Detroit Water and Sewerage Department

Wastewater Master Plan

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SSO Modeling and Calibration for SSO Case Studies

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Table of Contents

1 INTRODUCTION 1

1.1 Overview 1
1.2 Background 1

2 WET WEATHER RESPONSE IN SANITARY SEWERED AREAS 2

2.1 Definitions of common terms 2
2.2 Causes of wet weather response 4
2.3 GDRSS Approach to Characterization of Wet Weather Response 5
2.3.1 General 5
2.3.2 RDII Response Volume 5
2.3.3 RDII Response Shape 7
2.3.4 GDRSS Model Development 8
2.3.5 Limitations of the GDRSS Approach 11
2.3.6 GDRSS Model Updates 12
2.4 Other Approaches To Characterization Of Wet Weather Response 13
2.4.1 General 13
2.4.2 Western Wayne Sub-model (Wayne County, Michigan) 14
2.4.3 Clinton-Oakland System (Oakland County, Michigan) 15
2.4.4 Twelve Towns Drainage District (Oakland County, Michigan) 16
2.4.5 System Identification Methodology 16
2.4.6 King County Dept. of Metropolitan Services (Seattle, Washington) 17
2.4.7 Miami-Dade Water and Sewer Dept. (Miami, Florida) 18
2.4.8 Greater Houston Wastewater Program (Houston, Texas) 18

3 CASE STUDIES SSO MODELING 20

3.1 Design Storm Events 20
3.2 Center Line 20
3.2.1 Existing Analysis 20
3.2.2 Flow and Rainfall Data 21
3.2.3 Flow and Rainfall Data Analysis and Results 22
3.2.4 Integration with the GDRSS Model Results 23
3.2.5 Dry Weather Flow 24
3.2.6 Wet Weather Volumes 24
3.2.7 Contract Exceedance Volumes 25

3.2.8 Sewer System Modeling 26
3.2.9 Sanitary Sewer Overflow Volumes 26
3.3 Clinton Township 27
3.3.1 Existing Analysis 27
3.3.2 Flow and Rainfall Data Analysis and Results 28
3.3.3 Dry Weather Flow 29
3.3.4 Wet Weather Volumes 29
3.3.5 Sewer System Modeling 30
3.3.6 Sanitary Sewer Overflow Volumes 31
3.3.7 Contract Exceedance Volumes 32
3.4 Fraser 33
3.4.1 Existing Analysis 33
3.4.2 Flow and Rainfall Data 34
3.4.3 Data Analysis and Results 35
3.4.4 Dry Weather Flow 37
3.4.5 Wet Weather Volumes 37
3.4.6 Contract Exceedance Volumes 38
3.4.7 Sewer System Modeling 39
3.4.8 Sanitary Sewer Overflow Volumes 40
3.5 Melvindale 41
3.5.1 Existing Analysis 41
3.5.2 Flow and Rainfall Data 42
3.5.3 Data Analysis and Results 43
3.5.4 Dry Weather Flow 45
3.5.5 Response Shape 45
3.5.6 Wet Weather Volumes 45
3.5.7 Contract Exceedance Volumes 46
3.5.8 Sanitary Sewer Modeling 47
3.5.9 Sanitary Sewer Overflow Volumes 47
3.6 Allen Park 47
3.6.1 Existing Analysis 47
3.6.2 Flow and Rainfall Data 48
3.6.3 Data Analysis and Results 48
3.6.4 Dry Weather Flow 48
3.6.5 RDII Volume Response 48
3.6.6 Response Shape 49

3.6.7 Wet Weather Volumes 49
3.6.8 Contract Exceedance Volumes 49
3.6.9 Sewer System Modeling 50
3.6.10 Sanitary Sewer Overflow Volumes 50
3.7 Garden City 50
3.7.1 Background 50
3.7.2 Data Analysis and Results 51
3.7.3 Dry Weather Flow 52
3.7.4 RDII Volume Response 52
3.7.5 Response Shape 52
3.7.6 Wet Weather Volumes 52
3.7.7 Contract Exceedance Volumes 53
3.7.8 SSO Volumes 53
4 SUMMARY 53
5 REFERENCES AND BIBLIOGRAPHY 54

SSO Modeling and Calibration for SSO Case Studies

1. Introduction

1.1 Overview

The characterization of the sanitary sewer overflow (SSO) case studies is included in Volume 6 of the Detroit Water and Sewerage Department (DWSD) Wastewater Master Plan (WWMP). This technical memorandum provides additional detail and the technical basis for the characterization of the six case study communities.

The approach to characterizing the wet weather response for the case studies is based on the formulation as used in the Greater Detroit Regional Sewer System (GDRSS) Model. Thus the first part of this memo presents the approach as developed for the GDRSS Model. Approaches used in other areas are also briefly discussed to provide context for how SSO characterization is being addressed in this project. The second half of the memo provides additional details of the analysis as performed for the six case studies. These details include sources of data used to characterize the area and results for the selected design events. Discussion of alternative development and modeling is provided in the WWMP Technical Memorandum titled *Local Alternatives for SSO Control*.

1.2 Background

A component of the WWMP is to review local and regional approaches to dealing with SSO problems within the system. The purpose of the regional approach is to find a cost-effective solution to the elimination of sanitary sewer overflows from the DWSD service area. As part of this effort, the following alternatives are evaluated:

- Elimination of the sources of high infiltration/inflow that cause SSOs;
- Local storage or treatment of SSOs; and
- Regional transmission, storage and treatment of SSOs.

These alternative evaluations are performed for six case studies. The six local municipalities that are serving as case studies in the regional analysis include:

- Center Line
- Clinton Township
- Fraser
- Melvindale
- Allen Park

- Garden City

The purpose of each case study is not only to determine a cost-effective solution to the local SSO problems, but also to gain insight on how the results might be transferred to other potential or known problem areas in the DWSD service area. Additional background and purpose is provided in Volume 6 of the WWMP.

2. Wet Weather Response in Sanitary Sewer Areas

2.1 Definitions of common terms

The following terms are defined for use in this memorandum. The sources for these definitions are from the GDRSS Technical Memorandum 31 and from the WWMP *Interim Report on SSO Characterization*, Chapter 2.

1. Combined Sewer

   A sewer that conveys both residential sewage and storm runoff flows. This single pipe system typically has relief points discharging flows to the receiving stream during some wet weather events.

2. Separate Sanitary Sewer

   A sewer intended to convey residential, commercial, and/or industrial sewage only. Storm runoff is transported with another conveyance system.

3. Infiltration

   The water entering a sewer system and/or service connections from the ground, through such means as, but not limited to, defective pipes, pipe joints, connections, or manhole wells. Infiltration does not include, and is distinguished from, inflow.

4. Inflow

   The water discharged into a sewer system, including service connections, from such sources as, but not limited to, roof leaders, cellar drains, yards and area drains, foundation drains, cooling water discharges, drains from springs and swampy areas, manhole covers, cross connections from storm and combined sewers, catch basins, stormwater, surface runoff, street wash waters, or drainage. Inflow does not include, and is distinguished from, infiltration.

5. Dry Weather Flow

   Dry weather flow includes the wastewater collected from residential, commercial, and/or industrial establishments as well as groundwater infiltration and certain dry weather inflow sources, such as cooling water discharges.

6. Wet Weather Flow

   Wet weather flow includes dry weather flow and any sources of inflow and infiltration directly impacted by precipitation and/or snow melt. Wet weather impacts may extend well beyond a specific event. However, wet weather impacts do not include long-term changes to groundwater elevation and the infiltration accompanying these changes.

7. Rain Dependent Infiltration/Inflow (RDII)

   Rain Dependent Infiltration/Inflow is the fraction of rainfall that enters the collection system due to precipitation in excess of the initial abstraction. It is described as the ratio of the inflow that enters a sanitary sewer system during a precipitation event to the total precipitation minus initial abstraction for the selected rainfall event.

8. Initial Abstraction

   The amount of rainfall below which little or no wet weather response is observed. Capacity of soil to sorb rainfall as soil infiltration begins prevents a wet weather response due to that portion of the rainfall being sorbed by the soil. This can impact both inflow and infiltration components of the response. A portion of the initial abstraction can be due to surface depression storage as well as the sorption by the soil.

9. Seasons

   For purposes of characterizing the RDII response, two seasons have been defined: dormant and growth.

   The dormant season spans the months of November through April, while the growth season spans the months of June through September. The months of May and October have been defined as transitional months, during which

time, the wet weather response can exhibit either dormant or growth characteristics, depending on the conditions for any given year.

10. Antecedent Soil Moisture

    Antecedent soil moisture is an indicator of the wetness of the soil and the availability of soil storage prior to a storm event. It can have a significant effect on the amount and rate of runoff for any given storm event. Various approaches have been developed to quantify antecedent moisture conditions (AMC) for hydrologic analysis, including using an index determined by summation of weighted daily rainfalls for a period preceding the runoff in question.

2.2 Causes of wet weather response

To characterize the wet weather response in sanitary sewer areas, it is helpful to first understand its causes. These causes are discussed in detail in Volume 6 of the WWMP. A brief discussion is provided here as support to the development of modeling this phenomenon.

By definition, separate sanitary systems are not designed for acceptance and conveyance of storm related flows. However, due to a number of factors, these systems can exhibit a wet weather response to storm events. Generally, the sources of wet weather flows into a sanitary system are classified as infiltration-related sources or inflow-related sources. Infiltration is generally any water other than the intended wastewater that enters a sewer system from the ground through cracks or openings in defective pipes, connections, or manholes. Inflow sources are generally any direct connection to the sanitary sewer such as roof leaders, yard drains, manhole covers, cross connections from storm drains, and basement foundation drains.

These sources of wet weather flows are defined as rain dependent inflow and infiltration (RDII) to distinguish from dry weather inflow and infiltration (DWII) that could occur during dry weather. The amount of response can vary, depending on the factors causing the response. For many older systems, footing drains of residential homes can be a major contributor. Footing drain connections to the sanitary sewer used to be allowed, provided the drains were set above the normal groundwater levels (NSF 1964, p.71).

RDII flow is an important component of the sanitary flow because all of it must be conveyed to the wastewater treatment plant (WWTP) for treatment. It is a significant source of flow in the regional collection system because of the size of the sanitary areas that are tributary to the DWSD WWTP. As a result, the RDII flows can impact the amount of WWTP capacity that is available for handling wet weather flows from the combined areas.

2.3 GDRSS Approach to Characterization of Wet Weather Response

2.3.1 General

The approach used in characterizing the wet weather response for the six case studies is based on the approach used in the development of the Greater Detroit Regional Sewer System Model. The GDRSS Model uses the U.S. EPA's Storm Water Management Model (SWMM) RUNOFF module to predict the flows that are generated in response to wet weather for both combined and separated sewer systems.

For combined service areas, RUNOFF estimates surface runoff and overland flow routing. For sanitary service areas, RUNOFF can estimate the rain dependent inflow/infiltration. These responses are generated for a single storm event or for a continuous rainfall record for an extended period of time.

After the wet weather response is determined, the GDRSS Model uses SWMM TRANSPORT and SWMM Extended Transport (EXTRAN) hydraulic modules to simulate the routing of flows through the collection system. These models provide the ability to understand flows and overflows during specific events and for long term precipitation records.

2.3.2 RDII Response Volume

For sanitary areas, RUNOFF determines the RDII response volume as the fraction of rainfall that enters a sanitary sewer system during a rainfall event after satisfying the requirements of initial abstraction. The amount of RDII response to a rainfall event is calculated as follows:

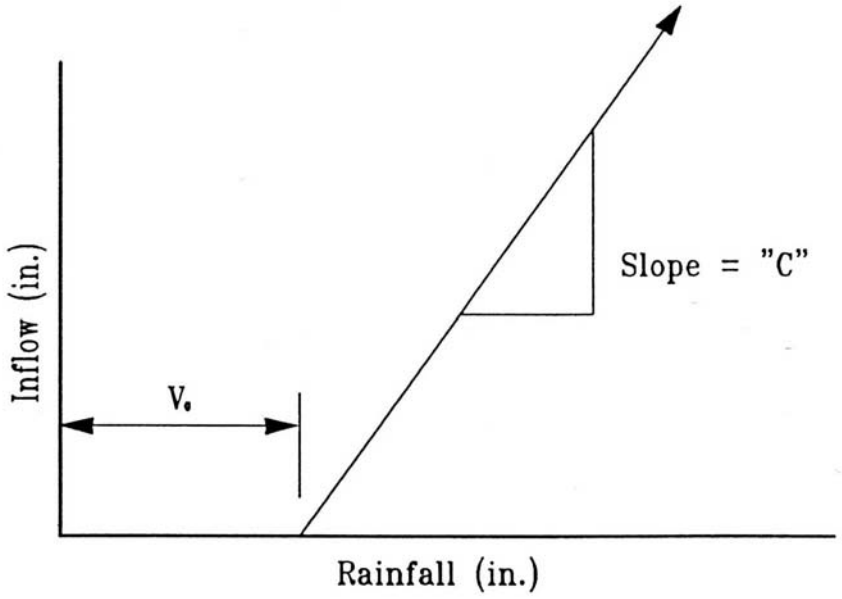
$$\text{RDII Volume} = C\,(P - Vo)\,A$$

Where C is the RDII response factor, P is the rainfall, Vo is the initial abstraction or amount of rainfall below which a response is typically not seen, and A is the tributary area.

The RDII C factor has been defined as the slope of a best fit line, which can be estimated by dividing the measured runoff by rainfall minus initial abstraction for a number of selected rainfall events, as shown in Figure 2.3.1. In this figure, a fraction of rainfall described as Vo represents initial abstraction, below which wet weather response is not realized in the collection system. The line is a best-fit line (linear regression) for a number of points determined as inflow and infiltration vs. rainfall. The slope of the line is defined as RDII C factor.

In RUNOFF, the initial abstraction is regenerated during dry weather at a rate defined by the DREC term. This term is required in RUNOFF to simulate multiple or continuous rainfall records.

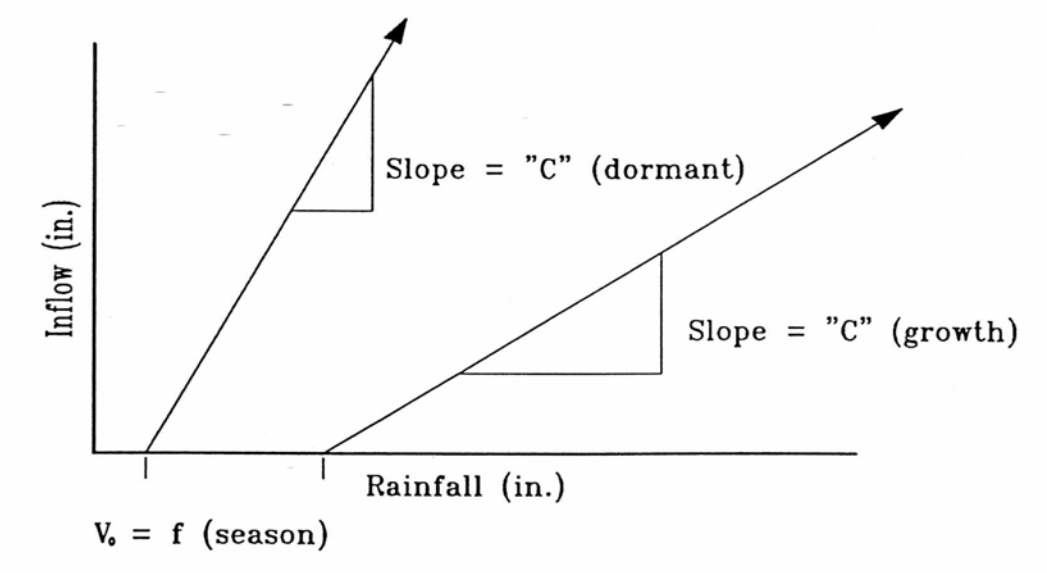
Figure 2.3.1 RDII Characterization in RUNOFF



During the GDRSS Model development, the inflow and infiltration vs. rainfall analysis conducted on the data provided by different communities tributary to the DWSD wastewater collection system revealed that the initial abstraction and RDII terms are seasonally dependent. This variation in the response is graphically shown in Figure 2.3.2.

This seasonal dependence is attributed to the groundwater fluctuations due to natural recharge from rainfall and/or snowmelt and in the variation in the evapotranspiration rates throughout the year. With this representation, the wet weather response during dormant conditions will be higher than during the growth conditions, as the initial abstraction is lower and the slope of the response (C) is higher.

Figure 2.3.2 Seasonal Variation in the RDII response



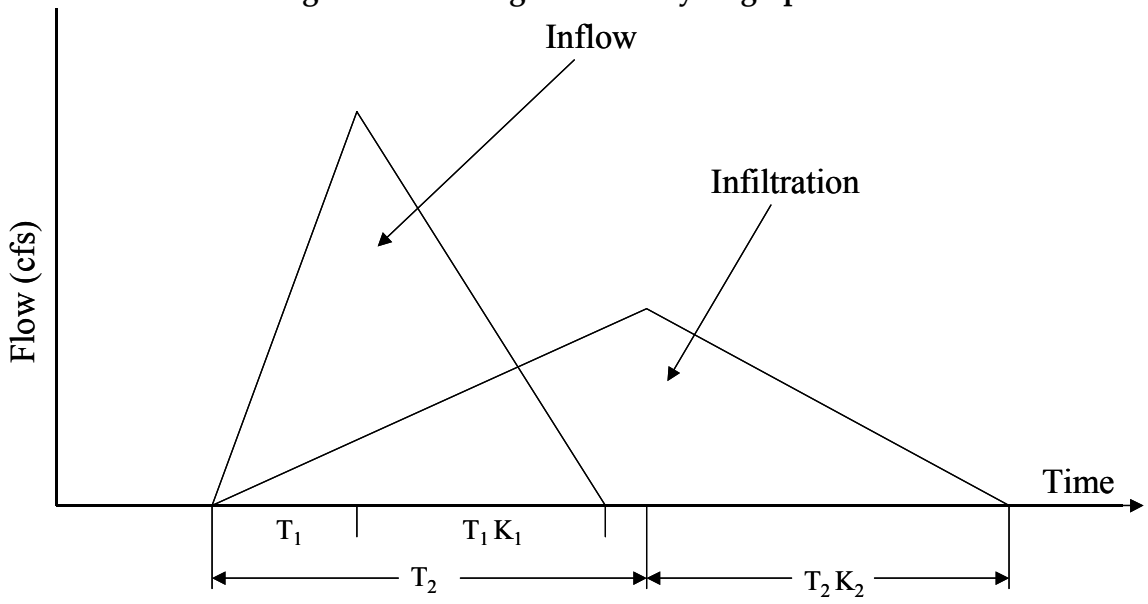
2.3.3 RDII Response Shape

The RDII C factor and the initial abstraction, Vo, are the RDII parameters used in RUNOFF to relate total response volumes to the precipitation and the season. Use of this approach allows for an accurate prediction of RDII volumes for other design or actual rainfall events; however, prediction of SSOs also requires estimating the peak flows that are being generated within the system. To quantify how the response volumes are distributed over time into the collection system, up to three triangular unit hydrographs can be defined in RUNOFF so that one may define a fast response, a delayed response, and a lengthy response, as needed to properly represent the actual flow regime. This method was developed by CDM staff members (CDM, 1985; Giguere and Riek, 1983) and has been used on sewer system master planning projects throughout the country since the mid-1980s. Routines based on this approach were added to RUNOFF in 1993 by CDM and are now part of the standard EPA SWMM program.

Parameters used in RUNOFF to describe these triangular unit hydrographs are T, K and the fraction of RDII C applied to each hydrograph. The T term represents the time from rainfall to the peak of the hydrograph and K is the ratio of the time to recession to the time to peak for the hydrograph. The fraction of RDII C applied to each hydrograph is based on the areas of each of the component hydrographs. All three hydrographs have the same starting time for each rainfall interval.

In most cases for the GDRSS Model, T and K parameters were determined for only two hydrographs: an inflow (direct response) component hydrograph and an infiltration (delayed response) component hydrograph. An example of this is shown in Figure 2.3.3. Due to lack of a pronounced direct response, some tributary areas were best described by a single hydrograph. Development of these parameters generally involves calibrating the parameters to several selected events.
This process is discussed further in the next subsection where the GDRSS Model development is discussed.

Figure 2.3.3 Triangular Unit Hydrographs



2.3.4 GDRSS Model Development

2.3.4.1 GDRSS RDII Data Analysis

Flow and precipitation data were collected from a total of 70 areas that ranged from approximately 25 acres to 12,000 acres in size. Representative dry weather flows (base flows) were determined for each metered location and superimposed on the wet weather flow hydrograph. The volume of response for a given storm event was then determined as the area between the wet weather and superimposed dry weather hydrographs. For each event analyzed in each region, a point was plotted as the volume of RDII response vs. rainfall. Data quality was evaluated. Unreliable or questionable data was identified and either reevaluated or discarded.

Average Vo values for both dormant and growth conditions were determined from the data collected. Regional averages were also determined to minimize error. The flow data analysis indicated that, even by region, there is very little difference in Vo values within the wastewater collection system.

For each area, a linear regression was performed to obtain a growth season and dormant season regression line. These regressions were forced through the growth and dormant period Vo design values, respectively. The RDII C factor for each season was then determined as the slope of the respective regression lines. The T, K, and the RDII C fraction for each component hydrograph were determined as follows:

- Isolate one-event responses
- Use events greater than 0.3-inches

- Estimate T and K for the inflow component
- Determine inflow component peak
- Estimate T and K for the infiltration component
- Determine infiltration component peak
- Calculate volume of component hydrograph and total volume
- Determine fraction of RDII C for the two component hydrographs
- Average results for up to four analyses per site to obtain final parameters

Determining the T and K parameters was limited by the following factors:

- The response shape can vary with the rainfall volume, intensity, and spatial and temporal distribution
- The response shape can vary seasonally

2.3.4.2 GDRSS RDII Calibration

As part of the GDRSS Model development, four months of flow data was collected for three small separate sewer study areas within the GDRSS service area. For each area, RUNOFF models were developed for calibration of the RDII parameters. A four-month continuous rainfall record was used for each simulation to allow the use of a number of events in a continuous simulation mode. This approach allowed for additional insight into some of the parameters required for the system-wide GDRSS model, especially for the DREC term.

The number of events used for calibration depended on the quality of both the flow and the rainfall data. An average of 13 events per study area were selected. The objectives of the calibration were to minimize the differences between the simulated and measured RDII for each event defined within the continuous record. The RDII parameters that affect volume of the response are the RDII C factors, the Vo volumes, and the DREC recovery rates for the two seasons.

Once the volume differences were minimized, adjusting the T and K values and the fraction of RDII C assigned to the inflow component hydrograph made further refinements. These five parameters were varied to improve calibration results, in terms of hydrograph shape, with emphasis on peak flow and overall duration of response. Throughout the various stages of the calibration, an overall check of the total absolute volume difference statistic was evaluated to ascertain the improvement. The calibration results confirmed the values determined for RDII C and Vo from the regression analysis. The average Vo values for the dormant and growth season were found to be 0.15-inches and 0.28-inches, respectively.

The continuous simulation also provided greater insight into DREC, a parameter for which no textbook or field data was available. The overall calibration results yielded a dormant season DREC of 0.06-in./day and a growth season DREC of 0.40-in./day.

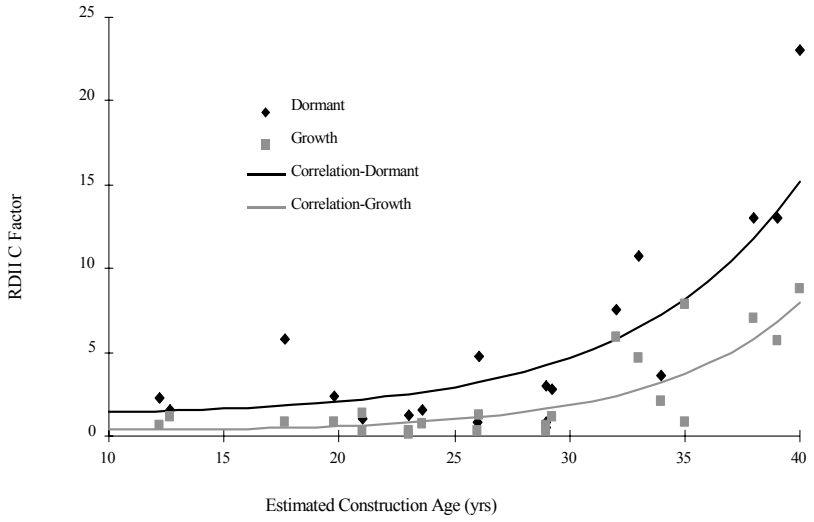
2.3.4.3 GDRSS RDII Spatial Variation

Despite the extensive analysis of RDII data throughout the modeled region, there remained many areas in which parameters had yet to be determined. Correlations were established to estimate the RDII C factors in areas where data was not available. The 1990 U.S. Census GIS coverage statistic for median building age was used as a surrogate for sewer system age. For sub-basins with greater than a 40-year construction age, 15% and 8% RDII C factors were used for the dormant and growth conditions, respectively. For sub-basins less than a 40-year construction age, the following equations were used:

$$\text{RDII C Factor} = 0.12 * e^{(0.14 * (\text{age}-6))} + 1.2 \text{ (Dormant Conditions)}$$
$$\text{RDII C Factor} = 0.033 * e^{(0.16 * (\text{age}-6))} + 0.3 \text{ (Growth Conditions)}$$

These correlations and the data used to generate them are shown in Figure 2.3.4.

Figure 2.3.4 RDII C Correlation to Sewer Age (GDRSS Model)



$$\textit{Growing}: \quad RDI/I\,C(\%) = 0.033 \cdot e^{(0.16(age-6))} + 0.3$$
$$\textit{Dormant}: \quad RDI/I(\%) = 0.12 \cdot e^{(0.14(age-6))} + 1.2$$

For the shape of the response, a typical response shape was determined where data was available for the various major districts. If actual data was not available for a sub-area, then the typical shape defined for the appropriate district was used.

Additional data has been collected since the GDRSS Model has been released, and it is anticipated that actual data will always be used when available and as needed to meet any future needs. For the case studies, for example, additional data has been collected and is being used to determine appropriate response factors, as is discussed later in this memo.

2.3.5 Limitations of the GDRSS Approach

Limitations to the GDRSS approach to wet weather characterization include the following:

- The RDII response factor is considered to be linear with the size of the storm events, once the initial abstraction is satisfied. This response might not be the case when extrapolating to very large events.

- A related limitation is that the volume of the response is primarily a function of rainfall volume, not intensity. Some data has been collected that seems to indicate that the intensity of the rainfall event can impact the amount of response seen in the collection system. In this particular case, the higher intensity event resulted in lower RDII response. One possible explanation being considered is that the higher intensity event resulted in a greater amount of flow being directed to the storm system due to less infiltration.

- Causes of seasonal impact are not included in the model's representation of the RDII response. That is, the variation in response is fixed to the time of year, rather than the particular seasonal conditions that might be causing the variation, such as ground water levels, temperature, and leaf area.

- RDII response factor correlations were based on median housing age. Recent data suggests that the presence of connected footing drains would also be a very strong factor.

- No correlations were developed for the shape parameters. These parameters were determined for areas without data based on a typical response shape defined for the given district, or, in some cases, being of similar size and land use as other areas for which shape parameters were defined. This level of detail was considered sufficient for the purposes of the model at the time, which was focused on CSO control; however, for purposes of the WWMP project, it is desired to develop an approach for extrapolating the information gained from the SSO case studies and other studies to other areas within the system to improve the model's predictive ability on the shape of the RDII response. Possible factors to use for correlation are being investigated as part of the SSO task under the WWMP project.

2.3.6 GDRSS Model Updates

There have been a number of updates to the GDRSS Model that have been made by various model users, some of which have been incorporated into the WWMP version of the GDRSS Model. More information pertaining to updates of the GDRSS model for the WWMP can be found in the *Greater Detroit Regional Sewer System Model Setup and Analysis* technical memorandum. Some of these updates included refinement of the hydrology. These updates are as follows:

Western Wayne North Huron Valley/Rouge Valley: The Western Wayne sub-model representation of wet weather response, the shape of the response in particular, has been updated using additional data by Wade-Trim. It is planned to obtain this update and incorporate it into the WWMP.

Southeast Oakland: An XP-SWMM model of the 12-Towns facility and the proposed improvements was developed several years ago. Various aspects of this model and the associated better representation of the 12-towns region, including the proposed improvements to the facility, have been incorporated into the WWMP Model.

Dearborn: Additional sub-areas were delineated as part of the Baby Creek Screening and Disinfection design project. These details have been incorporated into the GDRSS/WWMP Model as part of the update recently performed (see Detroit below).

Allen Park: A hydrologic model has been developed for Allen Park by the city. Some results of this modeling have been incorporated into the SSO case study. The hydraulics of the connection have been developed under the WWMP for review of regional impact of increased flows from Allen Park to the Northwest Interceptor (NWI).

Macomb Sanitary District: As part of the WWMP project, a sub-model has been developed for this district. This sub-model included a delineation of sub-areas for each billing meter and/or community. Previously, this district was represented by one sub-area. Data from the billing meters were used to define the RDII response parameters.

Clinton-Oakland District: A model prepared previously by the District in 1992 has been obtained and used as a basis to refine the level of detail for this district. This update included using the sub-areas as delineated versus using one sub-area as was previously configured in the GDRSS Model and determining appropriate RDII response parameters.

Oakwood District (Detroit): A copy of the sub-model developed for this district has been obtained and reviewed. No plans have been made to use it at this point--the level of detail is more appropriate for design vs. master planning; however, it would be relatively easy to add as a sub-model as it follows the same GDRSS model framework should it become useful for purposes of the project.

Detroit: At this point, the WWMP Model is synonymous with the GDRSS Model used for the CS-1281 CSO update submitted December 31, 2001, to the Michigan Department of Environmental Quality. This includes improved representation in the Baby Creek area, the Conner Creek area, some areas associated with in-system storage locations, 7-Mile and PF areas, etc.

The GDRSS Model is be updated as needed to support various projects that require input from the model. Information from the case studies provides additional information that may be used to update the GDRSS/WWMP regional model. The details of applying the results to the model are being developed.

2.4 Other Approaches To Characterization Of Wet Weather Response

2.4.1 General

Other approaches used to characterize the wet weather response in sanitary areas are discussed and illustrated for a few selected cases. A fairly recent report by the Water Environment Research Foundation documents in some detail the various flow prediction technologies that have been used (WERF, 1999). The three primary approaches that were tested with case studies involved the following:

1. Synthetic unit hydrographs: Documentation of this approach includes the application as used in SWMM as discussed above.
2. Probabilistic: This approach involves a frequency analysis of peak RDII flows to obtain a relationship between peak RDII flow and recurrence interval. It gives a good representation of the probability of occurrence of peak RDII flow, but it doesn't produce a RDII hydrograph for specific storm events. As a result, this method would not be able to simulate SSO reductions. Another disadvantage of this approach is that it requires long-term data to perform a frequency analysis.
3. Regression: This approach uses multiple linear regression methods to derive a relationship between any number of defined parameters and RDII. In addition to rainfall volume, intensity and duration, the parameters can include factors such as number of antecedent dry days, previous week rainfall, and/or previous month rainfall. Use of these additional parameters provides a way to account for antecedent conditions or other factors that impact RDII response. This approach was used in one case to extrapolate the RDII C factor from measured conditions to a design storm condition under a variety of antecedent conditions and ground water infiltration (Vallabhaneni, 2001).
   These projected Cs were still used with the unit hydrographs of a SWMM model to analyze the sewer system response and evaluate SSO elimination alternatives. Another related approach involved the use of an index rainfall to account for antecedent conditions (Miles, 1996). In this case, the amount of scatter in the RDII volume versus rainfall plot, as typically seen in such plots, was greatly reduced.

The review concluded that the synthetic unit hydrograph seems to have the greatest flexibility for multiple purposes, followed closely by the rainfall/runoff flow regression methodology. The GDRSS approach in effect incorporates both of these approaches as a (1) **regression** is used to determine the RDII C factor for use in the (2) **unit hydrographs** in SWMM RUNOFF. The regression is linear instead of multiple, but it is performed for two seasons.

A possible improvement to the current GDRSS approach would be to include additional parameters, as data is available, in determining a range of design C factors. However, this approach would not necessarily answer the question of what design conditions should be used. The current approach of using dormant and growth conditions is considered to be sufficient to span the potential design conditions for planning purposes. This approach was first developed for the GDRSS Model. The RDII routines in SWMM RUNOFF were coded to allow the parameters to vary by month to account for this characterization.

As a side note, RDII has been simulated using the standard rainfall-runoff algorithms in SWMM RUNOFF. This approach was used in the Clinton-Oakland district model, which was developed before the current RDII routines were added to the model (Cook, 1991). In other cases, the inflow has been modeled using the rainfall-runoff algorithms and the infiltration has been modeled using the groundwater routines (see subsection 2.4.3 below). Although both of these approaches are physically based, accurate representation of these physical processes can be difficult. In the case of the Clinton-Oakland model, the area of the tributary sub-areas was reduced to calibrate the response to the monitored flow data.

The three approaches to simulating wet weather response in sanitary areas in RUNOFF, (1) RDII routines, (2) storm sub-catchments and (3) storm sub-catchments with groundwater routines, were discussed by Vallabhaneni in a paper on I/I simulations (2001). He states that the empirical method as now included in SWMM can provide a better representation of the RDII response if a sufficient flow dataset is available.

Several other studies were selected and are summarized in the following subsections to illustrate some of these as well as other approaches used for predicting RDII in other collection systems across North America.

2.4.2 Western Wayne Sub-model (Wayne County, Michigan)

Wade-Trim, Inc. developed the Western Wayne Sub-model for Wayne County based on the GDRSS model framework. The Western Wayne Sub-model contains both the North Huron Valley and Rouge Valley sanitary sewer districts.

Although the GDRSS model framework was used, Wade-Trim developed a different method for characterizing wet weather. The Western Wayne Sub-model did not vary initial abstraction by season. Instead, the service area was sub-divided into three possible categories: large areas, small areas, and unique hydraulic areas.

Large areas were defined as sub-areas with trunk sewer lengths greater than 10,000-ft. Small areas were defined as sub-areas with trunk sewer lengths less than 10,000-ft. Local data was used to determine shaping parameters for each sub-area. Consistent with the GDRSS model, shaping parameters used two triangular unit hydrographs, had a 50-50 volume split between inflow and infiltration, and were not varied by season. This analysis resulted in a set of shaping factors for large areas and a set of shaping factors for small areas was calculated. Even in this case, several areas still had to be calibrated to unique shape values; that is, the generalization did not hold in all cases. This result could be determined for these cases as data was available for verification.

2.4.3 Clinton-Oakland System (Oakland County, Michigan)

According to a 1991 study by Consoer Townsend & Associates, the inflow to the Clinton-Oakland Sewage Disposal System is only about 0.5% of rainfall. Normal runoff models are only accurate to about 4% of rainfall. Therefore, it was difficult to accurately represent the wet weather response in the Clinton-Oakland Sewage Disposal System.

The study analyzed several rain events. The study found that the model calibration was accurate for rain events following a wet period. However, the use of the same system for rains during dry periods or a combination of wet and dry periods resulted in peak rates and volumes that were too large. In an attempt to more accurately calibrate the dry period rains, the following input variables were addressed:

- Depression storage for the impervious area
- Percent impervious area with immediate runoff
- Depression storage for the pervious area
- Initial infiltration rate for the pervious area
- Minimum infiltration rate for the pervious area
- Decay rate
- Evaporation rate
- Rainwater infiltration

In each case, however, variable alterations resulted in insignificant changes in the model results. The study found that the area had to be reduced in order to get reasonable results.

2.4.4 Twelve Towns Drainage District (Oakland County, Michigan)

The Twelve Towns Drainage District includes 14 communities and approximately 38 square miles of drainage area. The City of Troy contributes separate sanitary sewage flow to the Dequindre Interceptor at 14-Mile Road and Dequindre Road. A flow metering study conducted by Hubbell, Roth & Clark, Inc. (HRC) indicated a dry weather flow of 23-cfs and a peak projected rain dependent inflow and infiltration of 48-cfs. Therefore, the total projected peak flow from the City of Troy to the Dequindre Interceptor is 71-cfs.

To simulate the dynamic condition of the increased flow of the sanitary sewer system during a specific rain event, the RDII flow was simulated as an additional storm water sub-catchment with an area of 1,000-acres. Model results were compared with metering to calibrate the model.

2.4.5. System Identification Methodology

An approach developed fairly recently involves using a methodology called system identification technique (Czachorski and VanPelt, 2001). System identification uses techniques from the fields of signal processing, control systems and time series analysis that are widely used in aerospace and electrical engineering disciplines. The approach relates the collection system response to past rainfall by extracting relevant model structure from the data itself. Once the model parameters are developed, the model can predict system response for future rainfall or other rainfall patterns that were not monitored.

The expressed purpose for developing this approach was to better account for the variation in the RDII response due to variations in the antecedent moisture conditions.

The use of the technique was tested using a 2-month flow dataset from one location. In this example, they were able to demonstrate the ability of the technique in accounting for the impact of antecedent conditions on the RDII response for both volume and shape. The technique seems to hold promise for better prediction of RDII response for various conditions; however, additional testing that includes other locations and seasonal influences would be needed to ensure that other types of variations can be handled.
More importantly, because it requires existing data to build itself, it would lack an ability to be used in simulating various alternatives to be evaluated in the elimination of SSOs or for projecting to other areas without data.

A SWMM model was also configured for the same dataset. With this model, they demonstrated SWMM's lack of ability to account for the antecedent conditions in predicting the RDII response. However, it is not known whether or how the Vo and

the DREC parameters were used in this model to account for the antecedent conditions, as discussed in section 2.3.2.

2.4.6 King County Dept. of Metropolitan Services (Seattle, Washington)

In *Modeling Inflow and Infiltration in Separated Sewer Systems*, Swarner et al. (1995) presented the development of wet weather characterization in King County (Seattle), Washington. The King County Department of Metropolitan Services (Metro) used the RUNOFF module of the U.S. EPA's Storm Water Management Model to determine rain dependent inflow and infiltration. The RUNOFF module was used to simulate the following components of flow:

- Base flow
- Dry weather infiltration
- Rain dependent inflow
- Rain dependent infiltration
- Long-term groundwater leakage

Metro's model used the Green-Ampt equation to compute the maximum infiltration rate into the soil. In addition, the King County model estimated the following parameters:

- Hydraulic conductivity
- Suction head
- Trench capacity
- Threshold storage
- Relationship of storage versus flow in pipes
- Peak rate flow into pipes
- Rate of flow going into ground water
- Decay rate of soil moisture
- Relationship between infiltrated volume and groundwater contribution

To calibrate the King County model, four storms with return intervals from one to 20 years that occurred in the Seattle area between December 1989 and April 1991 were used. The hydraulic routing model "UNSTDY" was used to simulate the routing of flows from the RUNOFF model basins through major conveyance pipes. The model

has been found to give credible simulation of inflow and infiltration in both dry and wet weather.

2.4.7 Miami-Dade Water and Sewer Dept. (Miami, Florida)

In *Computer Modeling of Sanitary Sewer Overflows Resulting from Peak Flow Conditions*, Walch et al. (1995) presented the RDII analysis conducted by the Miami-Dade Water and Sewer Department (MDWASD). For Dade County, RDII is a direct response to the intensity and duration of individual rainfall events. RDII combined with base wastewater flow and groundwater infiltration make up a total flow hydrograph that shows the quantities of flow over a given period.

MDWASD provides sewer service to all of Dade County. The system covers approximately 400 square miles and includes approximately 900 pump stations and 1,500 miles of force main. The flow from the system goes to one of three wastewater treatment plants. Flows can be shifted between the three plants by several booster stations. The ability to transfer flow to the different areas is critical in preventing SSOs.

To develop representative unit hydrographs for each pump station, the 900 pump station service areas (PSAs) were grouped into representatively similar categories. The parameters considered included construction material, density, age, groundwater elevation, tidal influence, land use, population, and soil type. Flow meters were installed in all representative PSAs. Rainfall is being obtained using software from WSI Corporation called Weather for Windows.

Unit hydrograph parameters will be calibrated for those areas where flow-monitoring data have been collected, using the U.S. EPA's Storm Water Management Model (XP-SWMM Version by XP-Software). Calibrated parameters will be extrapolated to other pump station service areas within the same group and used to predict RDII hydrographs from unmonitored areas in the system. This information, combined with groundwater and soils data, can be used to determine potential SSO areas. Once an area is identified as a potential overflow area, flows can be transferred throughout the system to avoid overflows.

2.4.8 Greater Houston Wastewater Program (Houston, Texas)

In *New Collection System Modeling Techniques Used in Houston*, Jeng et al. (1995) described efforts to model rain dependent inflow and infiltration by the Greater Houston Wastewater Program.
Houston experiences an average of 41-inches of rainfall per year, with a low monthly average of 2.3-inches in March and a high monthly average of 4.4-inches in June. Flow monitoring data revealed the nature of the RDII problem in Houston. The ratio of the peak wet weather flow to average dry weather flow is the wet weather peaking factor. A review of Houston's flow monitoring data showed that the wet weather peaking factors of 30 were typically recorded. Factors as high as 50 were recorded in individual basins.

Houston initially chose to predict RDII volumes by plotting the flow data on a two-dimensional plot of RDII volume vs. rainfall. An upper envelope was drawn in such a manner that most of the plotted points fall below the line.

Often the upper envelope is curvilinear, indicating a relationship in which the percentage of rainfall that enters the system as RDII decreases with increasing rainfall. This is indicative of collection systems with capacity constraints and soil permeability limits.

The curvilinear rainfall to RDII relationship could not be detected in the Houston data. This is because Houston sewers surcharge before collector line and soil permeability limits are reached.

The original two-dimensional plots were reanalyzed in three-dimensions. RDII volume was plotted on the z-axis, rainfall volume was plotted on the x-axis, and storm duration was plotted on the y-axis. When analyzed in three dimensions, a plane could be plotted through the points with a high degree of correlation. In Houston for any given rainfall amount, the percentage entering the system as RDII increases directly with the duration of the storm.

The shape of the RDII was modeled using the unit hydrograph theory. The methodology adopted for Houston, first developed for the East Bay Municipal Utility District in California, uses a combination of three triangular-shaped unit hydrographs and applies a percentage of each unit of rainfall to each of the three hydrographs. In this manner, any observed hydrograph could be approximated by a combination of unit hydrographs simply by varying the unit hydrograph parameters (time to peak, recession time, and volume percentage assigned to each of the three unit hydrographs). An iterative process determines these parameters until the simulated hydrograph approximates the observed hydrographs.

Once the RDII shape had been calibrated, it was combined with a design rainfall to produce the design hydrograph for the basin. A 2-year, 6-hour design storm was selected to model the effects of RDII on SSOs in the Houston service area. A hydraulic model of the system was developed as well.

3. Case Studies SSO Modeling

Center Line, Clinton Township, Fraser, Melvindale, Allen Park, and Garden City were selected as case study communities for the regional analysis of SSOs in the DWSD service area. This section describes the model development involved with each of the six case studies.

3.1 Design Storm Events

For the case studies, a series of design storm events were used for review of existing conditions. The design storms used are the 1-month, 24-hour storm (0.617 inches); the 1-year, 1-hour storm (1.0 inches); the 10-year, 1-hour storm (1.8 inches); the 1-year, 24-hour storm (2.2 inches); the 10-year, 24-hour storm (3.6 inches); the 25-year, 24-hour storm (4.0 inches); and the 100-year, 24-hour storm (4.7 inches). The SWMM models developed for each case study were used to predict the amount of wet weather that would be produced for each of these events.

For the five 24-hour design storms, the Brater-Sherrill rainfall distributions were used. The Brater-Sherrill method uses a different rainfall distribution for dormant and growth conditions, respectively.

3.2 Center Line

3.2.1 Existing Analysis

The Center Line Sanitary Sewer Overflow is located at Van Dyke Avenue and Stephens Avenue, just downstream of the Stephens Pump Station. The sanitary sewer overflow tributary area is comprised of the entire city (993 acres).

The engineering consultant for Center Line is Anderson, Eckstein and Westrick, Inc. (AEW). In order to determine existing dry weather flows and predict design wet weather flows in the sanitary sewer system, portable flow meters were installed throughout Center Line. Sewage flow was recorded from August 2000 to December 2000. Rainfall amounts were also recorded.

Seven of the 23 sanitary sewer districts within Center Line were metered. Sigma area-velocity flow meters were initially installed and recorded flow, level, and velocity in five-minute intervals. A rain gauge also recorded rainfall in five-minute intervals. After four months of monitoring, the data for each sub-system was analyzed for a dry weather flow rate, calculated rain-dependent inflow and infiltration, predicted flow rate, and a peaking ratio.

For wet weather events, RDII was plotted versus rainfall amounts. These values were used to extrapolate an RDII value for a 10-year, 24-hour design rainfall event. Sufficient data was collected to estimate RDII values in seven of the 13 flow meter locations.

Predicted flow rates at seven flow meter locations were calculated by adding the RDII value to the dry weather flow rate. A peaking ratio (flow rate divided by dry weather flow) was also calculated.

According to AEW, the city's metered flows (average, peak, and projected) exceed theoretical flows. The high levels of flow within the system are due to RDII. Infiltration, evident in dry weather, is most likely attributed to leaking joints, shifted lateral connections, and cracks in pipes. Inflow can be attributed to footing drains, perforated manhole covers, and structures in low-lying areas. Residential compliance with downspout disconnection is confirmed and recent evaluation has shown near 100% commercial compliance. Perforated manhole covers persist citywide and are systematically being replaced.

3.2.2 Flow and Rainfall Data

Flow and rainfall data for the City of Center Line were obtained from AEW. Flow data were collected downstream of the SSO, at the intersection of Van Dyke Avenue and 8-Mile Road beginning in October 2000. In addition, SSO volumes were collected during the same period of time. Rainfall data were collected at the Center Line Department of Public Works, beginning in May 2000.

Both daily and 15-minute daily flow and rainfall data were obtained from the city's engineer for the period of April 2001 to October 2001. Figures 3.2.1 and 3.2.2 display daily flow and rainfall data for the City of Center Line from April 2001 to mid-July 2001 and late July 2001 to October 2001, respectively.

Figure 3.2.1 Center Line Flow and Rainfall Data (4/1/01 – 7/11/01)

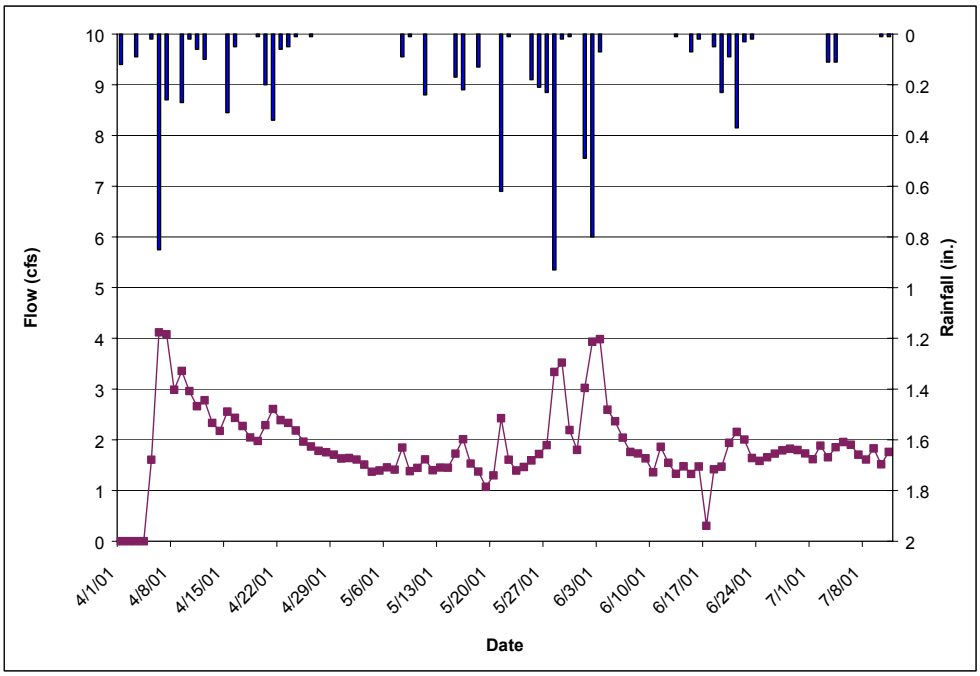
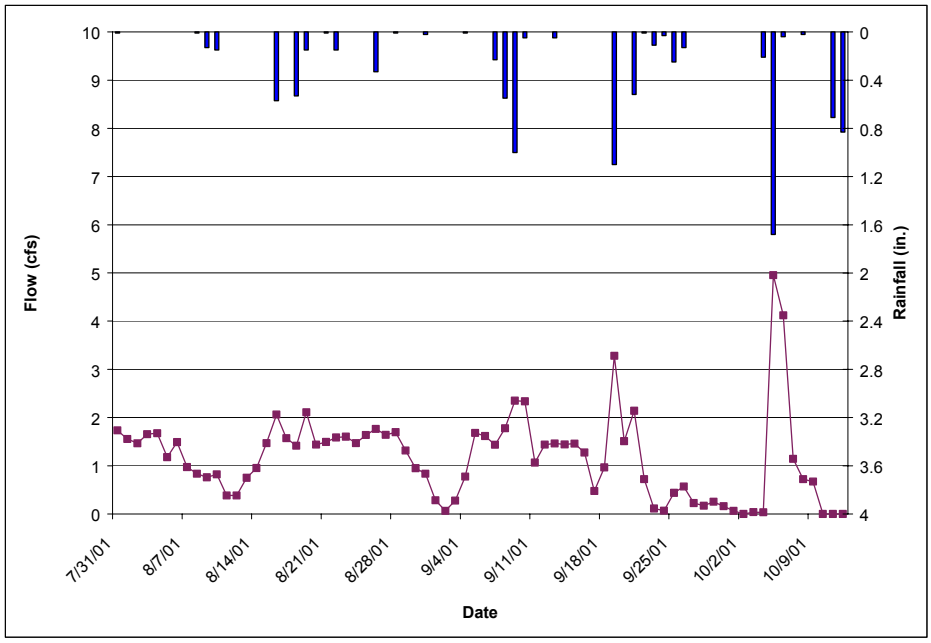


Figure 3.2.2 Center Line Flow and Rainfall Data (7/31/01 – 10/12/01)



3.2.3 Flow and Rainfall Data Analysis and Results

From the daily flow and rainfall data, nine rain events were studied. For each event, 15-minute flow and rainfall data were used to determine the wet weather volume in cubic feet and the total rainfall in inches. In cases where sanitary sewer overflows occurred, SSO volumes were added to the total. Wet weather volumes were converted to inches by dividing by the tributary area (993 acres). The rain dependent inflow and infiltration response factors (RDII C factors) were determined by dividing the wet weather volume by the total rainfall. Table 3.2.1 lists the results for the nine events.

Table 3.2.1 2001 Rain Events for Center Line

Event	Duration	Wet Weather Volume (ft^3)	Wet Weather Volume (in.)	Rainfall (in.)	RDII Factor
A	04-05-01 – 05-04-01	2,102,160	0.583	2.62	22.26%
B	05-05-01 – 05-14-01	79,799	0.022	0.34	6.51%
C	05-15-01 – 05-23-01	164,100	0.046	1.15	3.96%
D	05-24-01 – 06-10-01	1,435,222	0.398	2.94	13.54%
E	06-13-01 – 07-01-01	196,910	0.055	0.89	6.14%
F	08-13-01 – 08-31-01	1,098,693	0.305	1.77	17.22%
G	09-04-01 – 09-17-01	1,022,700	0.284	1.89	15.01%
H	09-17-01 – 10-01-01	614,161	0.170	2.15	7.92%
I	10-03-01 – 10-10-01	996,166	0.276	1.95	14.17%

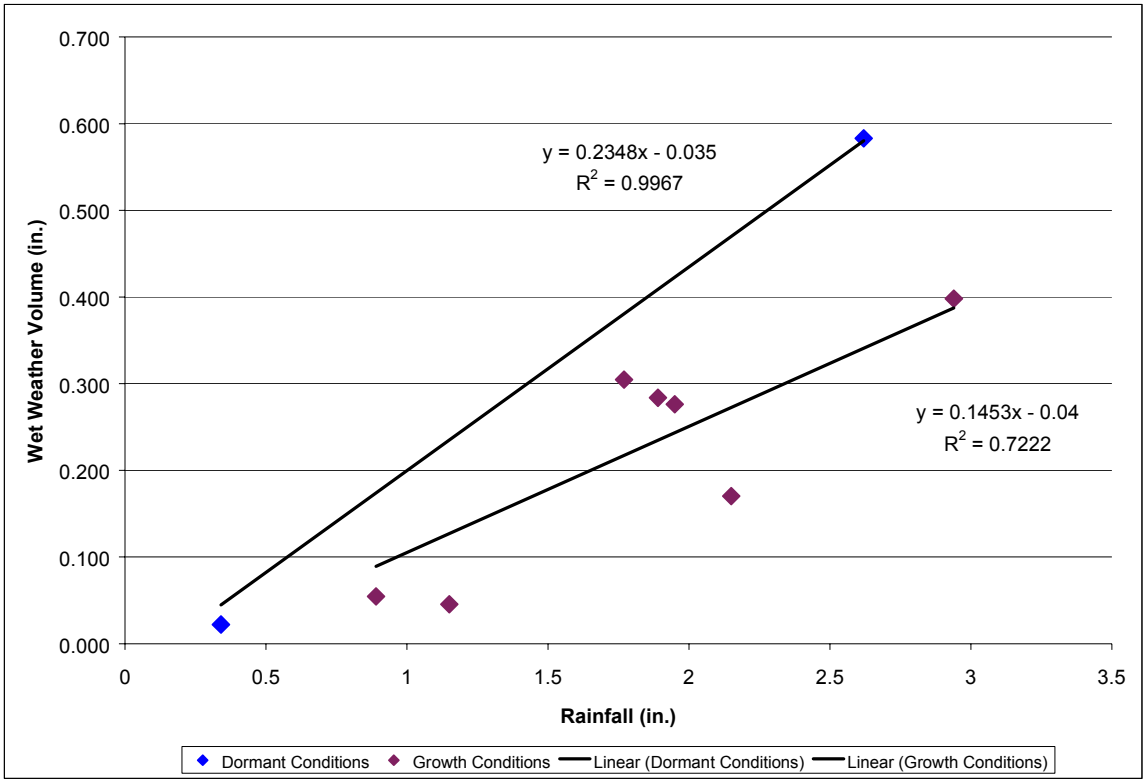
3.2.4 Integration with the GDRSS Model Results

Two seasons, dormant and growth, were defined for the GDRSS Model for all separate sewer service areas. Dormant months are November through April. Growth months are June through September. The months May and October are defined as transitional months.

According to the GDRSS Model, the RDII C factors for the City of Center Line were 10.73% and 4.64% for dormant conditions and growth conditions, respectively. The initial abstraction values were 0.15-inches for dormant conditions and 0.28-inches for growth conditions.

The results for all nine 2001 rain events are plotted in Figure 3.2.3. Two events are considered to occur during dormant conditions. Seven events are considered to occur during growth conditions.

Figure 3.2.3 2001 Center Line RDII Response Factors



Best-fit lines were drawn for each condition. In both cases, the initial abstraction was set to the same value in the GDRSS Model, 0.15-inches for dormant conditions and 0.28-inches for growth conditions. The corresponding RDII C factors from the 2001 events were 23.48% and 14.53% for dormant and growth conditions, respectively. The GDRSS Model data and the 2001 event data were averaged in order to determine RDII C factors for the design events.

The data was weighted according to the number of data points. The final RDII C factors were calculated to be 13.28% for dormant conditions and 7.11% for growth conditions.

3.2.5 Dry Weather Flow

The GDRSS Model reported dry weather flow for the City of Center Line is 1.81-cfs. 2001 field events estimate the dry weather flow in the City of Center Line to be between 0.1-cfs and 1.8-cfs. Due to the large variation in values from the field data, the GDRSS Model data of 1.6-cfs was used for base dry weather flow. Monthly dry weather flow factors from the GDRSS data were also applied.

3.2.6 Wet Weather Volumes

The RUNOFF Module of the U.S. EPA's Storm Water Management Model was used to calculate wet weather volumes for the seven design storm events. RDII response factors and initial abstraction values as defined above were entered into the RUNOFF data file. For the shape of the response, one triangular unit hydrograph was found to be sufficient. The time to peak was set to be 4 hours, with a recession of 8 hours (K = 2).

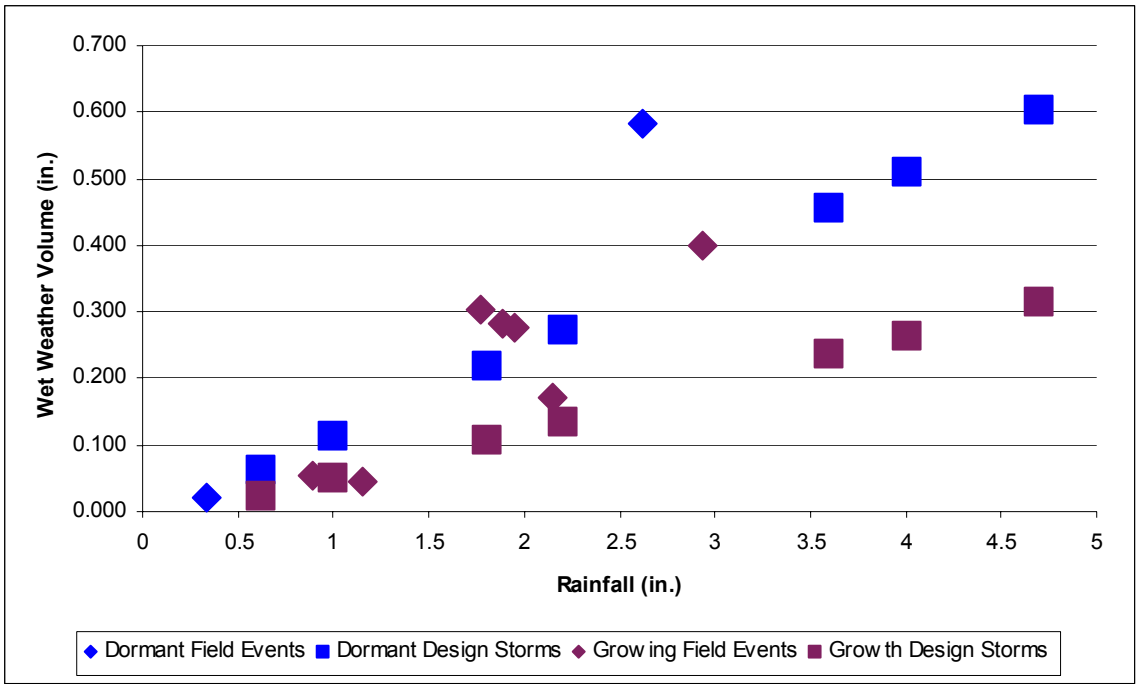
All seven design storms were simulated to occur in April and June to account for both dormant and growth conditions (14 simulations). The results calculated by RUNOFF are presented in Table 3.2.2.

Table 3.2.2 Center Line Design Storm Wet Weather Volumes

Design Storm Event (Rainfall - inches)	Wet Weather Volume (MG)	
	Growth Conditions	Dormant Conditions
1-Month, 24-Hour (0.62)	0.64	1.68
1-Year, 1-Hour (1.0)	1.38	3.05
10-Year, 1-Hour (1.8)	2.91	5.91
1-Year, 24-Hour (2.2)	3.68	7.35
10-Year, 24-Hour (3.6)	6.36	12.35
25-Year, 24-Hour (4.0)	7.13	13.78
100-Year, 24-Hour (4.7)	8.47	16.28

The wet weather volumes for the design storm events were plotted along with the 2001 field event data in Figure 3.2.4 for comparison. As can be seen in this comparison, the model-predicted volumes match the field-measured volumes fairly well for the most part. The variations seen confirm the variability that can occur due to event specific conditions such as the antecedent conditions.

Figure 3.2.4 Center Line Wet Weather Volumes (Design and 2001 Field Events)



3.2.7 Contract Exceedance Volumes

Center Line has a contract capacity of 6.5-cfs with DWSD, which includes both dry and wet weather flows. Contract exceedance volumes were calculated by limiting downstream flows to 6.5-cfs. The resulting contract exceedance volumes are listed in Table 3.2.3.

Table 3.2.3 Center Line Design Storm Contract Exceedance Volumes

Design Storm Event (Rainfall - inches)	Contract Exceedance Volume (MG)	
	Growth Conditions	Dormant Conditions
1-Month, 24-Hour (0.62)	0.00	0.00
1-Year, 1-Hour (1.0)	0.00	0.16
10-Year, 1-Hour (1.8)	0.00	1.14
1-Year, 24-Hour (2.2)	0.24	1.88
10-Year, 24-Hour (3.6)	1.33	4.30
25-Year, 24-Hour (4.0)	1.72	4.99
100-Year, 24-Hour (4.7)	2.37	6.19

3.2.8 Sewer System Modeling

The Center Line sewer system was modeled from the Stephens Road Pump Station at the intersection of Stevens Road and Van Dyke Avenue to the Connors Creek Sewer at the intersection of 7-Mile Road and Connors Avenue in Detroit. The invert elevations, pipe lengths, and ground elevations were provided by the DWSD and AEW.

Sanitary sewage enters the Stephens Road Pump Station in a 48-inch diameter pipe. There are three pumps in the pump station. Pump 1 has a pumping capacity of 1.6 cubic feet per second (cfs). Pump 2 has a capacity of 3.5 cfs. Pump 3 has a capacity of 5.5 cfs.

The sewage exits the pump station in an 80-foot long, 30-inch diameter pipe. Under dry weather conditions, the sewage continues south along Van Dyke in a 24-inch diameter pipe en route to the Detroit sewer system.

However, during elevated flow conditions such as can occur during wet weather, sewage can overflow via a weir and into a 36-inch diameter pipe. This pipe empties into a 78-inch diameter storm sewer pipe. The 78-inch diameter pipe empties into the Lorraine Drain, an 11-foot diameter county storm drain, which discharges into Bear Creek.

The Extended Transport (EXTRAN) Module of the U.S. EPA's SWMM program was used to model the sewer system hydraulics. The three pumps at the Stephens Road Pump Station were included in the EXTRAN data file. The on-off levels were set so that the 1.6-cfs capacity pump turns on first, then the 3.5-cfs capacity pump, and then finally the 5.5-cfs capacity pump. Also, storage was added to account for in-system storage in the 48-inch pipe upstream of the pump station.

In order to determine the appropriate amount of in-system storage to include in the model, two design events from 2001 with known SSO volumes were used. The first field event occurred from April 5, 2001 to May 4, 2001. The second field event occurred from May 24, 2001 to June 10, 2001. The RUNOFF data file for each event was set to generate the wet weather volume calculated from the flow data. The EXTRAN data file was then calibrated by changing the amount of storage until the model predicted SSO volume matched the field results for each event. The amount of in-system storage determined was then averaged for the two events. The average value was used in the EXTRAN data file for the modeling of each of the seven design storm events.

3.2.9 Sanitary Sewer Overflow Volumes

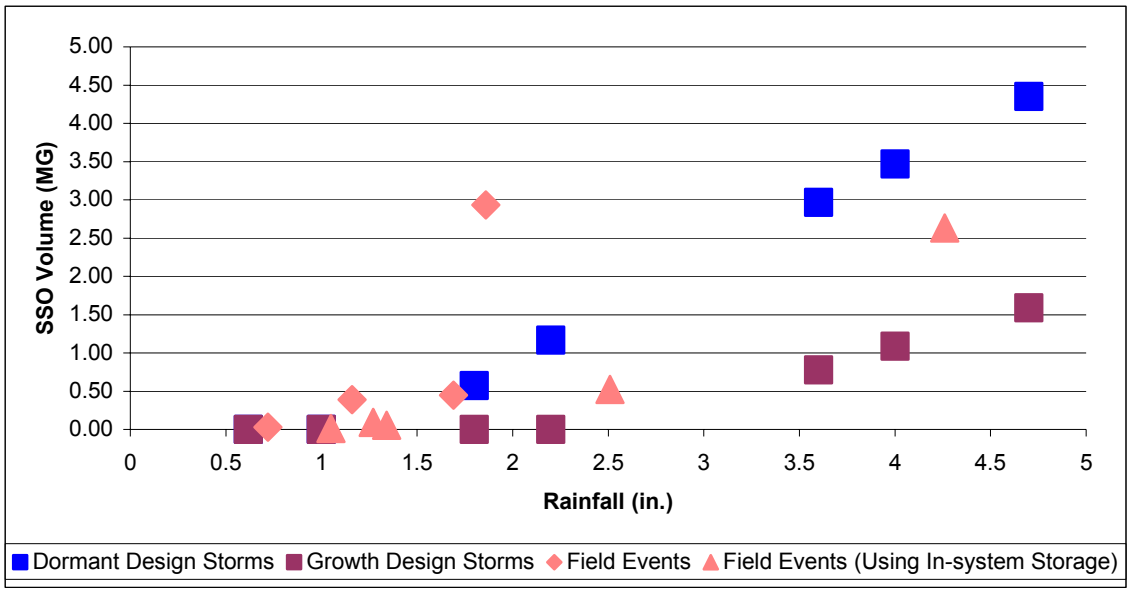
The RUNOFF/ EXTRAN model was run for the seven design storms. The model was simulated during April and June to account for both dormant and growth conditions. The predicted sanitary sewer overflow volumes from the model are listed in Table 3.2.4.

Table 3.2.4 Center Line Design Storm SSO Volumes

Design Storm Event (Rainfall - inches)	Sanitary Sewer Overflow Volume (MG)	
	Growth Conditions	Dormant Conditions
1-Month, 24-Hour (0.62)	0.00	0.00
1-Year, 1-Hour (1.0)	0.00	0.00
10-Year, 1-Hour (1.8)	0.00	0.61
1-Year, 24-Hour (2.2)	0.00	1.15
10-Year, 24-Hour (3.6)	0.76	3.00
25-Year, 24-Hour (4.0)	1.06	3.51
100-Year, 24-Hour (4.7)	1.56	4.41

The SSO volumes, both dormant and growth, for each of the seven design storms were compared to nine field events, in which both rainfall amounts and SSO volumes were known. Five of the nine field events occurred after Center Line began a short-term control measure maximizing in-system storage. The comparison is given in Figure 3.2.5.

Figure 3.2.5 Center Line SSO Volumes (Design Storms and Field Events)



3.3 Clinton Township

3.3.1 Existing Analysis

In the early 1980s, Clinton Township installed nine bypass relief pumps, with Michigan Department of Environmental Quality knowledge.

The pumps are found in a 2,305-acre portion of Clinton Township stretching south to 14-Mile Road, north to Mt. Clemens, just west of Groesbeck, and just east of Gratiot. The nine areas are composed of residential, commercial and industrial land uses. The nine districts contain 337,168 linear feet of 6-inch through 30-inch diameter pipe and 1,195 manholes.

The engineering consultant for Clinton Township is Spaulding DeDecker Associates, Inc. (SDA). SDA investigated wet weather inflow and infiltration in each of Clinton Township's nine SSO districts.

Relief pumps are no longer operational in Districts 7 and 8. Therefore, these two districts no longer have SSOs, but they were still included in the SDA study used to support information provided in this section.

Rain and flow data were collected. The nine primary flow meters were installed directly downstream of the relief pump station locations to collect dry and wet weather flow data for each pump district.

To collect rain data, two gauges were used. The rain gauges were placed in an open area and mounted on a PVC pole with a concrete base. The gauges tabulated flow every 15-minutes.

During the inflow and infiltration study, five rain events occurred that were greater than 0.5-inches in a 24-hour period. During these rain events, several of the emergency bypass pumps were in operation. SDA tracked the date and time the emergency bypass pumps were in operation, as well as the volume of SSO.

An analysis of the flow data from the study area determined that the nine study areas in Clinton Township produce approximately 8.38 million gallons of average day base flow annually from the study area. The study also noted high levels of infiltration in three of the nine SSO areas and high levels of inflow in all nine of the SSO areas.

3.3.2 Flow and Rainfall Data Analysis and Results

SDA provided flow and rain data from April 2001 through June 2001 for each of the seven current SSO tributary areas. Flow and rain data were used to determine the rain dependent inflow and infiltration response factors (RDII C factors) and initial abstraction values for both growth and dormant design periods. Table 3.3.1 lists the design parameters for each of the seven Clinton Township SSO tributary areas.

Table 3.3.1 Clinton Township Design Parameters

SSO Tributary Area	RDII C Factor (Growth)	RDII C Factor (Dormant)	Initial Abstraction (Growth)	Initial Abstraction (Dormant)
1	18.0%	3.5%	0.22	0.28
2	11.1%	3.1%	0.22	0.28
3	7.7%	3.1%	0.25	0.28
4	21.1%	4.7%	0.22	0.28
5	18.0%	8.4%	0.31	0.31
6	17.5%	7.7%	0.35	0.41
9	20.9%	8.4%	0.22	0.27

3.3.3 Dry Weather Flow

The flow data from April 2001 through June 2001 obtained from SDA were also used to determine the dry weather flow for each SSO tributary area. Dry weather flow factors were obtained from the Macomb County updates to the GDRSS Model. The dry weather flow for each SSO tributary area in Clinton Township is in Table 3.3.2.

Table 3.3.2 Dry Weather Flow for Clinton Township SSO Tributary Areas

SSO Tributary Area	Dry Weather Flow (cfs)
1	0.025
2	1.090
3	0.468
4	0.258
5	0.041
6	0.020
9	0.425

3.3.4 Wet Weather Volumes

The RUNOFF Module of the U.S. EPA's Storm Water Management Model was used to calculate wet weather volumes for the design storms. RDII response factors and initial abstraction values were entered into a RUNOFF data file.

Each Clinton Township SSO tributary area was modeled separately. The triangular unit hydrograph parameters for each tributary area are in Table 3.3.3. The Clinton Township SSO tributary area models used two triangular unit hydrographs to account for inflow and infiltration. T1 and T3 refer to the time to peak in the two triangular unit hydrographs. K1 and K3 refer to the ratio of the recession limb to the time to peak for the two hydrographs.

Table 3.3.3 Triangular Unit Hydrograph Parameters for Clinton Township

SSO Tributary Area	T1	K1	T3	K3	Percent Flow (Triangle 1)	Percent Flow (Triangle 3)
1	1.0	3.0	2.0	50.0	50%	50%
2	1.0	12.5	4.8	20.8	38%	62%
3	1.0	12.5	4.8	20.8	38%	62%
4	0.7	8.4	3.5	31.3	34%	66%
5	0.5	13.3	4.8	18.0	45%	55%
6	0.5	4.8	2.8	14.0	54%	46%
9	0.5	4.0	1.0	105.0	37%	63%

All seven design storms were simulated to occur in April and June to account for both dormant and growth conditions. The wet weather volumes for each SSO tributary area were calculated by RUNOFF. The Clinton Township wet weather flows for the seven design storms are presented in Table 3.3.4. In order to obtain wet weather volumes for Clinton Township, the results for all seven areas were summed.

Table 3.3.4 Clinton Township Design Storm Wet Weather Volumes

Design Storm Event (Rainfall - inches)	Wet Weather Volume (MG)	
	Growth Conditions	Dormant Conditions
1-Month, 24-Hour (0.62)	0.58	2.15
1-Year, 1-Hour (1.0)	1.30	4.40
10-Year, 1-Hour (1.8)	2.74	8.96
1-Year, 24-Hour (2.2)	3.39	11.00
10-Year, 24-Hour (3.6)	5.88	18.84
25-Year, 24-Hour (4.0)	6.60	21.08
100-Year, 24-Hour (4.7)	7.86	25.01

3.3.5 Sewer System Modeling

The Extended Transport (EXTRAN) Module of the U.S. EPA's SWMM program was used to model the capacity of the downstream pipe. For each of the seven areas with pumps, the size and design capacity of the pipe downstream of the SSO are known. The downstream pipe parameters are listed in Table 3.3.5.

Table 3.3.5 Clinton Township Downstream Pipe Parameters

SSO Tributary Area	Downstream Pipe Size (in.)	Downstream Pipe Capacity (cfs)
1	12	1.75
2	24	6.79
3	12	2.20
4	15	3.17
5	12	1.63
6	10	1.10
9	15	3.03

3.3.6 Sanitary Sewer Overflow Volumes

The RUNOFF/EXTRAN model was run for the seven design storms in each of the seven SSO tributary areas. The storm events were set to occur during April and June to account for both dormant and growth conditions.

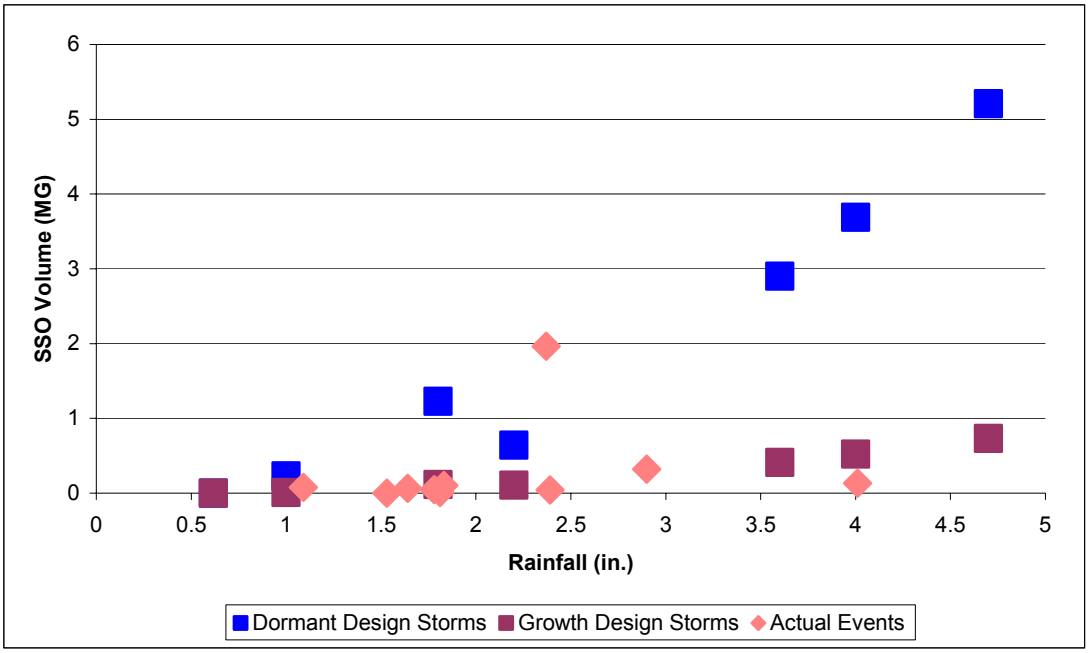
The predicted sanitary sewer overflow volumes from the model are listed in Table 3.3.6. For this table, the volumes were summed for the 7 areas.

Table 3.3.6 Clinton Township Design Storm SSO Volumes

Design Storm Event (Rainfall - inches)	Sanitary Sewer Overflow Volume (MG)	
	Growth Conditions	Dormant Conditions
1-Month, 24-Hour (0.62)	0.00	0.00
1-Year, 1-Hour (1.0)	0.01	0.23
10-Year, 1-Hour (1.8)	0.12	1.23
1-Year, 24-Hour (2.2)	0.11	0.64
10-Year, 24-Hour (3.6)	0.41	2.90
25-Year, 24-Hour (4.0)	0.52	3.69
100-Year, 24-Hour (4.7)	0.73	5.21

The SSO volumes, both dormant and growth, for each of the seven design storms were compared to 10 field events, in which both rainfall amounts and SSO volumes were known. The comparison is found in Figure 3.3.1.

Figure 3.3.1 Clinton Township SSO Volumes (Design Storms & Field Events)



3.3.7 Contract Exceedance Volumes

Clinton Township has a contract capacity of 0.4-cfs per 1000 residents. Using population estimates for each of the seven SSO tributary areas, the maximum contract flow for each SSO tributary area was calculated as given in Table 3.3.7.

Table 3.3.7 Clinton Township Maximum Contract Flows

SSO Tributary Area	Estimated Population	Maximum Contract Flow (cfs)
1	495	0.20
2	3,385	1.35
3	1,045	0.42
4	2,046	0.82
5	967	0.39
6	464	0.17
9	2,280	0.91

The maximum contract flows were used to determine contract exceedance volumes for Clinton Township. The contract exceedance volumes are the SSO volumes that would result if the downstream system were limited to accepting the maximum contract flow rather than the pipe design capacity flow rate.

The model was simulated for the seven design storms in each of the seven SSO tributary areas for both dormant and growth conditions using the maximum contract flow as the downstream condition. The results from the seven SSO tributary areas were combined in order to determine the overall contract exceedance volumes for Clinton Township for the seven design storms. The contract exceedance volumes are listed in Table 3.3.8.

Table 3.3.8 Clinton Township Design Storm Contract Exceedance Volumes

Design Storm Event (Rainfall - inches)	Contract Exceedance Volume (MG)	
	Growth Conditions	Dormant Conditions
1-Month, 24-Hour (0.62)	0.20	1.09
1-Year, 1-Hour (1.0)	0.49	2.69
10-Year, 1-Hour (1.8)	1.21	6.10
1-Year, 24-Hour (2.2)	1.54	7.82
10-Year, 24-Hour (3.6)	3.15	15.18
25-Year, 24-Hour (4.0)	3.69	17.39
100-Year, 24-Hour (4.7)	4.65	21.23

3.4 Fraser

3.4.1 Existing Analysis

The Fraser Sewer Overflow is located at Beacon Pump Station, near the intersection of Masonic Boulevard and Beacon Lane. The sanitary sewer overflow tributary area is comprised of the southeastern corner of Fraser (364 acres).

The engineering consultant for Fraser is Anderson, Eckstein and Westrick, Inc. (AEW). AEW studied both dry and wet weather flows in the Fraser SSO tributary area, as well as the rest of the city. In December 1998, AEW presented the city with a hydraulic metering plan to determine the capacity of the existing system and assess the quantity of inflow and infiltration.

Fraser was divided into 11 districts. Eleven meters, installed at the outlet of each district, were used to monitor the total contributing flow, level, and velocity of sewage at that location in the system. All 11 meters were in place on Feb. 15, 1999. All 11 were removed by July 8, 1999.

In order to relate increases in flow to rainfall, one tipping bucket rain gage was installed in Fraser. Rainfall was recorded in five-minute intervals. The metered flows were compared to a theoretical peak hour wet weather flow based on 275-gpcd. In evaluating sanitary systems, the Michigan Department of Environmental Quality typically uses flow for a 10-year storm to compare to its 275-gpcd guideline.
The mean duration of the recorded rain events was used in the RDII analysis. This equated to a seven-hour storm. The Rainfall Frequency Atlas for the Midwest

published by the National Weather Service, predicts that a 10-year, seven-hour storm generates 2.41 inches of rainfall in this region of the state. Using the RDII flow for this rainfall amount, the total flow can be estimated for a 10-year storm event by combining this RDII value and the average daily dry weather flow.

In nine of the city's 11 flow districts, the metered data was sufficient to predict projected wet weather flow values for the 10-year, seven-hour design storm. In eight of those nine districts, the estimated peak wet weather flow values were greater than the Theoretical Peak Hour Wet Weather Flow.

For wet weather events, meter data indicated that the lag time, the time from the beginning of a rain event to the time a meter records the peak flow, is relatively short. This indicates that inflow exists throughout Fraser.

3.4.2 Flow and Rainfall Data

Flow and rainfall data for the City of Fraser SSO tributary area were obtained from AEW for this case study analysis. Flow data was collected just downstream of the Beacon Pump Station beginning in January 1999. In addition, SSO volumes were collected beginning in mid-2000. Rainfall data was collected at the Beacon Lane Pump Station as well, beginning in April 1999.

Both daily and 15-minute flow and rainfall data from April 2001 to October 2001 were obtained. Figures 3.4.1 and 3.4.2 display daily flow and rainfall data for the City of Fraser SSO tributary area from April 2001 to June 2001 and July 2001 to October 2001, respectively.

Figure 3.4.1 Fraser SSO Tributary Area Flow and Rainfall Data (4/01 – 6/01)

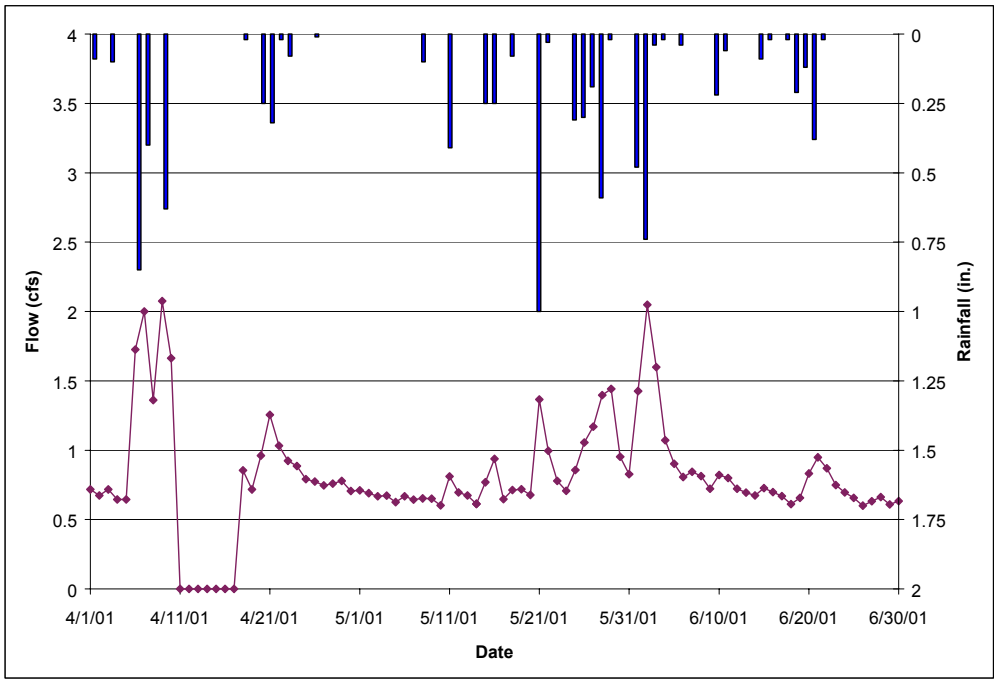
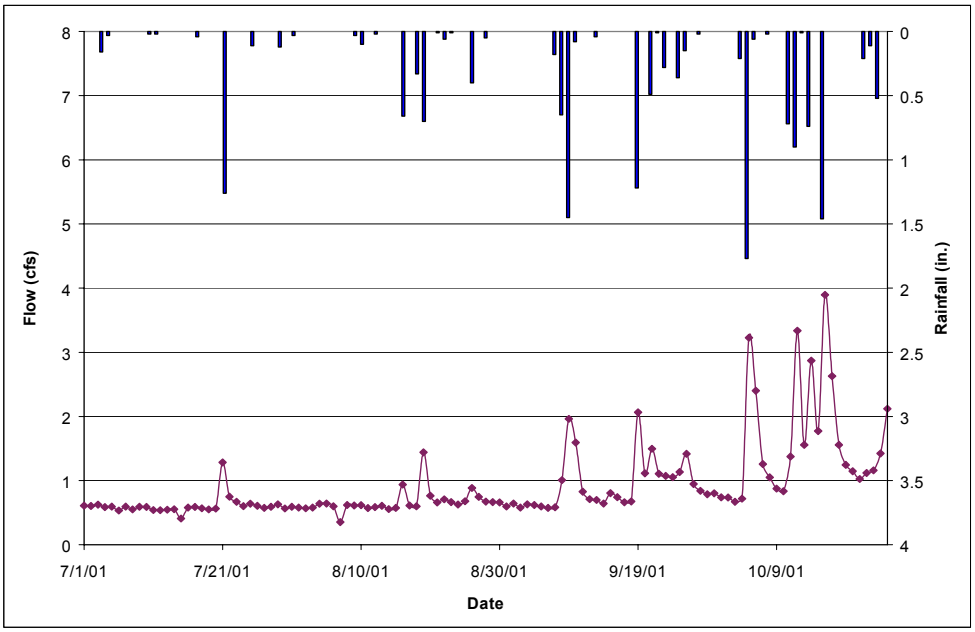


Figure 3.4.2 Fraser SSO Tributary Area Flow and Rainfall Data (7/01 – 10/01)



3.4.3 Data Analysis and Results

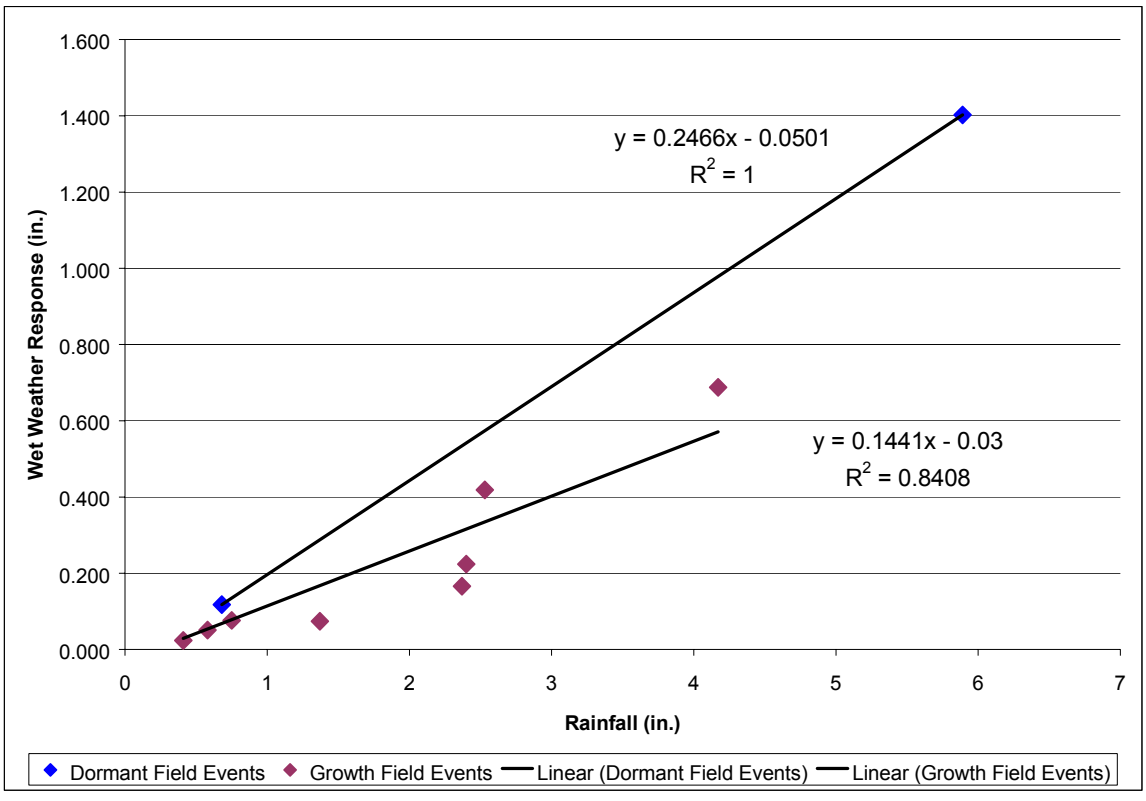
From the daily flow and rainfall data, 10 rain events were selected and analyzed. For each event, 15-minute flow and rainfall data were used to determine the wet weather volume in cubic feet and the total rainfall in inches. In cases where sanitary sewer overflows occurred, SSO volumes were added to the total. Wet weather volumes were converted to inches by dividing by the tributary area (364 acres). The rain dependent inflow and infiltration response factors (RDII C factors) were determined by dividing the wet weather volume by the total rainfall. Table 3.4.1 lists the 10 rain events.

Table 3.4.1 2001 Rain Events for Fraser SSO Tributary Area

Event	Duration	Wet Weather Volume (ft^3)	Wet Weather Volume (in.)	Rainfall (in.)	RDII Factor
A	04-19-01 – 04-30-01	155,287	0.118	0.68	17.28%
B	05-10-01 – 05-14-01	31,009	0.023	0.41	5.72%
C	05-14-01 – 05-20-01	67,340	0.051	0.58	8.79%
D	05-20-01 – 06-18-01	908,447	0.688	4.17	16.49%
E	06-18-01 – 06-26-01	100,820	0.076	0.75	10.17%
F	07-20-01 – 07-27-01	98,133	0.074	1.37	5.42%
G	08-15-01 – 08-31-01	219,599	0.166	2.37	7.01%
H	09-06-01 – 09-14-01	296,345	0.224	2.4	9.34%
I	09-14-01 – 10-03-01	552,882	0.418	2.53	16.54%
J	10-03-01 – 10-21-01	1,852,683	1.402	5.89	23.81%

The results for all the events are plotted in Figure 3.4.3. Two events are considered to occur during dormant conditions. Eight events are considered to occur during growth conditions.

Figure 3.4.3 2001 Fraser SSO Tributary Area RDII Response Factors



Best-fit lines were drawn for each condition. In both cases, the initial abstraction was set to 0.20 inches. The corresponding average RDII C factors from these events were determined to be 24.46% and 14.41% for dormant and growth conditions, respectively.

3.4.4 Dry Weather Flow

The 2001 flow data was analyzed and the estimated dry weather flow for the Fraser SSO tributary area was 0.6-cfs. Dry weather flow factors were obtained from the Macomb County update to the GDRSS Model.

3.4.5 Wet Weather Volumes

The RUNOFF Module of the U.S. EPA's Storm Water Management Model was used to calculate wet weather volumes for the design storms. RDII C factors and initial abstraction values were entered into a RUNOFF data file.

For each of the 10 events, the triangular unit hydrograph parameters were varied until the model response matched the field response.

Only the first and third triangular unit hydrographs were used, and the flow split between inflow and infiltration was set to be 50-50.

The resulting shape parameters for the 10 field events were averaged to develop design values. The average values were used in predicting the wet weather volumes from the seven design storms for the Fraser SSO tributary area.

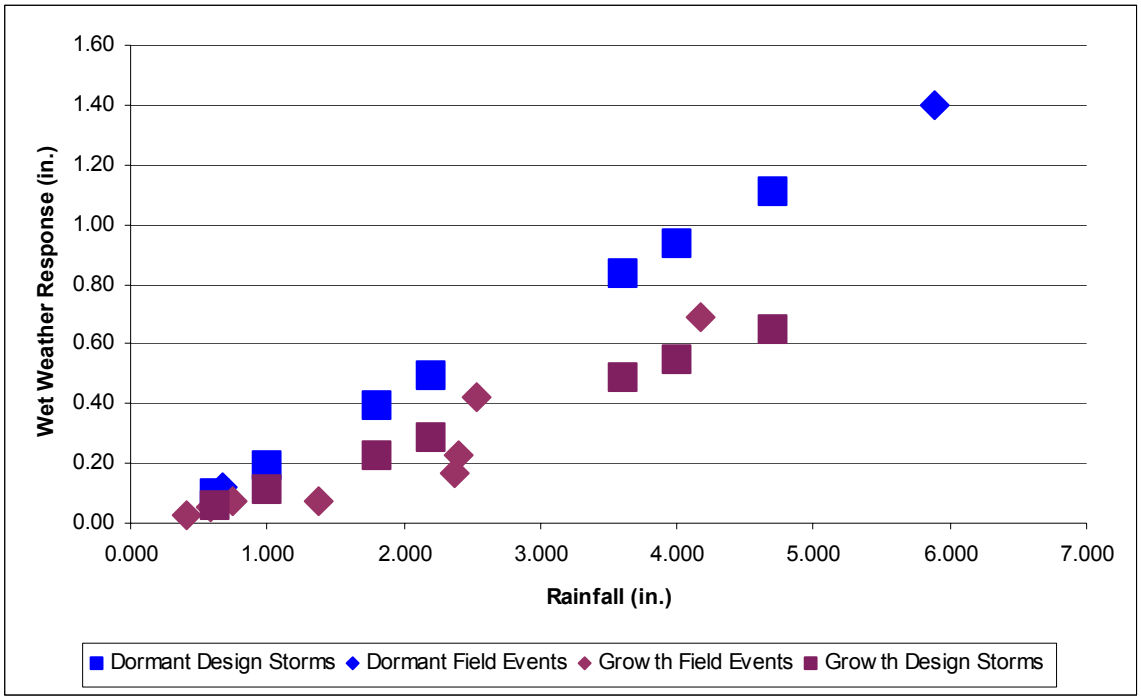
All seven design storms were simulated to occur in April and June to account for both dormant and growth conditions. The results calculated by RUNOFF are presented in Table 3.4.2.

Table 3.4.2 Fraser SSO Tributary Area Design Storm Wet Weather Volumes

Design Storm Event (Rainfall - inches)	Wet Weather Volume (MG)	
	Growth Conditions	Dormant Conditions
1-Month, 24-Hour (0.62)	0.59	1.02
1-Year, 1-Hour (1.0)	1.14	1.95
10-Year, 1-Hour (1.8)	2.28	3.90
1-Year, 24-Hour (2.2)	2.85	4.88
10-Year, 24-Hour (3.6)	4.84	8.28
25-Year, 24-Hour (4.0)	5.41	9.26
100-Year, 24-Hour (4.7)	6.41	10.96

The wet weather volumes for the design storm events were plotted along with the 2001 field event data in Figure 3.4.5 for comparison. The comparison supports the applicability of the model results for the design events.

Figure 3.4.4 Fraser SSO Tributary Area Wet Weather Volumes (Design and 2001 Field Events)



3.4.6 Contract Exceedance Volumes

The City of Fraser has a contract capacity of 0.4-cfs per 1000 residents, which includes both dry and wet weather flows. The estimated population in the SSO tributary area is 3,930. Based on the contract capacity of 0.4-cfs per 1000 residents, the contract capacity of the Fraser SSO tributary area is 1.57-cfs.

Contract exceedance volumes were calculated by limiting the downstream flow to 1.57-cfs. The flow above the contract limit was considered to be contract exceedance. The contract exceedance volumes are in Table 3.4.3.

Table 3.4.3 Fraser SSO Tributary Area Design Storm Contract Exceedance Volumes

Design Storm Event (Rainfall - inches)	Contract Exceedance Volume (MG)	
	Growth Conditions	Dormant Conditions
1-Month, 24-Hour (0.62)	0.10	0.30
1-Year, 1-Hour (1.0)	0.41	0.94
10-Year, 1-Hour (1.8)	0.99	2.54
1-Year, 24-Hour (2.2)	1.39	3.45
10-Year, 24-Hour (3.6)	3.17	6.72
25-Year, 24-Hour (4.0)	3.72	7.72
100-Year, 24-Hour (4.7)	4.72	9.32

3.4.7 Sewer System Modeling

A sewered population of 3,930, spread out over a 364-acre tributary area, contributes flow to the Beacon Pump Station. At the Beacon Pump Station, the sewage is pumped up and then continues to flow to the north by gravity in a 24-inch sanitary sewer. The sewage eventually enters the Detroit Sanitary Sewer Interceptor at the intersection of Garfield Road and 15 Mile Road.

Sometime in the mid-1960s, the Beacon Station was reconfigured to bypass sanitary sewage during rain events into a storm sewer system in the Masonic and Beacon Lane vicinity.

The reconfigured Beacon Pump Station consists of three pumps. The first pump, which connects to the sanitary system, has a capacity of approximately 3.5-cfs. This is the pump that operates under dry weather conditions.

When the upstream flow exceeds this rate in wet weather, the second and/or third pump begins to operate. The second pump operates at approximately 3.5-cfs. The third pump operates at 2.5-cfs. Both lift sewage directly into the storm sewer system. Based on the capacity of the 24-inch sewer downstream of the pump station, it is not feasible to simply redirect the two pump discharges into the sanitary sewer.

Once in the storm system, the sewage flows into a 14 acre-foot detention pond, and eventually into the Sweeney Drain. The flow in the Sweeney Drain enters the Harrington Drain, which flows into the Clinton River.

The Extended Transport (EXTRAN) Module of the EPA's SWMM program was used to model the sewer system in the vicinity of the pump station. The Beacon Pump Station was modeled, along with two reaches of pipe upstream and downstream of the facility. The hydraulics of the pump station, including pipe invert elevations, ground elevations, pump capacities, and pump on/off levels were provided by AEW.

3.4.8 Sanitary Sewer Overflow Volumes

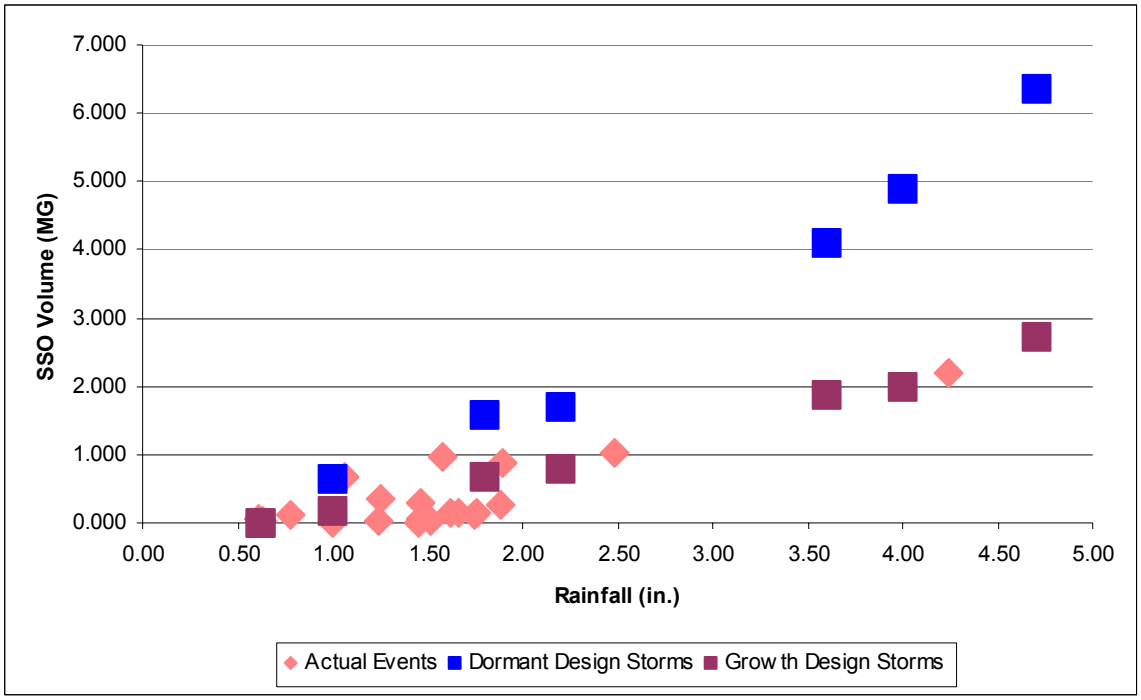
The RUNOFF/EXTRAN model was run for all seven design storms. The events were set to occur during April and June to account for both dormant and growth conditions. The predicted sanitary sewer overflow volumes from the model are listed in Table 3.4.4.

Table 3.4.4 Fraser SSO Tributary Area Design Storm SSO Volumes

Design Storm Event (Rainfall - inches)	Sanitary Sewer Overflow Volume (MG)	
	Growth Conditions	Dormant Conditions
1-Month, 24-Hour (0.62)	0.00	0.00
1-Year, 1-Hour (1.0)	0.18	0.63
10-Year, 1-Hour (1.8)	0.68	1.58
1-Year, 24-Hour (2.2)	0.80	1.70
10-Year, 24-Hour (3.6)	1.87	4.11
25-Year, 24-Hour (4.0)	1.98	4.90
100-Year, 24-Hour (4.7)	2.73	6.35

The SSO volumes, both dormant and growth, for each of the seven design storms were compared to 19 field events, in which both rainfall amounts and SSO volumes were known. The comparison is provided in Figure 3.4.5.

Figure 3.4.5 Fraser SSO Tributary Area SSO Volumes (Design Storms & Field Events)



3.5 Melvindale

3.5.1 Existing Analysis

In April 1989, the Charles E. Raines Company performed an infiltration and inflow determination study for Melvindale. In this study, flow monitoring was performed at 20 manholes to identify areas with high inflow and infiltration. In most cases measured flows were much higher (up to 50 percent higher) than what would have been expected based on the original design criteria. In addition, the flow monitoring also revealed that some sewer sections had velocities low enough to cause settling of solids to the extent of possible flow blockages being indicated at some locations.

According to Melvindale officials, the high inflow and infiltration (I/I) observed in this study is considered to be primarily due to footing drain connections. It is thought that the I/I is less likely due to infiltration through leaks and joints as the pipes in the system were all backfilled with hard clay instead of sand.

The sewer system in Melvindale was constructed as a separate system with residential footing drains connected. The original system discharged directly to the Rouge River, but was eventually connected to the DWSD Northwest Interceptor (NWI) using a pump station. This connection included an emergency bypass to the river for surcharge conditions. The pump station was located along the bank of the Rouge River near Greenfield Avenue and Wall Street.

In 1996, the deteriorating pumping station was replaced. The new pump station is located several hundred feet away. As there was a potential of damaging the aging NWI, Melvindale was required to use the existing tap into the interceptor. This required a 16" force main from the new pumping station up to the original pumping station location. The original emergency bypass to the Rouge River is available for surcharged conditions.

The only reported wet weather sanitary overflow point in Melvindale is this emergency bypass on the force main downstream of the pumping station. The entire city is tributary to the SSO.

Per the request of the city, the analysis for this case study did not include estimates of SSOs for the design storm events. Accordingly, only estimates of flow exceedances were calculated, as discussed later. In addition, as estimates of SSOs were not required, the hydraulics of the sewers related to the SSO were not modeled.

The City of Melvindale was delineated as a separate sub-area in the GDRSS Model version 3.12. In that model, the rain dependent inflow and infiltration (RDII) response factors of 15 percent, 8 percent, and 12 percent were defined for the dormant, growth, and transitional periods, respectively. These factors were determined from the correlation to the age of sewers, not from actual monitoring data. In addition, the shape factors as determined for a generic area were used. As part of the SSO characterization for the WWMP project, these parameters have been updated, as described in the following sections.

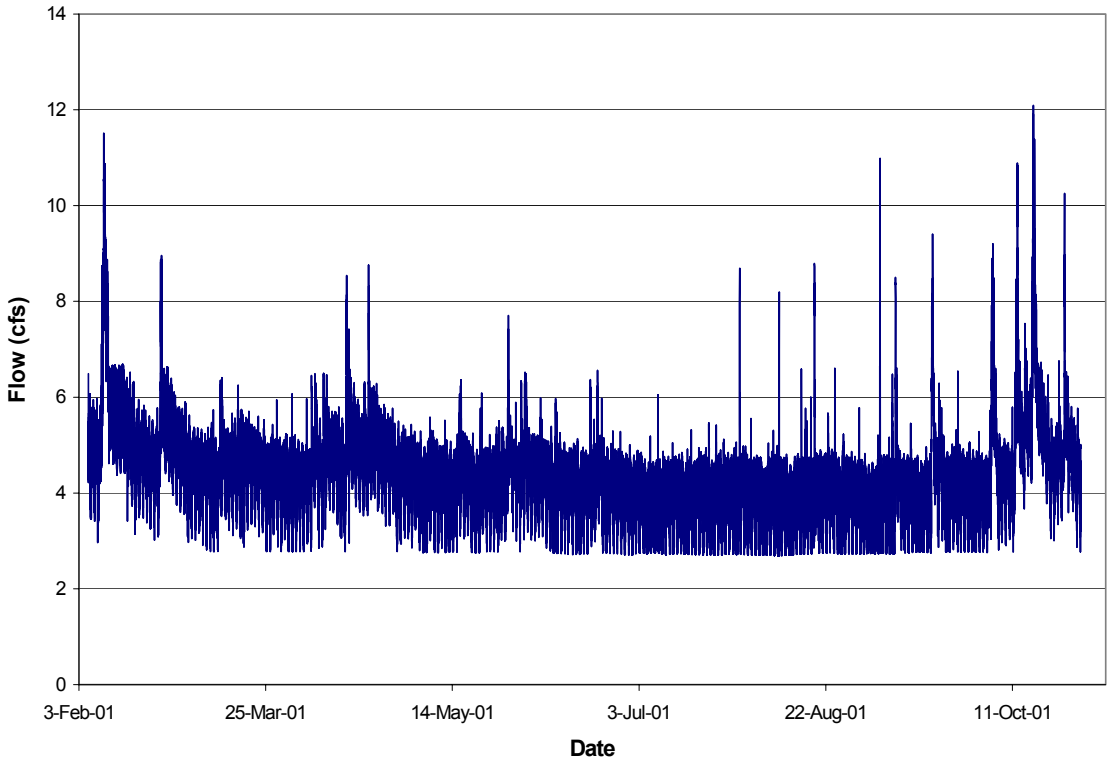
3.5.2 Flow and Rainfall Data

Flow data for the City of Melvindale SSO tributary area were obtained from the billing meter for the city. These flow data were collected at the pumping station upstream of the potential SSO location. Thus, the flow data include any potential SSO flows as they (the SSO flows) occurred downstream of the flow measurement. The period of records for which flow data were available was from February 5, 2001 to October 29, 2001.

Daily rainfall data were obtained from the SEMCOG web site (www.semcog.org). Several gages in the proximity of the city were reviewed. Rain gage W-8 was selected, as it was the closest to the City of Melvindale tributary area. Comparison of the daily rainfall totals to the surrounding gages did not indicate any large differences that might reveal an error in the rainfall data set used for the analysis.

Figure 3.5.1 displays the flow data for the City of Melvindale SSO tributary area within the period of record. As can be seen, the flow data are highly variable due to the pumps cycling on and off over short time intervals.

Figure 3.5.1 Melvindale Flow Data



3.5.3 Data Analysis and Results

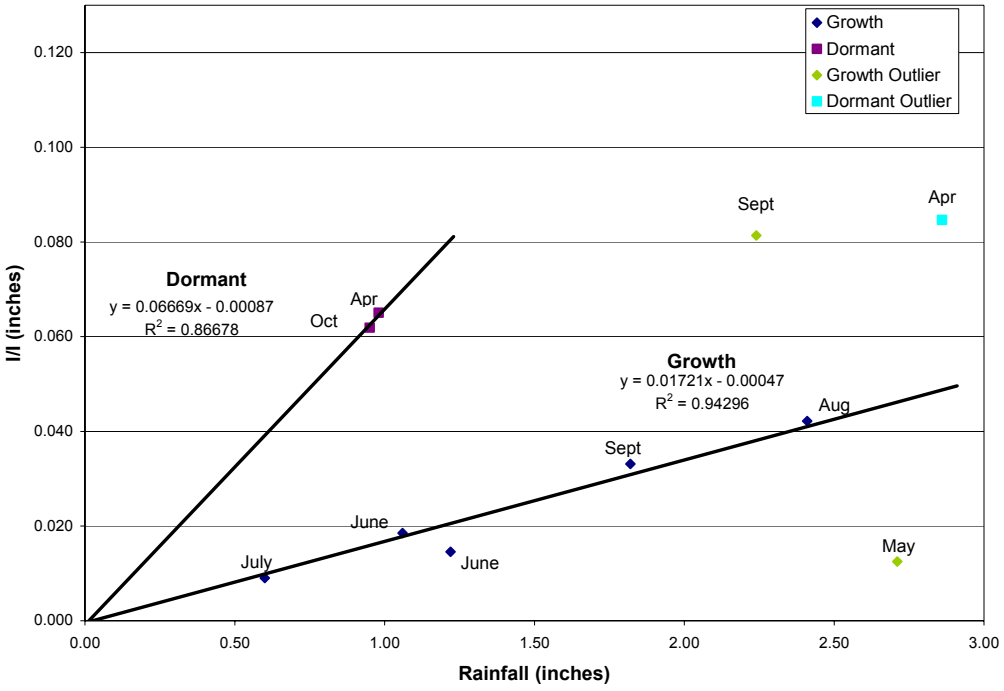
From the flow and rainfall data, ten rain events were selected and analyzed. For each event, flow and rainfall data were used to determine the wet weather volume in cubic feet and the total rainfall in inches. Wet weather volumes were converted to inches by dividing these volumes by the tributary sewered area (1,628 acres) after considering a proper conversion factor. The rain dependent inflow and infiltration response factors (RDII C factors) were determined by dividing the wet weather volume in inches by the total rainfall depth (also in inches). Table 3.5.1 summarizes the results for the ten rainfall events.

Table 3.5.1 Wet Weather Responses in Melvindale

Event	Period	Wet Weather Volume (ft^3)	Wet Weather Volume (in.)	Rainfall (in.)	RDII Factor
1	04/01/01 to 04/17/01	500,332	0.0847	2.86	3.0%
2	04/20/01 to 04/29/01	384,457	0.0651	0.98	6.6%
3	05/15/01 to 05/31/01	73,812	0.0125	2.71	0.5%
4	06/01/01 to 06/14/01	86,193	0.0146	1.22	1.2%
5	06/18/01 to 06/25/01	109,443	0.0185	1.06	1.7%
6	07/29/01 to 08/04/01	53,323	0.0090	0.60	1.5%
7	08/08/01 to 08/31/01	249,387	0.0422	2.41	1.8%
8	09/08/01 to 09/14/01	195,753	0.0331	1.82	1.8%
9	09/19/01 to 09/29/01	480,822	0.0814	2.24	3.6%
10	10/23/01 to 10/27/01	365,838	0.0619	0.95	6.5%

The rainfall depths and the corresponding wet weather volumes (inches) were plotted for the ten rainfall events in Figure 3.5.2. Two events were considered to occur during dormant conditions and five events were considered to occur during growth conditions. The results for the remaining three rainfall events were judged to be outliers and thus not used in the determination of the overall average RDII response factor.

Figure 3.5.2 RDII Response in Melvindale



A regression analysis was used to develop a best-fit line for each condition. These lines were set to intercept the x-axis at 0.15-inches and 0.28-inches to represent the initial abstractions for dormant and growth seasons, respectively. The corresponding RDII C factors for these events were 6.6% and 1.7% for dormant and growth conditions, respectively. These are lower than what was previously determined from the correlation to age used in the GDRSS Model, which was 15% for dormant and 8% for growth. One possible reason for this may be due to the fact that the residential areas make up only 37% of the total tributary area. No data was collected at internal locations to determine if the response is higher in the residential areas vs. the non-residential areas. The Melvindale SSO Model used an RDII response factor of 6.7% for dormant conditions and 4.6% for growth conditions.

3.5.4 Dry Weather Flow

The flow data were analyzed and the estimated average dry weather flow (DWF) for the tributary area was 4.3-cfs (2001 records period). The previous annual average DWF estimate from the GDRSS Model was 4.64-cfs.

For the model calibration, the DWF preceding each event was used. For the design storm events, the existing GDRSS DWF was used (4.56 for June and 5.29 for April).

3.5.5 Response Shape

The Melvindale SSO tributary area model was set up using the RDII features in SWMM RUNOFF. Three of the ten events were used to calibrate the shape of the response. The triangular unit hydrograph parameters were varied until the model response matched the field response. Only the first and third triangular unit hydrographs were used.

Typically, only 1 response shape is defined for a region to be used for both dormant and growth conditions. Table 3.5.2 lists the Melvindale SSO shape parameters. The C1-C3 ratio is the percent of RDII assumed to be inflow vs. the percent of RDII assumed to be infiltration.

Table 3.5.2 Melvindale Design Conditions

Shape Parameter	Value
T1	1.0
K1	2.8
T3	2.25
K3	3.3
C1-C3 Ratio	50-50

3.5.3 Wet Weather Volumes

Once the wet weather response factors were determined, the RUNOFF Module of the U.S. EPA's Storm Water Management Model was used to calculate wet weather volumes for seven different design storm events and for 2 different conditions, dormant and growth.

All design storms were simulated to occur in April and June to account for both dormant and growth conditions. The results calculated by RUNOFF are presented in Table 3.5.3.

Table 3.5.3 Design Storm Wet Weather Volumes for Melvindale

Design Storm Event (Rainfall - inches)	Wet Weather Volume (MG)	
	Growth Conditions	Dormant Conditions
1-Month, 24-Hour (0.62)	0.64	1.29
1-Year, 1-Hour (1.0)	1.36	2.33
10-Year, 1-Hour (1.8)	2.88	4.53
1-Year, 24-Hour (2.2)	3.64	5.64
10-Year, 24-Hour (3.6)	6.29	9.47
25-Year, 24-Hour (4.0)	7.05	10.57
100-Year, 24-Hour (4.7)	8.37	12.49

3.5.7 Contract Exceedance Volumes

The City of Melvindale had a contract capacity of 6.375-cfs with DWSD, which included both dry and wet weather flows. This contract value was used to calculate contract exceedance volumes for this report. Melvindale's most recent contract specifies a limit of 0.5-cfs per 1,000 residents. Contract exceedance volumes were calculated by inputting the runoff hydrograph for each event into a mini-EXTRAN model, which consisted of a flow split, with flows over the contract capacity being discharged as overflow. The volume of RDII over the 6.375-cfs contract limit was considered to be contract exceedance. It is important to note that the system hydraulics were not modeled directly; hence any limitations that might exist within the system are only taken into account indirectly through the shape of the runoff hydrographs as determined during the calibration process. The contract exceedance volumes are in Table 3.5.4.

Table 3.5.4 Design Storm Contract Exceedance Volumes for Melvindale

Design Storm Event (Rainfall - inches)	Contract Exceedance Volume (MG)	
	Growth Conditions	Dormant Conditions
1-Month, 24-Hour (0.62)	0.25	0.82
1-Year, 1-Hour (1.0)	0.94	2.03
10-Year, 1-Hour (1.8)	2.41	4.22
1-Year, 24-Hour (2.2)	3.02	4.96
10-Year, 24-Hour (3.6)	5.49	8.72
25-Year, 24-Hour (4.0)	6.19	9.81
100-Year, 24-Hour (4.7)	7.47	11.70

3.5.8 Sanitary Sewer Modeling

Per the city's request, the sewer system in the vicinity of the sanitary sewer overflow location was not modeled or reviewed.

3.5.9 Sanitary Sewer Overflow Volumes

Per the city's request, no estimates of SSO volumes were made for this case study.

3.6 Allen Park

3.6.1 Existing Analysis

Allen Park is tributary to both the DWSD sanitary system and to the Wayne County Downriver system. The northern half of Allen Park, District 1, is serviced by DWSD. By an agreement dated July 29, 1959, Detroit agreed to accept into the Northwest Interceptor wastewater flow from this district. The district has two connections to the Northwest Interceptor (NWI): APS-1 and APS-2.

Flows at the APS-1 connection are conveyed to this connection point via a 24-inch sewer that runs west along Enterprise Drive to Outer Drive. A pump station located at Outer Drive lifts flows collected from upstream areas for gravity discharge into the 24-inch sewer.

The APS-1 connection to the NWI includes a 24-inch overflow relief outfall to the Rouge River that was included in the system design and remains in place today. Field investigations conducted by Allen Park in 2001 indicate that although an overflow pathway to the Rouge River exists, it has not provided relief during recent storm events, as an internal flap gate has been corroded shut.

There is no provision for an overflow at the APS-2 connection. This connection currently services the Fairlane Business Park and the Ford Clay Mine landfill.

Though there is a potential for an SSO at the APS-1 connection, the SSOs recorded for Allen Park have consisted of bypass pumping to Ecorse Creek and flooded basements within the residential areas. The homes in these areas were built with footing drains connected to the sanitary system. The focus of the Wade-Trim (WT) study and other sewer system evaluation surveys conducted by the city in the past has been the problem of excessive flows within the city, not the potential SSO at the APS-1 connection.

Allen Park has retained WT to analyze their sewer system and to develop alternatives to address flooding and SSO (flooded basement) problems. As part of that study, flow and rainfall data have been collected for storm events and used to develop rain dependent inflow and infiltration response factors for the city. This analysis is currently under review and only limited results are available.

3.6.2 Flow and Rainfall Data

Measurement of flows at both connections has been problematic for years. Accusonic meters were installed at both locations in 1999 as part of the study conducted for the city by WT. Data were collected for a period of 4 months. These data were used to determine an average wet weather response of approximately 5% (RDII C factor).

As part of the GDRSS Phase III Modeling project, an ADS meter was installed in the 24-inch sewer upstream of the APS-1 connection. Wet weather flow data from this meter proved to be unreliable, and it was not used in that project for determination of a wet weather response.

Recently, new meters have been installed at both locations by DWSD with the intention of using the data for billing. The data collected were not sufficient at the time required for further analysis of the wet weather responses for this district.

3.6.3 Data Analysis and Results

Data were not available for direct analysis for this case study. Results presented here rely on previous data collected as part of the GDRSS project.

3.6.4 Dry Weather Flow

According to the GDRSS Phase III report, the annual average dry weather flow for Allen Park District 1 is estimated to be 2 cfs. This estimate was based on flow data collected for the project from an ADS meter.

3.6.5 RDII Volume Response

The WT analysis resulted in a RDII C factor of approximately 5%. This finding was based on events that were isolated from the flow data collected during the monitoring period. No further details were provided on the determination of this response parameter other than that these events occurred during summer conditions.

As part of the previous GDRSS Modeling project, RDII C factors were estimated to be 9.8%, 4.6%, and 7.2% for dormant, growth, and transitional conditions, respectively. These estimates were determined using the correlation to medium housing age as developed for the GDRSS project. The value for growth conditions agrees well with the value determined by the WT study, using data collected in 1999.

3.6.6Response Shape

The response shape for Allen Park in the GDRSS model was based on a typical response found for similar areas, with a time to peak of the inflow being 1 hour, with a recession of 1 hour and a time to peak for the infiltration being 3 hours, with a recession of 22 hours.

3.6.7 Wet Weather Volumes

Wet weather volumes were determined for the seven different design events and for two different conditions, dormant and growth. The total tributary (sewered) area within the district used in the development of these hydrographs is 895 acres. To provide estimates of flows, a SWMM RUNOFF Model was used. Results are presented in Table 3.6.1.

Table 3.6.1 Design Storm Wet Weather Volumes for Allen Park

Design Storm Event (Rainfall - inches)	Wet Weather Volume (MG)	
	Growth Conditions	Dormant Conditions
1-Month, 24-Hour (0.62)	0.38	1.11
1-Year, 1-Hour (1.0)	0.81	2.02
10-Year, 1-Hour (1.8)	1.71	3.91
1-Year, 24-Hour (2.2)	2.16	4.87
10-Year, 24-Hour (3.6)	3.73	8.17
25-Year, 24-Hour (4.0)	4.18	9.13
100-Year, 24-Hour (4.7)	4.96	10.78

3.6.8 Contract Exceedance Volumes

Allen Park is currently in the process of reviewing its contract with DWSD. However, it has been assumed in the past that the contract capacity for Allen Park District 1 is 6 cfs.

Contract exceedance volumes were calculated by adding dry weather flow to the RUNOFF hydrograph for each design storm event. The volume of flow over the assumed 6-cfs contract limit was considered to be contract exceedance. It is important to note that no potential in-system hydraulic limitations were taken into account. The contract exceedance volumes for the seven design events are in Table 3.6.2 for both dormant and growth conditions.

Table 3.6.2 Design Storm Contract Exceedance Volumes for Allen Park

Design Storm Event (Rainfall - inches)	Contract Exceedance Volume (MG)(1)	
	Growth Conditions	Dormant Conditions
1-Month, 24-Hour (0.62)	0.00	0.04
1-Year, 1-Hour (1.0)	0.18	0.81
10-Year, 1-Hour (1.8)	0.63	2.03
1-Year, 24-Hour (2.2)	0.64	2.25
10-Year, 24-Hour (3.6)	1.56	5.09
25-Year, 24-Hour (4.0)	1.88	5.96
100-Year, 24-Hour (4.7)	2.49	7.49

1) The contract capacity was being negotiated when the modeling was performed. The contract capacity used in the model was 6 cfs.

3.6.9 Sewer System Modeling

An EXTRAN model was developed for the sewer system in the vicinity of the APS-1 connection to the NWI. A schematic of the outfall hydraulics was provided in the Interim Report on SSO Characterization.

3.6.10 Sanitary Sewer Overflow Volumes

The wet weather responses for the design events were routed through EXTRAN to predict SSO volumes that would be generated by these storm events.
If the sub-model was defined to have free discharge into the Northwest Interceptor, the model predicts that no overflows would occur. This result might be expected, as the discharge pipe to the NWI is the same size as the trunk sewer conveying flows from Allen Park to the meter pit/overflow chamber.

If the discharge is limited to 6-cfs, then the model predicts overflows for the 10-year, 1-hour event for dormant conditions and for all larger events. Results for these simulations are not provided as the overflow volume is dependent on the shape of the wet weather response and the sub-model does not include the sewer system upstream of the APS-1 connection. Additional data are required to properly characterize the shape of the flows at the APS-1 connection and thus be able to predict potential SSO volumes at that location.

3.7 Garden City

3.7. Background

According to the draft report *City of Garden City Corrective Action Report - Step 7A, (*Wade-Trim, Inc., 2001) construction of the Garden City sewer system began around 1939. The sewer system was built mostly as a combined system. In the 1970s, the city adopted partial separation as its CSO philosophy and approximately one-third of the city had been separated at the end of the decade.

In the 1980s, Garden City began to initiate several large projects on its combined sewer system, including the construction of additional separate storm sewers.

In 1993, Garden City participated in the Rouge Valley Combined Sewer Overflow Control Project. Garden City developed a proposal that compared costs of separating the remaining portions of its sewer system and building combined sewer overflow retention basins.

Garden City chose to separate the remaining portions of its sewer system. The last partial separation in Garden City was completed in 1998. The last phases of the partial separation project included placing bulkheads at the overflows on both the Middlebelt and Merriman sanitary trunk lines, and installing in-line vortex valve/weir plate structures in the upstream sewers for in-line storage.

Garden City does not have a long history of sanitary sewer overflows. This is because, until 1998, the sewer system had been combined. Garden City reported that SSOs occurred during the September 11-12, 2000 storm event. They consisted of temporary bypass pumping sites located at the following intersections:

- Garden and Dawson
- Deering and Dawson
- Harrison and Kathryn
- Maplewood and Middlebelt

Data collected from the city's two end-of-system flow meters for actual storm events have been used to develop rain dependent inflow and infiltration response factors for the city's two discharge districts and the city overall. These factors were used by Wayne County in calibration of the North Huron Valley/Rouge Valley (NHV/RV) flow model extension of the GDRSS Model. These factors have been used to make preliminary predictions of the sewer system flows generated by the Garden City system for various design storm events.

The engineering consultant for Garden City, Wade-Trim, Inc., is currently examining the impacts that the one-year, one-hour, 10-year, one-hour, and 25-year, 24-hour design storms will have on the Garden City system. Wade-Trim is also examining various alternatives to reduce inflow and infiltration, store excess flows, and purchase additional capacity to the Wayne County Interceptor.

3.7.2 Data Analysis and Results

The Garden City SSO tributary area was divided into two areas: GC-1 and GC-2. GC-1 is 1883-acres. GC-2 is 1616-acres. Garden City has a contract capacity of 24.4-cfs. Based on the dry weather flow split, the contract capacity of GC-1 was determined to be 13.58-cfs. The contract capacity of GC-2 was determined to be 10.82-cfs.

3.7.3 Dry Weather Flow

The dry weather flow for Garden City SSO tributary area is 6.61-cfs. GC-1 has a dry weather flow of 3.68-cfs. GC-2 has a dry weather flow of 2.93-cfs.

3.7.4 RDII Volume Response

RDII C factors were determined separately for GC-1 and GC-2. For GC-1, the RDII C factors used in SWMM RUNOFF are 13.12% and 7.15% for dormant and growth conditions, respectively. For GC-2, RDII C-factors are 12.79% and 4.41% under dormant and growth conditions, respectively.

3.7.5 Response Shape

The Garden City SSO tributary area model was set up using the RDII features in SWMM RUNOFF. The response shapes for GC-1 and GC-2 are listed in Table 3.7.1.

Table 3.7.1 Garden City Response Shape Design Conditions

Area	T1	K1	T3	K3
GC-1	2.0	2.3	3.0	5.0
GC-2	2.1	2.5	4.0	3.0

3.7.6 Wet Weather Volumes

Wet weather volumes were determined for the seven different design events and for two different conditions, dormant and growth. The total tributary (sewered) area within the district used in the development of these hydrographs is 3499 acres. To provide estimates of flows, the RUNOFF Module of the SWMM Model was used. Results are presented in Table 3.7.2.

Table 3.7.2 Design Storm Wet Weather Volumes for Garden City

Design Storm Event (Rainfall - inches)	Wet Weather Volume (MG)	
	Growth Conditions	Dormant Conditions
1-Month, 24-Hour (0.62)	2.06	5.77
1-Year, 1-Hour (1.0)	3.99	10.47
10-Year, 1-Hour (1.8)	8.04	20.32
1-Year, 24-Hour (2.2)	10.06	25.28
10-Year, 24-Hour (3.6)	17.14	42.44
25-Year, 24-Hour (4.0)	19.16	47.39
100-Year, 24-Hour (4.7)	22.70	55.98

3.7.7 Contract Exceedance Volumes

The City of Garden City has a contract capacity of 24.4-cfs with DWSD, which includes both dry and wet weather flows. Contract exceedance volumes were calculated by inputting the runoff hydrograph for each event into a mini-EXTRAN model, which consisted of a flow split, with flows over the contract capacity being discharged as overflow. The volume of RDII over the 24.4-cfs contract limit was considered to be contract exceedance. It is important to note that the system hydraulics were not modeled directly; hence, any limitations that might exist within the system are only taken into account indirectly through the shape of the runoff hydrographs as determined during the calibration process. The contract exceedance volumes are in Table 3.7.3.

Table 3.7.3 Design Storm Contract Exceedance Volumes for Garden City

Design Storm Event (Rainfall - inches)	Contract Exceedance Volume (MG)	
	Growth Conditions	Dormant Conditions
1-Month, 24-Hour (0.62)	0.00	0.48
1-Year, 1-Hour (1.0)	0.26	4.95
10-Year, 1-Hour (1.8)	2.79	13.83
1-Year, 24-Hour (2.2)	3.68	15.94
10-Year, 24-Hour (3.6)	9.39	31.73
25-Year, 24-Hour (4.0)	11.07	36.38
100-Year, 24-Hour (4.7)	14.23	44.56

3.7.8 SSO Volumes

Per the city's request, estimates of SSO volumes were not made for this case study.

4. Summary

The goal of the regional SSO analysis is to present the various approaches used to find a cost-effective solution to the elimination of sanitary sewer overflows from the DWSD service area. The regional study is being performed concurrently with a number of local studies. The results of the local studies are being combined with the regional analysis so that the downstream impacts, if any, can be evaluated for each alternative. As the causes of SSOs vary, the most appropriate solution varies for the various case studies. To date, the following steps have been taken in review of the various solutions:

1. Determine wet weather response (volume and shape) for the established design conditions and storm events, using the calibrated RUNOFF model developed from the flow data.

2. Find amount of flow for each design event that is over contract capacity or some reasonable equivalent. If a SSO is internal to a district, that is, not at point of discharge where contract is applied, a portion of the contract capacity might be determined and used. A related issue is whether the contract is within range of what might be reasonable for a sanitary area.
3. If data is available, develop an EXTRAN model of the system and the SSO and calibrate using existing events.
4. Review the impact of short-term control measures: a number of the case studies are already pursuing various interim measures or corrective actions to reduce problems of excessive I/I. In some cases, the Michigan Department of Environmental Quality through an Administrative Consent Order (ACO) has mandated interim measures. If data are available, a qualitative assessment can be made of the impact of the wet weather response characterization. If the flow data used to characterize the wet weather response were collected before the implementation of these interim measures, additional data should be collected to quantify the amount of reduction that has been realized. For the case studies, no attempt was made in projecting the future impact of these measures.

Now that the wet weather response has been characterized and the causes of the SSOs have been established, several approaches can be utilized to address the SSOs within the case studies and DWSD service area. Local alternatives and corresponding costs for the six case studies will be examined first, followed by regional alternatives and corresponding costs.
These approaches can be categorized into three major groups:

- Elimination of the sources of high infiltration/inflow that cause SSOs;
- Local storage or treatment of SSO; and
- Regional transmission, storage and treatment of SSOs.

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