.16	.000
*	[I%= 8.0:S%= 2.00]									
	DUHYD	0134	1	5.0	57.22	.19	5.33	2.49	n/a	.000
	MAJOR SYSTEM:	0134	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:	0134	3	5.0	57.22	.19	5.33	2.49	n/a	.000
*	PIPE [2 : 0134]	0032	1	5.0	57.22	.13	5.58	2.49	n/a	.000
*	CALIB STANDHYD	0120	1	5.0	9.52	.04	5.25	2.49	.16	.000
*	[I%= 8.0:S%= 2.00]									
	DUHYD	0133	1	5.0	9.52	.04	5.25	2.49	n/a	.000
	MAJOR SYSTEM:	0133	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:	0133	3	5.0	9.52	.04	5.25	2.49	n/a	.000
*	PIPE [2 : 0133]	0035	1	5.0	9.52	.03	5.42	2.48	n/a	.000
*	ADD [0032 + 0035]	0081	3	5.0	66.74	.16	5.50	2.49	n/a	.000
*	CALIB STANDHYD	0118	1	5.0	8.32	.04	5.17	3.77	.24	.000
*	[I%= 8.0:S%= 2.00]									
	DUHYD	0123	1	5.0	8.32	.04	5.17	3.77	n/a	.000
	MAJOR SYSTEM:	0123	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:	0123	3	5.0	8.32	.04	5.17	3.77	n/a	.000
*	CALIB STANDHYD	0119	1	5.0	39.93	.14	5.33	2.49	.16	.000
*	[I%= 8.0:S%= 2.00]									
	DUHYD	0145	1	5.0	39.93	.14	5.33	2.49	n/a	.000
	MAJOR SYSTEM:	0145	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:	0145	3	5.0	39.93	.14	5.33	2.49	n/a	.000
*	PIPE [2 : 0145]	0056	1	5.0	39.93	.11	5.42	2.49	n/a	.000
*	ADD [0123 + 0056]	0080	3	5.0	48.25	.14	5.42	2.71	n/a	.000
*	ADD [0081 + 0080]	0082	3	5.0	114.99	.29	5.50	2.58	n/a	.000
*	PIPE [2 : 0082]	0077	1	5.0	114.99	.29	5.50	2.58	n/a	.000
*	CALIB STANDHYD	0117	1	5.0	4.59	.02	5.17	2.48	.16	.000
*	[I%= 8.0:S%= 2.00]									
	DUHYD	0124	1	5.0	4.59	.02	5.17	2.48	n/a	.000
	MAJOR SYSTEM:	0124	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:	0124	3	5.0	4.59	.02	5.17	2.48	n/a	.000
*	PIPE [2 : 0124]	0053	1	5.0	4.59	.02	5.25	2.48	n/a	.000
*	ADD [0077 + 0053]	0054	3	5.0	119.58	.30	5.50	2.58	n/a	.000
*	PIPE [2 : 0054]	0076	1	5.0	119.58	.29	5.58	2.58	n/a	.000
*	CALIB STANDHYD	0116	1	5.0	38.23	.14	5.33	2.49	.16	.000
*	[I%= 8.0:S%= 2.00]									
	DUHYD	0135	1	5.0	38.23	.14	5.33	2.49	n/a	.000
	MAJOR SYSTEM:	0135	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:	0135	3	5.0	38.23	.14	5.33	2.49	n/a	.000
*	PIPE [2 : 0135]	0029	1	5.0	38.23	.11	5.42	2.49	n/a	.000
*	ADD [0076 + 0029]	0030	3	5.0	157.81	.39	5.50	2.55	n/a	.000
*	PIPE [2 : 0030]	0075	1	5.0	157.81	.39	5.50	2.55	n/a	.000
*	CALIB STANDHYD	0115	1	5.0	10.02	.04	5.25	2.49	.16	.000
*	[I%= 8.0:S%= 2.00]									
	DUHYD	0136	1	5.0	10.02	.04	5.25	2.49	n/a	.000
	MAJOR SYSTEM:	0136	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:	0136	3	5.0	10.02	.04	5.25	2.49	n/a	.000
*	PIPE [2 : 0136]	0026	1	5.0	10.02	.04	5.33	2.49	n/a	.000
*	ADD [0075 + 0026]	0027	3	5.0	167.83	.42	5.50	2.55	n/a	.000

*	PIPE	[2 : 0027]	0072	1	5.0	167.83	.42	5.50	2.55	n/a	.000
*	CALIB STANDHYD		0114	1	5.0	5.61	.03	5.17	2.48	.16	.000
	[I%= 8.0:S%= 2.00]										
*	DUHYD		0125	1	5.0	5.61	.03	5.17	2.48	n/a	.000
	MAJOR SYSTEM:		0125	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:		0125	3	5.0	5.61	.03	5.17	2.48	n/a	.000
*	PIPE	[2 : 0125]	0050	1	5.0	5.61	.02	5.33	2.48	n/a	.000
*	ADD [0072 + 0050]		0051	3	5.0	173.44	.43	5.50	2.55	n/a	.000
*	PIPE	[2 : 0051]	0073	1	5.0	173.44	.43	5.58	2.55	n/a	.000
*	ADD [0070 + 0073]		0074	3	5.0	180.77	.45	5.58	2.55	n/a	.000
*	PIPE	[2 : 0074]	0068	1	5.0	180.77	.46	5.58	2.55	n/a	.000
*	CALIB STANDHYD		0111	1	5.0	3.36	.02	5.17	2.48	.16	.000
	[I%= 8.0:S%= 2.00]										
*	DUHYD		0137	1	5.0	3.36	.02	5.17	2.48	n/a	.000
	MAJOR SYSTEM:		0137	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:		0137	3	5.0	3.36	.02	5.17	2.48	n/a	.000
*	PIPE	[2 : 0137]	0023	1	5.0	3.36	.01	5.25	2.48	n/a	.000
*	ADD [0068 + 0023]		0024	3	5.0	184.13	.46	5.58	2.55	n/a	.000
*	PIPE	[2 : 0024]	0067	1	5.0	184.13	.47	5.58	2.55	n/a	.000
*	CALIB STANDHYD		0110	1	5.0	50.14	.17	5.33	2.49	.16	.000
	[I%= 8.0:S%= 2.00]										
*	DUHYD		0128	1	5.0	50.14	.17	5.33	2.49	n/a	.000
	MAJOR SYSTEM:		0128	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:		0128	3	5.0	50.14	.17	5.33	2.49	n/a	.000
*	PIPE	[2 : 0128]	0044	1	5.0	50.14	.12	5.50	2.49	n/a	.000
*	ADD [0067 + 0044]		0045	3	5.0	234.27	.59	5.58	2.54	n/a	.000
*	PIPE	[2 : 0045]	0066	1	5.0	234.27	.60	5.58	2.54	n/a	.000
*	CALIB STANDHYD		0108	1	5.0	37.51	.13	5.33	2.49	.16	.000
	[I%= 8.0:S%= 2.00]										
*	DUHYD		0138	1	5.0	37.51	.13	5.33	2.49	n/a	.000
	MAJOR SYSTEM:		0138	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:		0138	3	5.0	37.51	.13	5.33	2.49	n/a	.000
*	PIPE	[2 : 0138]	0020	1	5.0	37.51	.08	5.50	2.49	n/a	.000
*	ADD [0066 + 0020]		0021	3	5.0	271.78	.67	5.58	2.53	n/a	.000
*	CALIB STANDHYD		0109	1	5.0	12.77	.05	5.25	2.49	.16	.000
	[I%= 8.0:S%= 2.00]										
*	DUHYD		0129	1	5.0	12.77	.05	5.25	2.49	n/a	.000
	MAJOR SYSTEM:		0129	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:		0129	3	5.0	12.77	.05	5.25	2.49	n/a	.000
*	PIPE	[2 : 0129]	0041	1	5.0	12.77	.04	5.42	2.49	n/a	.000
*	ADD [0021 + 0041]		0042	3	5.0	284.55	.70	5.58	2.53	n/a	.000
*	PIPE	[2 : 0042]	0065	1	5.0	284.55	.69	5.58	2.53	n/a	.000
*	CALIB STANDHYD		0106	1	5.0	32.08	.12	5.25	2.49	.16	.000
	[I%= 8.0:S%= 2.00]										
*	DUHYD		0139	1	5.0	32.08	.12	5.25	2.49	n/a	.000
	MAJOR SYSTEM:		0139	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:		0139	3	5.0	32.08	.12	5.25	2.49	n/a	.000
*	PIPE	[2 : 0139]	0017	1	5.0	32.08	.07	5.50	2.48	n/a	.000
*	ADD [0065 + 0017]		0018	3	5.0	316.63	.76	5.58	2.52	n/a	.000
*	ADD [0130 + 0018]		0064	3	5.0	319.33	.76	5.58	2.52	n/a	.000

```

*
*   PIPE    [ 2 : 0064] 0062 1 5.0 319.33    .77 5.67 2.52 n/a .000
*
*   CALIB STANDHYD      0105 1 5.0 18.39    .07 5.25 2.49 .16 .000
*   [I%= 8.0:S%= 2.00]
*
*   DUHYD      0131 1 5.0 18.39    .07 5.25 2.49 n/a .000
*   MAJOR SYSTEM: 0131 2 5.0    .00 .00 .00 n/a .000
*   MINOR SYSTEM: 0131 3 5.0 18.39    .07 5.25 2.49 n/a .000
*
*   PIPE    [ 2 : 0131] 0059 1 5.0 18.39    .06 5.42 2.49 n/a .000
*
*   ADD [0062 + 0059] 0060 3 5.0 337.72    .80 5.67 2.52 n/a .000
*
*   CALIB STANDHYD      0104 1 5.0 3.73    .02 5.17 2.48 .16 .000
*   [I%= 8.0:S%= 2.00]
*
*   DUHYD      0140 1 5.0 3.73    .02 5.17 2.48 n/a .000
*   MAJOR SYSTEM: 0140 2 5.0    .00 .00 .00 n/a .000
*   MINOR SYSTEM: 0140 3 5.0 3.73    .02 5.17 2.48 n/a .000
*
*   PIPE    [ 2 : 0140] 0014 1 5.0 3.73    .02 5.25 2.48 n/a .000
*
*   ADD [0060 + 0014] 0015 3 5.0 341.45    .80 5.67 2.52 n/a .000
*
*   PIPE    [ 2 : 0015] 0061 1 5.0 341.45    .83 5.67 2.52 n/a .000
*
*   CALIB STANDHYD      0103 1 5.0 1.18    .01 5.17 2.47 .16 .000
*   [I%= 8.0:S%= 2.00]
*
*   DUHYD      0141 1 5.0 1.18    .01 5.17 2.47 n/a .000
*   MAJOR SYSTEM: 0141 2 5.0    .00 .00 .00 n/a .000
*   MINOR SYSTEM: 0141 3 5.0 1.18    .01 5.17 2.47 n/a .000
*
*   PIPE    [ 2 : 0141] 0011 1 5.0 1.18    .01 5.17 2.46 n/a .000
*
*   ADD [0061 + 0011] 0012 3 5.0 342.63    .83 5.67 2.52 n/a .000
*
*   PIPE    [ 2 : 0012] 0005 1 5.0 342.63    .84 5.67 2.52 n/a .000
*
*   ADD [0008 + 0005] 0007 3 5.0 357.85    .87 5.67 2.52 n/a .000
*
*   CALIB STANDHYD      0101 1 5.0 1.22    .01 5.17 2.47 .16 .000
*   [I%= 8.0:S%= 2.00]
*
*   DUHYD      0142 1 5.0 1.22    .01 5.17 2.47 n/a .000
*   MAJOR SYSTEM: 0142 2 5.0    .00 .00 .00 n/a .000
*   MINOR SYSTEM: 0142 3 5.0 1.22    .01 5.17 2.47 n/a .000
*
*   PIPE    [ 2 : 0142] 0004 1 5.0 1.22    .01 5.25 2.46 n/a .000
*
*   ADD [0007 + 0004] 0006 3 5.0 359.07    .87 5.67 2.52 n/a .000
*
*   PIPE    [ 2 : 0006] 0002 1 5.0 359.07    .87 5.67 2.52 n/a .000

```

```

*****
** SIMULATION NUMBER: 3 **
*****

```

```

W/E COMMAND          HYD ID  DT    AREA  Qpeak Tpeak  R.V. R.C.  Qbase
                   min      ha    cms   hrs   mm
START @    .00 hrs
-----
READ STORM                      5.0
[ Ptot= 13.10 mm ]
fname : D:\School\Methoprene Model\20050802.stm
remark: Newtonbrook 2005 Aug 2 Rainfall
*
*   CALIB STANDHYD      0102 1 5.0 15.22    .11 16.08 1.77 .13 .000
*   [I%= 8.0:S%= 2.00]
*
*   DUHYD      0132 1 5.0 15.22    .11 16.08 1.77 n/a .000
*   MAJOR SYSTEM: 0132 2 5.0    .00 .00 .00 n/a .000
*   MINOR SYSTEM: 0132 3 5.0 15.22    .11 16.08 1.77 n/a .000
*
*   PIPE    [ 2 : 0132] 0008 1 5.0 15.22    .08 16.25 1.76 n/a .000
*
*   CALIB STANDHYD      0107 1 5.0 2.70    .02 16.08 1.76 .13 .000
*   [I%= 8.0:S%= 2.00]
*

```

	DUHYD	0130	1	5.0	2.70	.02	16.08	1.76	n/a	.000
	MAJOR SYSTEM:	0130	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:	0130	3	5.0	2.70	.02	16.08	1.76	n/a	.000
*										
*	CALIB STANDHYD	0112	1	5.0	1.09	.01	16.08	2.84	.22	.000
	[I%= 8.0:S%= 2.00]									
*										
	DUHYD	0127	1	5.0	1.09	.01	16.08	2.84	n/a	.000
	MAJOR SYSTEM:	0127	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:	0127	3	5.0	1.09	.01	16.08	2.84	n/a	.000
*										
*	CALIB STANDHYD	0113	1	5.0	6.24	.05	16.08	1.76	.13	.000
	[I%= 8.0:S%= 2.00]									
*										
	DUHYD	0143	1	5.0	6.24	.05	16.08	1.76	n/a	.000
	MAJOR SYSTEM:	0143	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:	0143	3	5.0	6.24	.05	16.08	1.76	n/a	.000
*										
	PIPE [2 : 0143]	0047	1	5.0	6.24	.03	16.25	1.76	n/a	.000
*										
	ADD [0127 + 0047]	0070	3	5.0	7.33	.04	16.25	1.92	n/a	.000
*										
*	CALIB STANDHYD	0121	1	5.0	57.22	.32	16.17	1.77	.13	.000
	[I%= 8.0:S%= 2.00]									
*										
	DUHYD	0134	1	5.0	57.22	.32	16.17	1.77	n/a	.000
	MAJOR SYSTEM:	0134	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:	0134	3	5.0	57.22	.32	16.17	1.77	n/a	.000
*										
	PIPE [2 : 0134]	0032	1	5.0	57.22	.23	16.42	1.77	n/a	.000
*										
*	CALIB STANDHYD	0120	1	5.0	9.52	.07	16.08	1.76	.13	.000
	[I%= 8.0:S%= 2.00]									
*										
	DUHYD	0133	1	5.0	9.52	.07	16.08	1.76	n/a	.000
	MAJOR SYSTEM:	0133	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:	0133	3	5.0	9.52	.07	16.08	1.76	n/a	.000
*										
	PIPE [2 : 0133]	0035	1	5.0	9.52	.05	16.25	1.76	n/a	.000
*										
	ADD [0032 + 0035]	0081	3	5.0	66.74	.28	16.33	1.77	n/a	.000
*										
*	CALIB STANDHYD	0118	1	5.0	8.32	.07	16.08	2.86	.22	.000
	[I%= 8.0:S%= 2.00]									
*										
	DUHYD	0123	1	5.0	8.32	.07	16.08	2.86	n/a	.000
	MAJOR SYSTEM:	0123	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:	0123	3	5.0	8.32	.07	16.08	2.86	n/a	.000
*										
*	CALIB STANDHYD	0119	1	5.0	39.93	.23	16.17	1.77	.13	.000
	[I%= 8.0:S%= 2.00]									
*										
	DUHYD	0145	1	5.0	39.93	.23	16.17	1.77	n/a	.000
	MAJOR SYSTEM:	0145	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:	0145	3	5.0	39.93	.23	16.17	1.77	n/a	.000
*										
	PIPE [2 : 0145]	0056	1	5.0	39.93	.18	16.33	1.77	n/a	.000
*										
	ADD [0123 + 0056]	0080	3	5.0	48.25	.24	16.33	1.95	n/a	.000
*										
	ADD [0081 + 0080]	0082	3	5.0	114.99	.51	16.33	1.84	n/a	.000
*										
	PIPE [2 : 0082]	0077	1	5.0	114.99	.52	16.33	1.84	n/a	.000
*										
*	CALIB STANDHYD	0117	1	5.0	4.59	.04	16.08	1.76	.13	.000
	[I%= 8.0:S%= 2.00]									
*										
	DUHYD	0124	1	5.0	4.59	.04	16.08	1.76	n/a	.000
	MAJOR SYSTEM:	0124	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:	0124	3	5.0	4.59	.04	16.08	1.76	n/a	.000
*										
	PIPE [2 : 0124]	0053	1	5.0	4.59	.03	16.17	1.76	n/a	.000
*										
	ADD [0077 + 0053]	0054	3	5.0	119.58	.54	16.33	1.84	n/a	.000
*										
	PIPE [2 : 0054]	0076	1	5.0	119.58	.53	16.42	1.84	n/a	.000
*										
*	CALIB STANDHYD	0116	1	5.0	38.23	.22	16.17	1.77	.13	.000
	[I%= 8.0:S%= 2.00]									
*										
	DUHYD	0135	1	5.0	38.23	.22	16.17	1.77	n/a	.000

	MAJOR SYSTEM:	0135	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:	0135	3	5.0	38.23	.22	16.17	1.77	n/a	.000
*										
*	PIPE [2 : 0135]	0029	1	5.0	38.23	.18	16.33	1.77	n/a	.000
*										
*	ADD [0076 + 0029]	0030	3	5.0	157.81	.70	16.42	1.82	n/a	.000
*										
*	PIPE [2 : 0030]	0075	1	5.0	157.81	.71	16.42	1.82	n/a	.000
*										
*	CALIB STANDHYD [I%= 8.0:S%= 2.00]	0115	1	5.0	10.02	.07	16.08	1.76	.13	.000
*										
	DUHYD	0136	1	5.0	10.02	.07	16.08	1.76	n/a	.000
	MAJOR SYSTEM:	0136	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:	0136	3	5.0	10.02	.07	16.08	1.76	n/a	.000
*										
*	PIPE [2 : 0136]	0026	1	5.0	10.02	.06	16.17	1.76	n/a	.000
*										
*	ADD [0075 + 0026]	0027	3	5.0	167.83	.75	16.42	1.82	n/a	.000
*										
*	PIPE [2 : 0027]	0072	1	5.0	167.83	.76	16.42	1.82	n/a	.000
*										
*	CALIB STANDHYD [I%= 8.0:S%= 2.00]	0114	1	5.0	5.61	.04	16.08	1.76	.13	.000
*										
	DUHYD	0125	1	5.0	5.61	.04	16.08	1.76	n/a	.000
	MAJOR SYSTEM:	0125	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:	0125	3	5.0	5.61	.04	16.08	1.76	n/a	.000
*										
*	PIPE [2 : 0125]	0050	1	5.0	5.61	.03	16.25	1.76	n/a	.000
*										
*	ADD [0072 + 0050]	0051	3	5.0	173.44	.78	16.42	1.82	n/a	.000
*										
*	PIPE [2 : 0051]	0073	1	5.0	173.44	.80	16.42	1.82	n/a	.000
*										
*	ADD [0070 + 0073]	0074	3	5.0	180.77	.83	16.42	1.82	n/a	.000
*										
*	PIPE [2 : 0074]	0068	1	5.0	180.77	.84	16.42	1.82	n/a	.000
*										
*	CALIB STANDHYD [I%= 8.0:S%= 2.00]	0111	1	5.0	3.36	.03	16.08	1.76	.13	.000
*										
	DUHYD	0137	1	5.0	3.36	.03	16.08	1.76	n/a	.000
	MAJOR SYSTEM:	0137	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:	0137	3	5.0	3.36	.03	16.08	1.76	n/a	.000
*										
*	PIPE [2 : 0137]	0023	1	5.0	3.36	.02	16.17	1.76	n/a	.000
*										
*	ADD [0068 + 0023]	0024	3	5.0	184.13	.85	16.42	1.82	n/a	.000
*										
*	PIPE [2 : 0024]	0067	1	5.0	184.13	.86	16.42	1.82	n/a	.000
*										
*	CALIB STANDHYD [I%= 8.0:S%= 2.00]	0110	1	5.0	50.14	.28	16.17	1.77	.13	.000
*										
	DUHYD	0128	1	5.0	50.14	.28	16.17	1.77	n/a	.000
	MAJOR SYSTEM:	0128	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:	0128	3	5.0	50.14	.28	16.17	1.77	n/a	.000
*										
*	PIPE [2 : 0128]	0044	1	5.0	50.14	.21	16.33	1.77	n/a	.000
*										
*	ADD [0067 + 0044]	0045	3	5.0	234.27	1.07	16.42	1.81	n/a	.000
*										
*	PIPE [2 : 0045]	0066	1	5.0	234.27	1.06	16.42	1.81	n/a	.000
*										
*	CALIB STANDHYD [I%= 8.0:S%= 2.00]	0108	1	5.0	37.51	.22	16.17	1.77	.13	.000
*										
	DUHYD	0138	1	5.0	37.51	.22	16.17	1.77	n/a	.000
	MAJOR SYSTEM:	0138	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:	0138	3	5.0	37.51	.22	16.17	1.77	n/a	.000
*										
*	PIPE [2 : 0138]	0020	1	5.0	37.51	.15	16.42	1.77	n/a	.000
*										
*	ADD [0066 + 0020]	0021	3	5.0	271.78	1.21	16.42	1.80	n/a	.000
*										
*	CALIB STANDHYD [I%= 8.0:S%= 2.00]	0109	1	5.0	12.77	.09	16.08	1.77	.13	.000
*										
	DUHYD	0129	1	5.0	12.77	.09	16.08	1.77	n/a	.000
	MAJOR SYSTEM:	0129	2	5.0	.00	.00	.00	.00	n/a	.000

```

      MINOR SYSTEM:  0129  3  5.0  12.77      .09 16.08  1.77 n/a  .000
*
      PIPE   [ 2 : 0129] 0041  1  5.0  12.77      .06 16.25  1.76 n/a  .000
*
      ADD [0021 + 0041] 0042  3  5.0  284.55    1.26 16.42  1.80 n/a  .000
*
      PIPE   [ 2 : 0042] 0065  1  5.0  284.55    1.25 16.50  1.80 n/a  .000
*
*  CALIB STANDHYD      0106  1  5.0  32.08      .19 16.17  1.77 .13  .000
  [I%= 8.0:S%= 2.00]
*
      DUHYD      0139  1  5.0  32.08      .19 16.17  1.77 n/a  .000
      MAJOR SYSTEM:  0139  2  5.0      .00      .00      .00 n/a  .000
      MINOR SYSTEM:  0139  3  5.0  32.08      .19 16.17  1.77 n/a  .000
*
      PIPE   [ 2 : 0139] 0017  1  5.0  32.08      .12 16.42  1.76 n/a  .000
*
      ADD [0065 + 0017] 0018  3  5.0  316.63    1.37 16.50  1.80 n/a  .000
*
      ADD [0130 + 0018] 0064  3  5.0  319.33    1.37 16.50  1.80 n/a  .000
*
      PIPE   [ 2 : 0064] 0062  1  5.0  319.33    1.40 16.50  1.80 n/a  .000
*
*  CALIB STANDHYD      0105  1  5.0  18.39      .12 16.17  1.77 .13  .000
  [I%= 8.0:S%= 2.00]
*
      DUHYD      0131  1  5.0  18.39      .12 16.17  1.77 n/a  .000
      MAJOR SYSTEM:  0131  2  5.0      .00      .00      .00 n/a  .000
      MINOR SYSTEM:  0131  3  5.0  18.39      .12 16.17  1.77 n/a  .000
*
      PIPE   [ 2 : 0131] 0059  1  5.0  18.39      .11 16.25  1.76 n/a  .000
*
      ADD [0062 + 0059] 0060  3  5.0  337.72    1.46 16.50  1.79 n/a  .000
*
*  CALIB STANDHYD      0104  1  5.0   3.73      .03 16.08  1.76 .13  .000
  [I%= 8.0:S%= 2.00]
*
      DUHYD      0140  1  5.0   3.73      .03 16.08  1.76 n/a  .000
      MAJOR SYSTEM:  0140  2  5.0      .00      .00      .00 n/a  .000
      MINOR SYSTEM:  0140  3  5.0   3.73      .03 16.08  1.76 n/a  .000
*
      PIPE   [ 2 : 0140] 0014  1  5.0   3.73      .03 16.17  1.76 n/a  .000
*
      ADD [0060 + 0014] 0015  3  5.0  341.45    1.47 16.50  1.79 n/a  .000
*
      PIPE   [ 2 : 0015] 0061  1  5.0  341.45    1.50 16.50  1.79 n/a  .000
*
*  CALIB STANDHYD      0103  1  5.0   1.18      .01 16.08  1.75 .13  .000
  [I%= 8.0:S%= 2.00]
*
      DUHYD      0141  1  5.0   1.18      .01 16.08  1.75 n/a  .000
      MAJOR SYSTEM:  0141  2  5.0      .00      .00      .00 n/a  .000
      MINOR SYSTEM:  0141  3  5.0   1.18      .01 16.08  1.75 n/a  .000
*
      PIPE   [ 2 : 0141] 0011  1  5.0   1.18      .01 16.08  1.74 n/a  .000
*
      ADD [0061 + 0011] 0012  3  5.0  342.63    1.50 16.50  1.79 n/a  .000
*
      PIPE   [ 2 : 0012] 0005  1  5.0  342.63    1.51 16.50  1.79 n/a  .000
*
      ADD [0008 + 0005] 0007  3  5.0  357.85    1.56 16.50  1.79 n/a  .000
*
*  CALIB STANDHYD      0101  1  5.0   1.22      .01 16.08  1.75 .13  .000
  [I%= 8.0:S%= 2.00]
*
      DUHYD      0142  1  5.0   1.22      .01 16.08  1.75 n/a  .000
      MAJOR SYSTEM:  0142  2  5.0      .00      .00      .00 n/a  .000
      MINOR SYSTEM:  0142  3  5.0   1.22      .01 16.08  1.75 n/a  .000
*
      PIPE   [ 2 : 0142] 0004  1  5.0   1.22      .01 16.17  1.74 n/a  .000
*
      ADD [0007 + 0004] 0006  3  5.0  359.07    1.56 16.50  1.79 n/a  .000
*
      PIPE   [ 2 : 0006] 0002  1  5.0  359.07    1.57 16.50  1.79 n/a  .000
*
*****
** SIMULATION NUMBER:  4 **
*****

```

W/E COMMAND	HYD ID	DT min	AREA ha	Qpeak cms	Tpeak hrs	R.V. mm	R.C.	Qbase cms
-------------	--------	-----------	------------	--------------	--------------	------------	------	--------------

START @ .00 hrs

READ STORM 5.0

[Ptot= 10.00 mm]

fname : D:\School\Methoprene Model\20050810.stm

remark: Newtonbrook 2005 August 10 Rainfall

```
*
* CALIB STANDHYD      0102  1  5.0  15.22   .15 14.67   .98 .10   .000
* [I%= 8.0:S%= 2.00]
*
* DUHYD      0132  1  5.0  15.22   .15 14.67   .98 n/a   .000
*   MAJOR SYSTEM:  0132  2  5.0    .00   .00 .00   .00 n/a   .000
*   MINOR SYSTEM:  0132  3  5.0  15.22   .15 14.67   .98 n/a   .000
*
* PIPE [ 2 : 0132] 0008  1  5.0  15.22   .08 14.75   .98 n/a   .000
*
* CALIB STANDHYD      0107  1  5.0   2.70   .03 14.67   .97 .10   .000
* [I%= 8.0:S%= 2.00]
*
* DUHYD      0130  1  5.0   2.70   .03 14.67   .97 n/a   .000
*   MAJOR SYSTEM:  0130  2  5.0    .00   .00 .00   .00 n/a   .000
*   MINOR SYSTEM:  0130  3  5.0   2.70   .03 14.67   .97 n/a   .000
*
* CALIB STANDHYD      0112  1  5.0   1.09   .02 14.67   1.77 .18   .000
* [I%= 8.0:S%= 2.00]
*
* DUHYD      0127  1  5.0   1.09   .02 14.67   1.77 n/a   .000
*   MAJOR SYSTEM:  0127  2  5.0    .00   .00 .00   .00 n/a   .000
*   MINOR SYSTEM:  0127  3  5.0   1.09   .02 14.67   1.77 n/a   .000
*
* CALIB STANDHYD      0113  1  5.0   6.24   .07 14.67   .98 .10   .000
* [I%= 8.0:S%= 2.00]
*
* DUHYD      0143  1  5.0   6.24   .07 14.67   .98 n/a   .000
*   MAJOR SYSTEM:  0143  2  5.0    .00   .00 .00   .00 n/a   .000
*   MINOR SYSTEM:  0143  3  5.0   6.24   .07 14.67   .98 n/a   .000
*
* PIPE [ 2 : 0143] 0047  1  5.0   6.24   .03 14.75   .98 n/a   .000
*
* ADD [0127 + 0047] 0070  3  5.0   7.33   .04 14.75   1.09 n/a   .000
*
* CALIB STANDHYD      0121  1  5.0  57.22   .34 14.75   .99 .10   .000
* [I%= 8.0:S%= 2.00]
*
* DUHYD      0134  1  5.0  57.22   .34 14.75   .99 n/a   .000
*   MAJOR SYSTEM:  0134  2  5.0    .00   .00 .00   .00 n/a   .000
*   MINOR SYSTEM:  0134  3  5.0  57.22   .34 14.75   .99 n/a   .000
*
* PIPE [ 2 : 0134] 0032  1  5.0  57.22   .18 14.92   .99 n/a   .000
*
* CALIB STANDHYD      0120  1  5.0   9.52   .10 14.67   .98 .10   .000
* [I%= 8.0:S%= 2.00]
*
* DUHYD      0133  1  5.0   9.52   .10 14.67   .98 n/a   .000
*   MAJOR SYSTEM:  0133  2  5.0    .00   .00 .00   .00 n/a   .000
*   MINOR SYSTEM:  0133  3  5.0   9.52   .10 14.67   .98 n/a   .000
*
* PIPE [ 2 : 0133] 0035  1  5.0   9.52   .06 14.75   .98 n/a   .000
*
* ADD [0032 + 0035] 0081  3  5.0  66.74   .22 14.83   .99 n/a   .000
*
* CALIB STANDHYD      0118  1  5.0   8.32   .09 14.67   1.79 .18   .000
* [I%= 8.0:S%= 2.00]
*
* DUHYD      0123  1  5.0   8.32   .09 14.67   1.79 n/a   .000
*   MAJOR SYSTEM:  0123  2  5.0    .00   .00 .00   .00 n/a   .000
*   MINOR SYSTEM:  0123  3  5.0   8.32   .09 14.67   1.79 n/a   .000
*
* CALIB STANDHYD      0119  1  5.0  39.93   .25 14.75   .99 .10   .000
* [I%= 8.0:S%= 2.00]
*
* DUHYD      0145  1  5.0  39.93   .25 14.75   .99 n/a   .000
*   MAJOR SYSTEM:  0145  2  5.0    .00   .00 .00   .00 n/a   .000
*   MINOR SYSTEM:  0145  3  5.0  39.93   .25 14.75   .99 n/a   .000
*
* PIPE [ 2 : 0145] 0056  1  5.0  39.93   .15 14.83   .99 n/a   .000
*
* ADD [0123 + 0056] 0080  3  5.0  48.25   .18 14.83   1.12 n/a   .000
*
* ADD [0081 + 0080] 0082  3  5.0 114.99   .40 14.83   1.04 n/a   .000
```

*	PIPE	[2 : 0082]	0077	1	5.0	114.99	.39	14.92	1.04	n/a	.000
*	CALIB STANDHYD		0117	1	5.0	4.59	.05	14.67	.98	.10	.000
*	[I%= 8.0:S%= 2.00]										
*	DUHYD		0124	1	5.0	4.59	.05	14.67	.98	n/a	.000
	MAJOR SYSTEM:		0124	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:		0124	3	5.0	4.59	.05	14.67	.98	n/a	.000
*	PIPE	[2 : 0124]	0053	1	5.0	4.59	.04	14.75	.98	n/a	.000
*	ADD [0077 + 0053]		0054	3	5.0	119.58	.40	14.83	1.04	n/a	.000
*	PIPE	[2 : 0054]	0076	1	5.0	119.58	.40	14.92	1.04	n/a	.000
*	CALIB STANDHYD		0116	1	5.0	38.23	.24	14.75	.99	.10	.000
*	[I%= 8.0:S%= 2.00]										
*	DUHYD		0135	1	5.0	38.23	.24	14.75	.99	n/a	.000
	MAJOR SYSTEM:		0135	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:		0135	3	5.0	38.23	.24	14.75	.99	n/a	.000
*	PIPE	[2 : 0135]	0029	1	5.0	38.23	.15	14.83	.99	n/a	.000
*	ADD [0076 + 0029]		0030	3	5.0	157.81	.54	14.92	1.03	n/a	.000
*	PIPE	[2 : 0030]	0075	1	5.0	157.81	.55	14.92	1.03	n/a	.000
*	CALIB STANDHYD		0115	1	5.0	10.02	.10	14.67	.98	.10	.000
*	[I%= 8.0:S%= 2.00]										
*	DUHYD		0136	1	5.0	10.02	.10	14.67	.98	n/a	.000
	MAJOR SYSTEM:		0136	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:		0136	3	5.0	10.02	.10	14.67	.98	n/a	.000
*	PIPE	[2 : 0136]	0026	1	5.0	10.02	.07	14.75	.98	n/a	.000
*	ADD [0075 + 0026]		0027	3	5.0	167.83	.57	14.92	1.02	n/a	.000
*	PIPE	[2 : 0027]	0072	1	5.0	167.83	.57	14.92	1.02	n/a	.000
*	CALIB STANDHYD		0114	1	5.0	5.61	.06	14.67	.98	.10	.000
*	[I%= 8.0:S%= 2.00]										
*	DUHYD		0125	1	5.0	5.61	.06	14.67	.98	n/a	.000
	MAJOR SYSTEM:		0125	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:		0125	3	5.0	5.61	.06	14.67	.98	n/a	.000
*	PIPE	[2 : 0125]	0050	1	5.0	5.61	.03	14.75	.98	n/a	.000
*	ADD [0072 + 0050]		0051	3	5.0	173.44	.58	14.92	1.02	n/a	.000
*	PIPE	[2 : 0051]	0073	1	5.0	173.44	.58	15.00	1.02	n/a	.000
*	ADD [0070 + 0073]		0074	3	5.0	180.77	.59	14.92	1.03	n/a	.000
*	PIPE	[2 : 0074]	0068	1	5.0	180.77	.61	15.00	1.03	n/a	.000
*	CALIB STANDHYD		0111	1	5.0	3.36	.04	14.67	.97	.10	.000
*	[I%= 8.0:S%= 2.00]										
*	DUHYD		0137	1	5.0	3.36	.04	14.67	.97	n/a	.000
	MAJOR SYSTEM:		0137	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:		0137	3	5.0	3.36	.04	14.67	.97	n/a	.000
*	PIPE	[2 : 0137]	0023	1	5.0	3.36	.03	14.75	.97	n/a	.000
*	ADD [0068 + 0023]		0024	3	5.0	184.13	.61	15.00	1.02	n/a	.000
*	PIPE	[2 : 0024]	0067	1	5.0	184.13	.63	15.00	1.02	n/a	.000
*	CALIB STANDHYD		0110	1	5.0	50.14	.30	14.75	.99	.10	.000
*	[I%= 8.0:S%= 2.00]										
*	DUHYD		0128	1	5.0	50.14	.30	14.75	.99	n/a	.000
	MAJOR SYSTEM:		0128	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:		0128	3	5.0	50.14	.30	14.75	.99	n/a	.000
*	PIPE	[2 : 0128]	0044	1	5.0	50.14	.17	14.92	.99	n/a	.000

*	ADD [0067 + 0044]	0045	3	5.0	234.27	.77	15.00	1.02	n/a	.000
*	PIPE [2 : 0045]	0066	1	5.0	234.27	.79	15.00	1.02	n/a	.000
*	CALIB STANDHYD [I%= 8.0:S%= 2.00]	0108	1	5.0	37.51	.24	14.75	.99	.10	.000
*	DUHYD	0138	1	5.0	37.51	.24	14.75	.99	n/a	.000
	MAJOR SYSTEM:	0138	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:	0138	3	5.0	37.51	.24	14.75	.99	n/a	.000
*	PIPE [2 : 0138]	0020	1	5.0	37.51	.11	14.92	.99	n/a	.000
*	ADD [0066 + 0020]	0021	3	5.0	271.78	.88	15.00	1.01	n/a	.000
*	CALIB STANDHYD [I%= 8.0:S%= 2.00]	0109	1	5.0	12.77	.13	14.67	.98	.10	.000
*	DUHYD	0129	1	5.0	12.77	.13	14.67	.98	n/a	.000
	MAJOR SYSTEM:	0129	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:	0129	3	5.0	12.77	.13	14.67	.98	n/a	.000
*	PIPE [2 : 0129]	0041	1	5.0	12.77	.06	14.75	.98	n/a	.000
*	ADD [0021 + 0041]	0042	3	5.0	284.55	.91	15.00	1.01	n/a	.000
*	PIPE [2 : 0042]	0065	1	5.0	284.55	.91	15.00	1.01	n/a	.000
*	CALIB STANDHYD [I%= 8.0:S%= 2.00]	0106	1	5.0	32.08	.21	14.75	.99	.10	.000
*	DUHYD	0139	1	5.0	32.08	.21	14.75	.99	n/a	.000
	MAJOR SYSTEM:	0139	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:	0139	3	5.0	32.08	.21	14.75	.99	n/a	.000
*	PIPE [2 : 0139]	0017	1	5.0	32.08	.09	14.92	.98	n/a	.000
*	ADD [0065 + 0017]	0018	3	5.0	316.63	.99	15.00	1.01	n/a	.000
*	ADD [0130 + 0018]	0064	3	5.0	319.33	1.00	15.00	1.01	n/a	.000
*	PIPE [2 : 0064]	0062	1	5.0	319.33	.99	15.00	1.01	n/a	.000
*	CALIB STANDHYD [I%= 8.0:S%= 2.00]	0105	1	5.0	18.39	.13	14.75	.98	.10	.000
*	DUHYD	0131	1	5.0	18.39	.13	14.75	.98	n/a	.000
	MAJOR SYSTEM:	0131	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:	0131	3	5.0	18.39	.13	14.75	.98	n/a	.000
*	PIPE [2 : 0131]	0059	1	5.0	18.39	.10	14.83	.98	n/a	.000
*	ADD [0062 + 0059]	0060	3	5.0	337.72	1.04	15.00	1.01	n/a	.000
*	CALIB STANDHYD [I%= 8.0:S%= 2.00]	0104	1	5.0	3.73	.04	14.67	.98	.10	.000
*	DUHYD	0140	1	5.0	3.73	.04	14.67	.98	n/a	.000
	MAJOR SYSTEM:	0140	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:	0140	3	5.0	3.73	.04	14.67	.98	n/a	.000
*	PIPE [2 : 0140]	0014	1	5.0	3.73	.03	14.75	.97	n/a	.000
*	ADD [0060 + 0014]	0015	3	5.0	341.45	1.05	15.00	1.01	n/a	.000
*	PIPE [2 : 0015]	0061	1	5.0	341.45	1.03	15.08	1.01	n/a	.000
*	CALIB STANDHYD [I%= 8.0:S%= 2.00]	0103	1	5.0	1.18	.02	14.67	.95	.10	.000
*	DUHYD	0141	1	5.0	1.18	.02	14.67	.95	n/a	.000
	MAJOR SYSTEM:	0141	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:	0141	3	5.0	1.18	.02	14.67	.95	n/a	.000
*	PIPE [2 : 0141]	0011	1	5.0	1.18	.01	14.75	.95	n/a	.000
*	ADD [0061 + 0011]	0012	3	5.0	342.63	1.03	15.08	1.01	n/a	.000
*	PIPE [2 : 0012]	0005	1	5.0	342.63	1.05	15.08	1.01	n/a	.000
*	ADD [0008 + 0005]	0007	3	5.0	357.85	1.07	15.08	1.00	n/a	.000

```

*
* CALIB STANDHYD      0101  1  5.0    1.22    .02 14.67    .95 .10    .000
  [I%= 8.0:S%= 2.00]
*
  DUHYD                0142  1  5.0    1.22    .02 14.67    .95 n/a    .000
    MAJOR SYSTEM:      0142  2  5.0      .00    .00 .00    .00 n/a    .000
    MINOR SYSTEM:      0142  3  5.0    1.22    .02 14.67    .95 n/a    .000
*
  PIPE   [ 2 : 0142] 0004  1  5.0    1.22    .01 14.75    .95 n/a    .000
*
  ADD [0007 + 0004] 0006  3  5.0  359.07    1.08 15.08    1.00 n/a    .000
*
  PIPE   [ 2 : 0006] 0002  1  5.0  359.07    1.08 15.08    1.00 n/a    .000
*

```

```

*****
** SIMULATION NUMBER: 5 **
*****

```

W/E COMMAND	HYD ID	DT min	AREA ha	Qpeak cms	Tpeak hrs	R.V. mm	R.C.	Qbase cms
START @ .00 hrs								

READ STORM 5.0								
[Ptot= 13.90 mm]								
fname : D:\School\Methoprene Model\20050819.stm								
remark: Newtonbrook 2005 Aug 19 Rainfall								
* CALIB STANDHYD	0102	1	5.0	15.22	.04	8.00	2.00	.14
[I%= 8.0:S%= 2.00]								
* DUHYD	0132	1	5.0	15.22	.04	8.00	2.00	n/a
MAJOR SYSTEM:	0132	2	5.0	.00	.00	.00	n/a	.000
MINOR SYSTEM:	0132	3	5.0	15.22	.04	8.00	2.00	n/a
* PIPE [2 : 0132]	0008	1	5.0	15.22	.04	8.08	2.00	n/a
* CALIB STANDHYD	0107	1	5.0	2.70	.01	7.83	1.99	.14
[I%= 8.0:S%= 2.00]								
* DUHYD	0130	1	5.0	2.70	.01	7.83	1.99	n/a
MAJOR SYSTEM:	0130	2	5.0	.00	.00	.00	n/a	.000
MINOR SYSTEM:	0130	3	5.0	2.70	.01	7.83	1.99	n/a
* CALIB STANDHYD	0112	1	5.0	1.09	.00	7.83	3.14	.23
[I%= 8.0:S%= 2.00]								
* DUHYD	0127	1	5.0	1.09	.00	7.83	3.14	n/a
MAJOR SYSTEM:	0127	2	5.0	.00	.00	.00	n/a	.000
MINOR SYSTEM:	0127	3	5.0	1.09	.00	7.83	3.14	n/a
* CALIB STANDHYD	0113	1	5.0	6.24	.02	7.92	2.00	.14
[I%= 8.0:S%= 2.00]								
* DUHYD	0143	1	5.0	6.24	.02	7.92	2.00	n/a
MAJOR SYSTEM:	0143	2	5.0	.00	.00	.00	n/a	.000
MINOR SYSTEM:	0143	3	5.0	6.24	.02	7.92	2.00	n/a
* PIPE [2 : 0143]	0047	1	5.0	6.24	.01	8.00	1.99	n/a
* ADD [0127 + 0047]	0070	3	5.0	7.33	.02	8.00	2.17	n/a
* CALIB STANDHYD	0121	1	5.0	57.22	.13	8.08	2.00	.14
[I%= 8.0:S%= 2.00]								
* DUHYD	0134	1	5.0	57.22	.13	8.08	2.00	n/a
MAJOR SYSTEM:	0134	2	5.0	.00	.00	.00	n/a	.000
MINOR SYSTEM:	0134	3	5.0	57.22	.13	8.08	2.00	n/a
* PIPE [2 : 0134]	0032	1	5.0	57.22	.12	8.25	2.00	n/a
* CALIB STANDHYD	0120	1	5.0	9.52	.02	7.92	2.00	.14
[I%= 8.0:S%= 2.00]								
* DUHYD	0133	1	5.0	9.52	.02	7.92	2.00	n/a
MAJOR SYSTEM:	0133	2	5.0	.00	.00	.00	n/a	.000
MINOR SYSTEM:	0133	3	5.0	9.52	.02	7.92	2.00	n/a
* PIPE [2 : 0133]	0035	1	5.0	9.52	.02	8.08	2.00	n/a
* ADD [0032 + 0035]	0081	3	5.0	66.74	.14	8.17	2.00	n/a

*	CALIB STANDHYD [I%= 8.0:S%= 2.00]	0118	1	5.0	8.32	.03	7.92	3.16	.23	.000
*	DUHYD	0123	1	5.0	8.32	.03	7.92	3.16	n/a	.000
	MAJOR SYSTEM:	0123	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:	0123	3	5.0	8.32	.03	7.92	3.16	n/a	.000
*	CALIB STANDHYD [I%= 8.0:S%= 2.00]	0119	1	5.0	39.93	.09	8.08	2.00	.14	.000
*	DUHYD	0145	1	5.0	39.93	.09	8.08	2.00	n/a	.000
	MAJOR SYSTEM:	0145	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:	0145	3	5.0	39.93	.09	8.08	2.00	n/a	.000
*	PIPE [2 : 0145]	0056	1	5.0	39.93	.09	8.25	2.00	n/a	.000
*	ADD [0123 + 0056]	0080	3	5.0	48.25	.12	8.17	2.20	n/a	.000
*	ADD [0081 + 0080]	0082	3	5.0	114.99	.26	8.17	2.09	n/a	.000
*	PIPE [2 : 0082]	0077	1	5.0	114.99	.26	8.25	2.09	n/a	.000
*	CALIB STANDHYD [I%= 8.0:S%= 2.00]	0117	1	5.0	4.59	.01	7.92	2.00	.14	.000
*	DUHYD	0124	1	5.0	4.59	.01	7.92	2.00	n/a	.000
	MAJOR SYSTEM:	0124	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:	0124	3	5.0	4.59	.01	7.92	2.00	n/a	.000
*	PIPE [2 : 0124]	0053	1	5.0	4.59	.01	7.92	2.00	n/a	.000
*	ADD [0077 + 0053]	0054	3	5.0	119.58	.27	8.17	2.08	n/a	.000
*	PIPE [2 : 0054]	0076	1	5.0	119.58	.27	8.25	2.08	n/a	.000
*	CALIB STANDHYD [I%= 8.0:S%= 2.00]	0116	1	5.0	38.23	.09	8.00	2.00	.14	.000
*	DUHYD	0135	1	5.0	38.23	.09	8.00	2.00	n/a	.000
	MAJOR SYSTEM:	0135	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:	0135	3	5.0	38.23	.09	8.00	2.00	n/a	.000
*	PIPE [2 : 0135]	0029	1	5.0	38.23	.08	8.17	2.00	n/a	.000
*	ADD [0076 + 0029]	0030	3	5.0	157.81	.35	8.25	2.06	n/a	.000
*	PIPE [2 : 0030]	0075	1	5.0	157.81	.35	8.25	2.06	n/a	.000
*	CALIB STANDHYD [I%= 8.0:S%= 2.00]	0115	1	5.0	10.02	.03	7.92	2.00	.14	.000
*	DUHYD	0136	1	5.0	10.02	.03	7.92	2.00	n/a	.000
	MAJOR SYSTEM:	0136	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:	0136	3	5.0	10.02	.03	7.92	2.00	n/a	.000
*	PIPE [2 : 0136]	0026	1	5.0	10.02	.02	8.00	2.00	n/a	.000
*	ADD [0075 + 0026]	0027	3	5.0	167.83	.37	8.25	2.06	n/a	.000
*	PIPE [2 : 0027]	0072	1	5.0	167.83	.37	8.25	2.06	n/a	.000
*	CALIB STANDHYD [I%= 8.0:S%= 2.00]	0114	1	5.0	5.61	.01	7.92	2.00	.14	.000
*	DUHYD	0125	1	5.0	5.61	.01	7.92	2.00	n/a	.000
	MAJOR SYSTEM:	0125	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:	0125	3	5.0	5.61	.01	7.92	2.00	n/a	.000
*	PIPE [2 : 0125]	0050	1	5.0	5.61	.01	8.00	2.00	n/a	.000
*	ADD [0072 + 0050]	0051	3	5.0	173.44	.38	8.25	2.06	n/a	.000
*	PIPE [2 : 0051]	0073	1	5.0	173.44	.38	8.25	2.06	n/a	.000
*	ADD [0070 + 0073]	0074	3	5.0	180.77	.40	8.25	2.06	n/a	.000
*	PIPE [2 : 0074]	0068	1	5.0	180.77	.40	8.25	2.06	n/a	.000
*	CALIB STANDHYD [I%= 8.0:S%= 2.00]	0111	1	5.0	3.36	.01	7.92	2.00	.14	.000

* * *	DUHYD	0137	1	5.0	3.36	.01	7.92	2.00	n/a	.000
	MAJOR SYSTEM:	0137	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:	0137	3	5.0	3.36	.01	7.92	2.00	n/a	.000
* * *	PIPE [2 : 0137]	0023	1	5.0	3.36	.01	8.00	1.99	n/a	.000
* * *	ADD [0068 + 0023]	0024	3	5.0	184.13	.40	8.25	2.06	n/a	.000
* * *	PIPE [2 : 0024]	0067	1	5.0	184.13	.40	8.33	2.06	n/a	.000
* * *	CALIB STANDHYD [I%= 8.0:S%= 2.00]	0110	1	5.0	50.14	.11	8.08	2.00	.14	.000
* * *	DUHYD	0128	1	5.0	50.14	.11	8.08	2.00	n/a	.000
	MAJOR SYSTEM:	0128	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:	0128	3	5.0	50.14	.11	8.08	2.00	n/a	.000
* * *	PIPE [2 : 0128]	0044	1	5.0	50.14	.11	8.17	2.00	n/a	.000
* * *	ADD [0067 + 0044]	0045	3	5.0	234.27	.51	8.25	2.05	n/a	.000
* * *	PIPE [2 : 0045]	0066	1	5.0	234.27	.51	8.33	2.05	n/a	.000
* * *	CALIB STANDHYD [I%= 8.0:S%= 2.00]	0108	1	5.0	37.51	.09	8.00	2.00	.14	.000
* * *	DUHYD	0138	1	5.0	37.51	.09	8.00	2.00	n/a	.000
	MAJOR SYSTEM:	0138	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:	0138	3	5.0	37.51	.09	8.00	2.00	n/a	.000
* * *	PIPE [2 : 0138]	0020	1	5.0	37.51	.08	8.25	2.00	n/a	.000
* * *	ADD [0066 + 0020]	0021	3	5.0	271.78	.59	8.33	2.04	n/a	.000
* * *	CALIB STANDHYD [I%= 8.0:S%= 2.00]	0109	1	5.0	12.77	.03	7.92	2.00	.14	.000
* * *	DUHYD	0129	1	5.0	12.77	.03	7.92	2.00	n/a	.000
	MAJOR SYSTEM:	0129	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:	0129	3	5.0	12.77	.03	7.92	2.00	n/a	.000
* * *	PIPE [2 : 0129]	0041	1	5.0	12.77	.03	8.08	2.00	n/a	.000
* * *	ADD [0021 + 0041]	0042	3	5.0	284.55	.61	8.25	2.04	n/a	.000
* * *	PIPE [2 : 0042]	0065	1	5.0	284.55	.61	8.33	2.04	n/a	.000
* * *	CALIB STANDHYD [I%= 8.0:S%= 2.00]	0106	1	5.0	32.08	.08	8.00	2.00	.14	.000
* * *	DUHYD	0139	1	5.0	32.08	.08	8.00	2.00	n/a	.000
	MAJOR SYSTEM:	0139	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:	0139	3	5.0	32.08	.08	8.00	2.00	n/a	.000
* * *	PIPE [2 : 0139]	0017	1	5.0	32.08	.07	8.25	2.00	n/a	.000
* * *	ADD [0065 + 0017]	0018	3	5.0	316.63	.68	8.33	2.04	n/a	.000
* * *	ADD [0130 + 0018]	0064	3	5.0	319.33	.68	8.33	2.04	n/a	.000
* * *	PIPE [2 : 0064]	0062	1	5.0	319.33	.68	8.33	2.04	n/a	.000
* * *	CALIB STANDHYD [I%= 8.0:S%= 2.00]	0105	1	5.0	18.39	.05	8.00	2.00	.14	.000
* * *	DUHYD	0131	1	5.0	18.39	.05	8.00	2.00	n/a	.000
	MAJOR SYSTEM:	0131	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:	0131	3	5.0	18.39	.05	8.00	2.00	n/a	.000
* * *	PIPE [2 : 0131]	0059	1	5.0	18.39	.04	8.08	2.00	n/a	.000
* * *	ADD [0062 + 0059]	0060	3	5.0	337.72	.72	8.25	2.03	n/a	.000
* * *	CALIB STANDHYD [I%= 8.0:S%= 2.00]	0104	1	5.0	3.73	.01	7.92	2.00	.14	.000
* * *	DUHYD	0140	1	5.0	3.73	.01				

*	PIPE	[2 : 0140]	0014	1	5.0	3.73	.01	7.92	1.99	n/a	.000
*	ADD	[0060 + 0014]	0015	3	5.0	341.45	.73	8.25	2.03	n/a	.000
*	PIPE	[2 : 0015]	0061	1	5.0	341.45	.73	8.25	2.03	n/a	.000
*	CALIB STANDHYD		0103	1	5.0	1.18	.00	7.83	1.98	.14	.000
	[I%= 8.0:S%= 2.00]										
*	DUHYD		0141	1	5.0	1.18	.00	7.83	1.98	n/a	.000
	MAJOR SYSTEM:		0141	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:		0141	3	5.0	1.18	.00	7.83	1.98	n/a	.000
*	PIPE	[2 : 0141]	0011	1	5.0	1.18	.00	7.83	1.98	n/a	.000
*	ADD	[0061 + 0011]	0012	3	5.0	342.63	.74	8.25	2.03	n/a	.000
*	PIPE	[2 : 0012]	0005	1	5.0	342.63	.74	8.25	2.03	n/a	.000
*	ADD	[0008 + 0005]	0007	3	5.0	357.85	.77	8.25	2.03	n/a	.000
*	CALIB STANDHYD		0101	1	5.0	1.22	.00	7.83	1.98	.14	.000
	[I%= 8.0:S%= 2.00]										
*	DUHYD		0142	1	5.0	1.22	.00	7.83	1.98	n/a	.000
	MAJOR SYSTEM:		0142	2	5.0	.00	.00	.00	.00	n/a	.000
	MINOR SYSTEM:		0142	3	5.0	1.22	.00	7.83	1.98	n/a	.000
*	PIPE	[2 : 0142]	0004	1	5.0	1.22	.00	7.92	1.98	n/a	.000
*	ADD	[0007 + 0004]	0006	3	5.0	359.07	.77	8.25	2.03	n/a	.000
*	PIPE	[2 : 0006]	0002	1	5.0	359.07	.77	8.25	2.03	n/a	.000
*	FINISH										

=====

APPENDIX B

MASS BALANCE MODELS

[illegible]

[illegible]