ATTACHMENT 1 TO THE SPECIAL ORDER BY CONSENT
REGIONAL TECHNICAL STANDARDS

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SECTION 1 INTRODUCTION AND PURPOSE

1.1 INTRODUCTION

This document is Attachment 1 – Regional Technical Standards (Standards) to the Special Order by Consent (Consent Order) issued by the State Water Control Board (SWCB) to HRSD and the Hampton Roads Localities. These Regional Technical Standards provide detailed requirements for completion of the work embodied in the Consent Order, and were developed to ensure a consistent regional approach. These Standards include completion dates for various activities, which are described in terms of months from the effective date of the Consent Order.

1.2 PURPOSE

The purpose of the Consent Order and these Regional Technical Standards is to reduce the occurrence of sanitary sewer overflows (SSOs) in the Regional Sanitary Sewer System. These standards cover the analysis of existing data, collection of additional system data, preparation of rehabilitation plans, correction of serious defects requiring prompt attention, development of a hydraulic model, and assessment of the hydraulic performance of the Regional Sanitary Sewer System. These Standards have been developed to be information-based so that resources are focused on the areas that require attention to mitigate SSOs. Where appropriate, these Standards include quality assurance/quality control procedures related to field data collection.

These Standards also address the relationship between the hydraulic performance of the Regional Sanitary Sewer System, Rehabilitation Plans that will be developed and implemented by HRSD and the Hampton Roads Localities, and the Regional Wet Weather Management Plan. The longer-term repairs of the sanitary sewer system will occur after the term of this Consent Order in accordance with plans developed, submitted and approved pursuant to this Consent Order.

1.3 RELATIONSHIP WITH THE MEMORANDUM OF AGREEMENT

The Localities and HRSD are entering into a Memorandum of Agreement (MOA) which is a long term agreement related to regional collaboration. These Regional Technical Standards have been developed primarily to support the fulfillment of the Consent Order requirements, and are incorporated into the MOA by reference. Future work done outside the context of the Consent Order, and future regulatory actions, should generally be conducted in accordance with these standards when it is appropriate. For example, future flow monitoring performed outside the context of the Consent Order and future regulatory actions would generally be performed in accordance with these standards, but the duration and magnitude of qualifying events could be different from the standards in this document. Similarly, SSES and hydraulic modeling conducted for purposes unrelated to the Consent Order should follow these Standards, with appropriate modifications to reflect the specific application.

Two components of these Standards will survive the fulfillment of the Consent Order and are enforceable under the MOA. These are Exhibit A – Regional Design Guidelines and Exhibit B – Regional Sanitary Sewer System Operating Guidelines.

1.4 SUMMARY OF THE REGIONAL TECHNICAL STANDARDS

The following is a brief overview of each section of these Regional Technical Standards:

Section 1 – Introduction and Purpose
This section establishes the context for the Regional Technical Standards.

Section 2 – Definition of Terms
This section provides definitions for the major terms used in the Standards.

Section 3 – Data Collection and Flow Monitoring
This section provides direction on SSO characterization, use of previously developed information, system inventory mapping and GIS data standards, flow monitoring procedures for both model calibration and SSES basin identification, rainfall monitoring, sewer flow evaluation and flow evaluation reporting. Taken together, this section provides the guidance for identification of SSES Basins, which require further investigation.

Section 4 – Condition Assessment of Sewers and Pump Stations
This section provides the guidelines for conducting detailed condition assessment, assessment standards for SSES Basins, and assessment reporting requirements. The information developed through these efforts will be used to develop the SSES Plans in accordance with the requirements in Section 5.

Section 5 – SSES Planning
This section establishes the SSES Basin criteria and the requirements for preparing a prioritized plan for conducting the SSES work. This plan must be submitted to DEQ within 15 months of the effective date of the Consent Order for their review and approval.

Section 6 – Hydraulic Performance Assessment
This section provides the standards for development and application of a hydraulic model that will be used to evaluate system performance under a variety of hydrologic conditions. The model will be used to evaluate the capacity of the existing Regional

Sanitary Sewer System, and to develop and review alternatives for providing adequate capacity. Procedures and standards for model development, calibration and verification are included. The model shall be developed within 38 months of the effective date of the Consent Order.

Section 7 – Rehabilitation Planning
This section discusses using the results of the SSES work to develop specific plans for rehabilitation, including evaluation of the effectiveness of rehabilitation on inflow and infiltration reduction, cost estimates and schedules. The Rehabilitation Plans will be submitted to DEQ for review and approval within 62 months of the effective date of the Consent Order. Implementation of the plans is outside the scope of the current Consent Order. Localities will assess the feasibility and cost of achieving specific peak flow reduction outcomes, which will inform the Regional Wet Weather Management Plan.

Section 8 – Regional Wet Weather Management Plan Development
This section provides the guidelines for developing the Regional Wet Weather Management Plan (RWWMP) that will identify the Regional Sanitary Sewer System improvements necessary to provide capacity to meet an agreed upon level of service. This section includes direction on capacity assessment, level of service selection, development of capacity enhancement solutions, affordability and provides a preliminary outline for the content of the RWWMP. The Regional Wet Weather Management Plan will be submitted to DEQ for review and approval within 74 months of the effective date of the Consent Order.

Exhibit A – Regional Design Guidelines
This section presents regional design guidelines that will be used for design of any new or enhanced major sewer infrastructure until the RWWMP is complete.

Exhibit B – Regional Sanitary Sewer System Operating Guidelines
This section provides guidelines related to operating flow and pressure in the Regional Sanitary Sewer System.

1.5 REVISIONS TO THE REGIONAL TECHNICAL STANDARDS

The parties agree that minor changes may be made in the Standards without triggering a modification of the Order, provided that such changes are the subject of unanimous agreement of the General Manager of HRSD and the Hampton Roads Localities Directors of Utilities and are approved by the Director of DEQ's Tidewater Regional Office.

2 DEFINITION OF TERMS

The following words and terms that have been used in Attachment 1 – Regional Technical Standards shall have the meanings assigned to them below unless the context clearly indicates otherwise. Other commonly used terms used in Attachment 1 are defined by reference to terms in the Sewage Collection and Treatment Regulations (SCATR) [9VAC 25-790] unless otherwise specifically defined in these Regional Technical Standards.

"ADF" means Average Daily Flow.

"Adequate Capacity" means that the Sanitary Sewer System has a demonstrated ability to manage peak flows at a specific peak flow recurrence interval without causing or contributing to overflows from any component of the Regional Sanitary Sewer System. The specific peak flow recurrence that will be used for the basis of identifying capacity enhancements shall be established within the Regional Wet Weather Management Plan.

Demonstration of adequate capacity for wastewater pumping stations requires each pump station to be capable of transmitting specific peak flows with the largest pump out of service, without causing or contributing to overflows. Evaluation of adequate capacity shall consider the interrelationship between: i) each pump and the pump station immediately upstream from that pump station, ii) all pump stations through which flow from that pump station passes to the wastewater treatment plant receiving such flow, and iii) all pump stations discharging directly to the HRSD Sanitary Sewer System, which receive flow from that pump station.

For gravity systems, adequate capacity shall mean that the system can convey the peak flow without exceeding a surcharge level of 1.5 feet below the rim of a manhole.

"ASCII" means American Standard Code for Information Interchange.

"CCTV" means closed-circuit television.

"CMMS" means computerized maintenance and management system.

"DEQ" means the Department of Environmental Quality, an agency of the Commonwealth of Virginia as described in Code § 10.1-1183.

"Design Flow Rate" means the flow rate specifically used as the basis of design for facilities within the regional sanitary sewer system.

"Diurnal curve" means a graphical or tabular representation of the variation of wastewater flow (excluding rainfall derived I/I contributions) over a typical, 24-hour cycle.

"DWI" means dry weather infiltration.

"Dry Weather Overflow" means any sanitary sewer overflow for which the underlying cause is not attributable to precipitation related flows.

"Event of Interest" means any wastewater flow event or specific rainfall event, which is used to evaluate the performance of the sanitary sewer system.

"Excessive Pump Run Time" means a threshold at which a pumping station meets the relevant SSES Basin planning criterion. Excessive Pump Run Time can be identified by evaluating the daily total run time of all pumps within a pump station under wet weather/peak flow conditions. Excessive Pump Run Time exists when the total run time for all pumps within a pump station exceeds an average of 24 hours per day per pump with one pump out of service. This threshold can be calculated using the following equation,:

Excessive Pump Run Time = [(Number of Pumps) – 1] X 24 hours

Excessive pump run time is a threshold that must be compared to actual pump run time under specific flow conditions to identify indications of potential capacity limitations. Excessive pump run time and actual pump runtime should be directly compared for pump stations that are comprised of constant speed pumps of equal size, or multi-speed pumps that are running at full speed.

"GIS" means Geographic Information System.

"Gravity Sewer Line" means a pipe that receives, contains and conveys wastewater not normally under pressure, but is intended to flow under the influence of gravity.

"Ground Water" means sub-surface water that is stored in the voids between soil particles.

"Hampton Roads Localities" means the cities of Chesapeake, Hampton, Newport News, Poquoson, Portsmouth, Suffolk, Virginia Beach, and Williamsburg; the counties of Gloucester, Isle of Wight, James City, and York; and the town of Smithfield.

"Hampton Roads Locality" or "Locality" means one of the Hampton Roads Localities.

HRPDC" means Hampton Roads Planning District Commission, a political subdivision of the state. The purpose of planning district commissions, as set out in the Code of Virginia, Section 15.2-4207 is "...to encourage and facilitate local government cooperation and state-local cooperation in addressing on a regional basis problems of greater than local significance".

"HRSD" means Hampton Roads Sanitation District, a political subdivision created by a 1940 Act of the General Assembly of Virginia and charged with the responsibility to provide sewage collection, conveyance, and treatment services for the communities in the Hampton Roads metropolitan area.

"HRSD Master Meter" means a permanent flow or pressure meter installed in a location mutually agreed upon between HRSD and the Hampton Roads Localities, owned and operated by HRSD, and specified within the HRSD Master Metering Program. HRSD Master Meters are used to evaluating Operating Flow.

"Hydrograph" means the graphical or tabular representation of flow volume over time, which could depict a specific hydrologic condition.

"I/I" means infiltration and inflow, which is a component of sewer flow contributed as a result of groundwater and precipitation that enters the sanitary sewer system.

"Illicit Connection" means an unauthorized connection to the sanitary sewer system, including but not limited to area drains, foundation drains, roof drains and sump pumps. Illicit connections are connections that have been made to the sanitary sewer system without the knowledge and/or approval of the Locality or HRSD.

"IMS" means information management system, which is a formalized system to manage data.

"Infiltration" means water other than wastewater that enters a sewer system (including sewer service connections) from the ground through such means as defective pipes, pipe joints, connections, or manhole walls. Infiltration does not include, and is distinguished from, inflow.

"Inflow" means water other than wastewater that enters a sewer system (including sewer service connections) from sources such as, but not limited to, roof leaders, cellar drains, yard drains, area drains, drains from springs and swampy areas, manhole covers, cleanouts, cross connections between storm sewers and sanitary sewers, catch basins, cooling towers, storm waters, surface runoff, street wash waters, or drainage. Inflow does not include, and is distinguished from, infiltration.

"Interceptor Sewer" means a sewer, typically without individual sewer customer connections, that is used to collect and carry flows from main and trunk sewers to a central point for treatment and discharge.

"LACP" means Lateral Assessment Certification Program developed by National Association of Sewer Service Companies.

"Level of Service" means the peak sewer flow recurrence interval that the Regional Sanitary Sewer System can convey without resulting in a capacity-related SSO.

"MACP" means Manhole Assessment Certification Program developed by the National Association of Sewer Service Companies.

"Management, Operations, and Maintenance or MOM" means a flexible program of accepted industry practices to properly manage, operate and maintain a sanitary sewer system.

"NASSCO" means National Association of Sewer Service Companies.

"ODBC" means Open Database Connectivity.

"Operating Flow" means three times the actual average potable water consumption for domestic flow and smaller commercial flow within a specific sewer basin (or pump station service area). Major industrial and commercial wastewater flows (100,000 gpd and greater) are added to the Operating Flow based on their peak metered flow rates. When the peak hourly flow rate as measured at HRSD Master Metering sites exceeds the corresponding Operating Flow, HRSD and the effected Localities will jointly evaluate the hydraulic capacity of the impacted facilities and determine the appropriate course of action.

"PACP" means Pipeline Assessment Certification Program developed by NASSCO.

"Peak Flow" means the maximum hourly wastewater flow that occurs at a specific location within the sanitary sewer system.

"Peak Flow Recurrence" means the statistical probability of achieving a certain peak sewer flow. Typically, these values are expressed in terms of return years, or return frequency. As an example, a 10-year peak flow recurrence represents the probable peak sewer flow that is expected to occur once every 10 years.

"Peak Flow Threshold" means the calculated flow of 775 gallons per day per existing residential unit plus 3 times commercial water consumption plus actual major commercial and industrial (100,000 gpd and greater) flows.

"Preventable Overflow" or "Preventable SSO" means overflows, which could have reasonably been prevented through due diligence, proper operations and maintenance, reduction in I/I, or increased capacity of the sanitary sewer system.

"Private Service Connection/Lateral" means that portion of the collection system used to convey wastewater from a building or buildings to that portion of the sanitary sewer system owned by the Locality.

"Pumping Station" means facilities comprised of pumps which lift wastewater to a point physically higher than the wastewater elevation in the wet well, including all related electrical, mechanical, and structural systems necessary to the operation of that pumping station.

"RDII" means rainfall-derived inflow and infiltration. RDII is a parameter that can be measured, estimated or synthetically generated through other means, such as flow monitoring data or hydraulic modeling.

"Regional Design Guidelines" means the standards adopted by HRSD, the Hampton Roads Localities and DEQ for the design of any new or enhanced major sewer infrastructure (i.e., regional pump stations, major interceptors, etc.) until the Regional Wet Weather Management Plan is complete. The adopted Regional Design Standards will be based a on peak hourly residential wastewater flow of 250 gallons per capita per day at an assumed 3.1 persons per household, or 775 gallons per residential unit per day; plus peak hourly commercial/industrial wastewater flow based on actual flow if available, or 3 times the average projected water consumption if not available. The relationship of peak water consumption to peak wastewater flow is assumed to be 3 times the water consumption is equal to 2.5 times wastewater flow.

"Regional Hydraulic Model" means the hydraulic model of the following components of the regional sanitary sewer system:

- All HRSD pipes, HRSD pumping stations, and HRSD pressure reducing stations, in the regional sanitary sewer system
- Locality pumping stations that directly discharge into a HRSD interceptor sewer
- The gravity sewers extending one manhole upstream from each Locality pumping station that directly discharges to a HRSD interceptor sewer (Note that some pumping stations may receive discharge from multiple sewers; in theses instances, the first upstream manhole on each line will be included).
- Locality gravity sewers extending one manhole upstream from the point of connection with an HRSD gravity interceptor.

"Regional Sanitary Sewer System" means the collective sanitary sewer systems owned and operated by the Localities, as well as the HRSD sanitary sewer system including gravity sewer lines, manholes, pump stations, lift stations, pressure reducing stations, force mains, wastewater treatment plants, and all associated appurtenances.

"Regional Wet Weather Management Plan (RWWMP)" means the document to be developed jointly by HRSD and the Hampton Roads Localities that defines prioritized capital and operating improvements in the Regional Sanitary Sewer System necessary to manage peak wet weather flows to achieve a mutually agreed upon level of service.

"Rehabilitation Plan" means documents to be developed individually by each Hampton Roads Locality and HRSD that define specific measures to reduce SSOs, address deficiencies identified in SSES Basins; identify system-wide improvements including control of I/I sources and improvements needed to ensure sustainability of the sanitary sewer infrastructure.

"Replacement" means obtaining and installing equipment, accessories, or appurtenances which are necessary at the end of the design or useful life, whichever is longer, of the sanitary sewer system to maintain the capacity and performance for which such works were designed and constructed.

"Rainfall Recurrence Interval" means the statistical probability of achieving a rainfall of specific intensity, volume and duration. Typically, these values are expressed in terms of return years. As an example, a rainfall with a 2-year recurrence interval has a probability of occurring once every two years.

"Sanitary Sewer Overflow (SSO)" means the unauthorized intentional or unintentional spill, release, or discharge to waters of the State of untreated wastewater from any portion of a sanitary sewer system before the headworks of a Wastewater Treatment Facility.

"Sanitary Sewer System" means the wastewater collection and transmission system that is comprised of all portions of the individual Hampton Roads Locality or HRSD collection systems, including manholes, gravity sewers and force mains, lift stations, pump stations, and associated appurtenances.. Building sewer laterals are not considered part of the Locality's sanitary sewer system.

"Sewer Basin" means all portions of the sanitary sewer system tributary to an interceptor sewer or pump station (also referred to as a pump station service area). Generally, the sewers within a Sewer Basin are hydraulically linked.

"Sewer Basin Criticality" means an expression of the condition of a sewer basin as it relates to consequences of failures within the associated sanitary sewer system. Sewer Basin criticality may consider factors such as environmental risk, public health risk (including potential impacts to drinking water sources from SSOs), economic risk (including potential impacts on new service connections due to sanitary sewer system capacity limitations), and operational risk.

"Sewer System Evaluation Survey (SSES)" means a systematic examination of a sanitary sewer system or portion thereof to, at a minimum: i) identify the condition of sewers, manholes, pump stations and associated appurtenances; ii) identify I/I sources, locations, and associated extraneous flow rates; iii) characterize the wastewater flow; and iv) determine technically feasible, cost effective methods of rehabilitation.

"Significant Rainfall Event" means a rainfall event, which results in an associated measurable increase of wastewater flow in the sanitary sewer system above dry weather flows. Significant rainfall events are defined solely for the purposes of flow monitoring data analysis.

"SSES Basin" means a defined portion of the sanitary sewer system where historical data and/or flow monitoring data collected pursuant to this Attachment indicate high levels of RDII, unresolved SSOs, or other characteristics described in Section 5.1 that warrant investigation. SSES Basins will be subject to investigation to identify infrastructure deficiencies and define the potential for peak flow reduction.

"Supervisory Control and Data Acquisition (SCADA)" means a computer system for gathering and analyzing real time data.

"Surcharge" means the condition where gravity sewer flow depth exceeds the diameter of the sewer line that is conveying the flow.

"TAZ" means Traffic Analysis Zone. Demographic data for each TAZ is maintained by HRPDC in a GIS database, and includes population and workforce data used to predict growth and future flows for modeling purposes.

"Unpermitted Discharge" means the discharge of pollutants from a point source into waters of the State, which is not authorized by a VPDES Permit, including but not limited to any SSO, which reaches waters of the Commonwealth.

"Unresolved SSO" means any SSO for which the underlying cause has not been resolved so as to prevent future reoccurrences at that location from that cause.

"Useful Life" means the length of time, or period during which infrastructure assets operate. Useful life is not synonymous with "design life" which is the period over which infrastructure assets are planned to be used and designed to be operated.

"Water Consumption" means the volume of potable water consumed by residential, commercial, and industrial users as measured by potable water meters.

SECTION 3 DATA COLLECTION AND FLOW MONITORING

3.1 REVIEW OF EXISTING INFORMATION

Development of the SSES program components requires sound system knowledge. Existing sewer system information shall be compiled and evaluated to establish the basis for identifying additional data needs.

Information sources shall include the following, as available and appropriate for the specific system:

- Sewer system maps
- Engineering and design studies, including hydraulic analyses
- SSES studies
- Any existing system condition/inspection data
- Maintenance staff interviews
- Operation and maintenance records
- Treatment plant flow and operation records
- Pumping station flow records and SCADA data
- Sanitary Sewer Overflow (SSO) reports
- Customer complaint records
- Existing Asset Condition Data (e.g., CCTV records)

A suitable data acquisition plan shall be developed and implemented to address data gaps and information needs.

3.1.1 Sanitary Sewer Overflow Characterization

The cause, location, estimated quantity and frequency of all sanitary sewer overflows (SSOs) that have occurred during the past five (5) years, if available, shall be analyzed to determine where there may be unresolved maintenance, structural, and capacity issues. SSOs may be classified according to the following causes (or a similar classification system):

- Maintenance
  - Grease
  - Roots
  - Debris (including sediment accumulation)
- Infrastructure
  - Pipe Failure/Defects
  - Equipment Failure
- Capacity
  - Excessive I/I

- Unanticipated Wastewater Flows
    - Pressure Problems
    - Reverse Grade
    - Hydraulic Bottlenecks
    - Inadequately Sized Facilities
- Damage by Others
    - Vandalism
    - Contractor Damage
    - Illegal Discharges
- Power Outages
    - Response Times

SSO evaluation shall be conducted to identify chronic problems and develop appropriate mitigation actions for each SSO. The SSO locations shall be identified on a sanitary sewer system map, preferably in GIS, and coded by cause. This action will facilitate the SSO analysis.

3.1.2 Prior Studies/Planned Construction

Studies that have been completed within five (5) years of the execution date of the Special Order by Consent may be considered valid, and the area may be excluded from further SSES work under the Special Order by Consent, provided that the work included in the study substantially meets requirements of the Regional Technical Standards established herein. Studies older than 5 years may be used to develop the SSES Plan provided that any changes that have occurred in the sanitary sewer system that may impact the results of the study are understood and considered in the use of the data. The areas addressed within prior studies will be identified within the SSES Plan described in Section 5.

Areas of the system that have been rehabilitated within five years prior to the execution date of the Special Order by Consent will be excluded from further SSES work under these guidelines, provided they do not meet the criteria contained in Section 5.1.

Areas covered by prior studies that will be included in the Rehabilitation Plan under the Special Order by Consent will not be reevaluated, except at the discretion of the Locality or HRSD for their respective rehabilitation plans.

Areas that are, or will be, scheduled for rehabilitation prior to submittal of the Rehabilitation Plan described in Section 7 will be excluded from further SSES work, provided that the rehabilitation project is consistent with Attachment 1 – Regional Technical Standards, as appropriate. Rehabilitation projects that have been initiated prior to execution of the Special Order by Consent and have advanced beyond the Preliminary Engineering Report stage will not be impacted by the provisions of the Special Order by Consent.

3.1.3 Engineering and Operations

Sewer system engineering and operational information that is useful in SSES Planning includes:

- Mapping of the project area showing sanitary sewer systems, streets and roads, contours and spot elevations, and storm sewers and appurtenances
- Design drawings, pump curves, design reports, and operating data (pump run time logs)
- SCADA information to include system pressure, metered flow, pump run times, wet well levels, and alarm and event data
- Information on work order history and maintenance records for sewer facilities
- Historical water consumption data
- Rainfall gauge data
- Groundwater monitoring data where deemed necessary by the Locality

These data shall be used, where available, to identify problem areas within the sanitary sewer system that result from connectivity issues, design limitations, or maintenance issues. These data may also be used to help define the activities needed to further investigate and/or collect additional information about the system.

3.1.4 Other Performance Documentation

Known ongoing operational and/or maintenance problems shall be reviewed prior to the initiation of the field investigations. This information will be obtained through consultation with the Locality's and HRSD's staff. The list below is representative of the types of issues that shall be investigated:

1. Based on the experience of the staff, where are the significant problem areas in the sanitary sewer system?

2. Have there been any significant recent changes in the patterns or type of sewer problems (overflows, stoppages, collapses, etc.) from those identified in prior investigations or other prior studies?

3. Have there been repairs conducted that were identified in prior investigations?

4. Which sewer lines within the study area are currently on a routine cleaning program, and do they correlate with past problem areas?

5. Can reported problems such as grit, grease, roots or inflow be substantiated through a preliminary inspection of critical manholes or sewer segments?

6. Are there any easement or right-of-way issues affecting the access, such as backyard locations?

7. What are the local issues regarding traffic control, site accessibility, and maintenance activities?

8. Is the force main manifolded with another pumping station or an HRSD pumping station? If so, are there discharge pressure issues?

9. Under what conditions and how long does the pumping station require all pumps to operate?

10. Does unacceptable surcharging occur in the system? If so, where and under what conditions does this surcharging occur?

11. Have there been construction activities by others within the sanitary sewer system service area where trenchless techniques have been used that may have damaged pipes?

3.2 SYSTEM INVENTORY

An inventory of the sewer system's components shall be prepared so that those components can be consistently referenced during the SSES and subsequent analyses. The inventory shall include:

- Gravity mains
- Laterals
- Manholes
- Pump stations
- Force mains
- Vacuum systems
- Appurtenances (i.e., valves, clean outs, siphons)

3.2.1 Mapping Standards

The mapping shall be developed using the Virginia State Plane Coordinate System with a known vertical control that can be easily transferred to other standard vertical datum.

3.2.2 GIS Data Standards

To compile a GIS dataset for the regional sanitary sewer system, the following major datasets are needed:

- Regional GIS base mapping from HRSD
- Available supplemental GIS base mapping data from each locality
- Existing sanitary sewer system GIS data from each locality
- Existing hard copy or other electronic format of sanitary sewer system maps for localities where GIS data is not available

Sewer system GIS data shall include gravity pipes, manholes, pump stations, force mains, valves, pressure reducing stations and other pertinent facilities. The GIS data shall be transferable to HRSD for hydraulic model development. The GIS data formatting shall be agreed upon between the Locality and HRSD prior to data collection activities associated with the Special Order by Consent. HRSD shall provide each Locality with a data-mapping scheme for the transfer of GIS data. The Locality shall provide the necessary data to HRSD in the agreed upon format. All GIS data shall have metadata associated with each data set.

3.2.3 Existing Physical Attribution

Physical attribution is needed to describe the various facilities within the system. At a minimum, the following attributions shall be included for each feature used in modeling:

Pipe:

- feature ID
- upstream and downstream manholes or junctions
- pipe size (inside diameter)
- length
- gravity line invert elevations (upstream and downstream)
- pipe material
- approximate pipe installation date / age
- pipe condition
- pipe type, i.e., force main or gravity sewer

Manholes:

- manhole ID
- diameter/size
- spatial coordinates
- invert elevation
- pipe invert elevations
- rim elevation
- ground elevation

- sealed or unsealed lid
- sump elevation
- approximate manhole installation date / age

Pumping Stations:

- pump station ID
- wet-well physical attributes (i.e. dimensions)
- pumping capacity (i.e. pump performance curves, draw down test results)
- number of pumps
- type of drive (i.e. variable speed, dual speed, or constant speed)
- control logic (i.e., wet well elevations at which each pump turns on, reaches full speed, and turns off)
- piping details
- flow equalization/storage attributes and control strategy
- special equipment (e.g. pressure regulating valves)
- flood plain location
- approximate pump/pump station installation date / age

Where the data is not available, assumptions must be made to complete the data set based on engineering judgment.

3.3 FLOW MONITORING PROGRAM

Flow monitoring shall be conducted to characterize the flow regime in the sanitary sewer system. The objectives of the flow-monitoring program are as follows:

- Collect representative dry and wet weather flow data for the sewer basin(s)
- Identify conditions that cause sewer surcharging
- Observe and quantify dry weather infiltration
- Quantify rainfall derived inflow and infiltration (RDII) volumes
- Correlate RDII with rainfall volumes and intensities
- Determine and assist in prioritizing SSES Basins
- Obtain data necessary for hydraulic model calibration
- Facilitate development of the Regional Wet Weather Management Plan
- Observe and quantify potential dry-weather inflow (e.g. manholes located in low-lying areas which may be inundated in dry-weather by tidal effects or stream flow)

The scope of the flow-monitoring program shall be developed to ensure data collection is adequate to meet the program objectives. Flow data that has been collected five (5) years prior to execution of the Special Order by Consent, which meets the requirements established within these Technical Standards, may be used. Before defining the scope, the Locality shall determine:

- The adequacy of existing data from prior studies (e.g., study areas in which no significant changes have occurred since the flow monitoring took place)
- Extent that pump station data can be used to quantify flows
- Equipment types and availability
- Where flow monitoring is needed
- Types of flow to be monitored
- Cost to collect and evaluate the data
- The seasonal variations of flow within the sanitary sewer system, if significant

3.3.1 Meter Site Selection and Basin Delineation

Selection of meter location sites is critical to defining sewer basins. Flow meter sites shall be selected so that the entire flow for the area of interest can be characterized. This may require multiple meters for areas with parallel sewers or complex connectivity. Metering sites should also be considered at boundary points for calibration and validation of hydraulic model(s). Meter sites shall be compatible with the minimum requirement of the flow monitoring equipment manufacturer relative to physical site constraints.

Sewer basin delineation can be accomplished through use of sewer mapping. It is important that the meter locations are strategically selected to provide an appropriate delineation of sanitary sewer system basins.

3.3.2 Acceptable Flow Measures and Recording

Equipment may consist of one or more of the following: open channel flow monitors, SCADA data (pump run times, discharge pressure and volumetric data) capable of computing flow, or monitoring flow in force mains. Flow monitoring equipment shall include a data logger, communication device and sensing unit. Where pressure pipe flow monitoring is to be performed for pump discharge flow measurements, magnetic flow meters or ultrasonic meters should be used. Where flow is measured in force mains, pressure shall also be measured. All gravity sewer metering equipment shall be capable of recording in both low flow and surcharged conditions for wet weather monitoring. The Locality and HRSD must utilize engineering judgment in the selection of flow monitoring methods and the application of the resulting data.

Strengths and limitations for each flow monitoring method shall be evaluated considering characteristics of the flow to be measured and the location to be monitored. Note that the pump station volumetric method of determining flow rate is not reliable for conditions where wet well levels surcharge into the incoming sewer lines, or where variable frequency drive units are in place, unless other metering is used to account for flows being discharged from or entering the pump station. Pump curves and system curves shall be verified when using this methodology to estimate flow rates. Caution should be exercised in application of this methodology. It is most appropriate for pump or lift stations with constant speed pumps that discharge to gravity sewers.

3.3.3 Duration of Flow Monitoring

For the purposes of model calibration and identifying areas for SSES activities, temporary flow measurement shall be conducted. The flow data shall capture a representative sample of dry weather flows as well as several storm events of varying magnitudes. Temporary flow monitoring shall be conducted for a duration that satisfies the following minimum criteria:

Flow Monitoring for Model Calibration and Verification:

- Flow monitoring shall provide data that characterizes seasonal variations and captures the peak seasonal sanitary sewer flows.
- Flow monitoring shall record three (3) individual wet-weather flow events of greater than one (1) inch of accumulation, including at least one (1) event with at least a one-year recurrence interval. These events shall capture system response under a variety of antecedent rainfall and groundwater conditions.
- Flow monitoring shall continue for sufficient time between rain events for the flow to return to dry weather conditions.

Flow Monitoring for SSES Basin Identification:

- Flow monitoring period shall be of sufficient length to capture typical diurnal variations in dry-weather flow, including weekends and weekdays.
- Flow monitoring that captures three individual wet-weather events each of which provide a system flow response, including a rainfall event representative of those with a one year rainfall recurrence interval, or at least six months if the one year recurrence interval is not achieved provided that there is at least one event where the total 24 hour rainfall exceeds 1.5 inches.
- Flow monitoring shall be conducted during a period that provides the highest probability of wet conditions.

Flow monitoring for SSES Basin identification shall be completed within 12 months of the effective date of the Order. Notification that flow monitoring for SSES Basin identification has been completed shall be submitted to DEQ within 13 months of the effective date of the Order.

Flow monitoring for SSES Basin identification and hydraulic model calibration shall be conducted at a minimum of 20 percent of the pump station service areas within the

Locality's sanitary sewer system. Selection of locations for flow monitoring shall include pump stations that are representative of a group of pump stations that exhibit similar responses to the variables, which impact peak flow. Examples of the variables that shall be considered include, but are not limited to: the average age of the gravity sewers in the sewer basin; pipe material and joint type; soil-type and porosity; maximum, minimum and yearly groundwater elevations; proximity to surface water bodies; tidal influence; ratio of pervious to non-pervious surface area; service areas size; land use; historic I/I data; seasonal population patterns; and sanitary sewer system construction materials.

Additional flow monitoring beyond the 20 percent shall be conducted as necessary to accurately characterize flows for either SSES Basin identification and/or hydraulic model calibration.

Flow monitoring data shall be reviewed for conformance with the criteria for model calibration and verification, as well as SSES Basin identification. If the review of the monitoring data indicates the criteria have been satisfied temporary metering can be discontinued. Otherwise flow monitoring shall continue until adequate data are obtained.

Individual utilities may require additional flow monitoring data for model verification. Verification of a hydraulic model involves comparing flow-monitoring data outside of the data set used for calibration to the predicted results of the model for the same conditions. The verification process may identify inaccuracies in the model not identified during calibration phase. Data requirements for verification shall include wet-weather events not used for calibration.

3.3.4 Data Accuracy Specifications

Flow monitoring accuracies will be based on typical accuracies for the type of equipment used. Flow meters shall monitor flow between sample periods and provide maximum and minimum values at 15-minute intervals. Additionally, flow meters shall be capable of collecting and reporting data at five (5) minute intervals when the percent change in flow is greater than ten percent (10%) in any fifteen (15) minute interval.

Prior to installation of any meter and/or gauge, the device shall be calibrated according to manufacturer's recommendations. The calibration of open channel flow meters will be checked periodically after installation using supplemental velocity and/or level measurement devices, where the use of such devices is practical. Calibration records shall be included in the flow evaluation report to demonstrate that the equipment was properly calibrated. Any recalibration required during the monitoring period shall be noted and also included in the report. The meters should be maintained in a manner that shall provide for a minimum:

- Seventy-five percent (75%) data reliability for each individual meter during a monthly monitoring period

- Ninety percent (90%) for all meter data should be maintained during qualifying rain events described in Section 3.3.3

Data reliability means the percentage of flow data that has been collected and is not obviously incorrect (i.e., flat lines or drifted from known calibration levels).

Rainfall, flow and pressure monitoring shall be carried out in accordance with current standard practices, and shall generally be in conformance with widely used industry guidance such as WRC's "A Guide to Short Term Flow Surveys of Sewer Systems", WEF's MOP FD-6 "*Existing Sewer Evaluation and Rehabilitation*", and NASSCO's "*Manual of Practices*".

3.3.5 Rainfall Monitoring

Rainfall monitoring shall be done to obtain the data needed to compare wet weather sewer flow to rainfall volume, duration and intensity. The relationship between peak sewer flow and rainfall shall be used during the evaluation of the sewer system's performance and the prediction of rainfall derived inflow/infiltration (RDII). Rainfall gauges shall be of the continuous recording type, and store data in 15-minute increments. Rain gauges shall be distributed throughout the area covered by the sanitary sewer system on a minimum of every 10 square miles. The placement of rain gauges shall be coordinated between HRSD and the Localities. Localities with a total area covered by the sanitary sewer system of less than 10 square miles shall install at least one rain gauge. That density should provide reasonable coverage and representation of variations in rainfall intensity, duration and accumulation throughout the sewer system. Rainfall gauges shall be capable of recording rainfall at 0.1-inch intervals or less.

Rain data can be supplemented by data from gauges maintained by United States Geologic Survey (USGS) and/or the National Oceanic and Atmospheric Administration (NOAA). Rain gauge data may also be supplemented by radar rainfall records derived from radar information that is calibrated with rain gauges maintained by the USGS, NOAA, and the Localities.

3.3.6 Ground Water Monitoring

Ground water level data shall be used, where available, to establish the potential for ground water infiltration into the sewer system. Groundwater data can be used in conjunction with flow data to analyze infiltration based on the relationship between the groundwater table level and the elevation of the sewers.

3.3.7 Flow Monitoring Plan

A Flow Monitoring Plan shall be developed and submitted to DEQ for review and concurrence within 3 months of the effective date of the Order. DEQ will be deemed to concur if it makes no objection within 30 days of Flow Monitoring Plan submittal. The Flow Monitoring Plan shall include the following minimum information:

TITLE PAGE

- Project/Report Title
- Locality Contact Information

EXECUTIVE SUMMARY

EVALUATION OF EXISTING FLOW DATA FOR COMPLIANCE WITH REGIONAL TECHNICAL STANDARDS

- SCADA Derived Flow Data
- Sanitary Sewer Evaluation Studies
- Flow Surveys

ASSESSMENT OF FLOW DATA REQUIREMENTS FOR SANITARY SEWER HYDROGRAPH GENERATION/MODELING REQUIREMENTS

ASSESSMENT OF FLOW DATA REQUIREMENTS FOR SSES BASIN IDENTIFICATION

IDENTIFICATION OF BASINS/SERVICE AREAS REQUIRING ADDITIONAL FLOW DATA

FLOW MONITORING SITE SELECTION

- Site Selection Criteria
- Mapping of Flow Monitoring Sites

EQUIPMENT COMPONENTS

- Equipment types to be used
- Use of SCADA System
- Data acquisition plan

DEPLOYMENT SCHEDULE

QA/QC PROCEDURES

3.4 FLOW MONITORING IMPLEMENTATION

Sewer flow monitoring information shall be used to characterize the performance of the sanitary sewer system during dry and wet weather flow conditions and to characterize the flow conditions that cause surcharging and/or overflows within the system.

3.4.1 Data Collection

Sewer flow, force main pressure, and rainfall information shall be collected (downloaded) at periodic intervals for the duration of the monitoring period. In cases where area-velocity meters are used to monitor flow in gravity sewers, a site visit after a major storm event is advisable to confirm meter conditions and to download the meter data. Data logging of the sensor readings shall be as described in Section 3.3.4.

Electronic transmission or collection of data for flow monitoring and rainfall gauging sites is desirable, where feasible and appropriate.

3.4.2 Data Summaries

Flow data summaries to be included in the flow evaluation report shall present the flow data and observed flow conditions supported by graphical and tabular presentations of flow, wet well level, velocity, and pressure in the context of the rain events. Each summary shall include the following information:

- Graphical representation of data

  A graphical time-series plot (hydrograph) of flow rate vs. time data, as well as associated recorded rainfall data, shall be presented for each specific flow monitoring method below.

  Additional data summaries for various flow-monitoring methods are suggested below:

  - Open Channel Flow Meters: Graphs (scatter graph) of flow depth versus velocity
  - Force Main Flow Meters: Graphs of flow rate and associated system pressure versus time
  - Volumetric Flow Calculation: Graphs of wet well levels and calculated flow rate
  - Alternate methodologies for flow measurement and hydrograph development: Verified pump and system curves

- Tabular data

A tabulation of daily average, maximum, minimum, and peak hour flow rate recorded during the flow-monitoring period shall be presented. The following data shall be tabulated for each specific flow metering method:

- Open Channel Flow Meters:
    - Time
    - Flow depth
    - Velocity
    - Flow rate
- Force Main Flow Meters:
    - Time
    - Flow rate
    - Pressure
    - Pump run status
- Volumetric Flow Calculation:
    - Time
    - Wet well levels
    - Pump run status
    - Pump run times
    - Flow rate calculation
    - Pressures, where available
- Alternate methodologies for flow measurement and hydrograph development:
    - Time
    - Wet well levels
    - Pump run status
    - Pump run times
    - Discharge pressure data
    - Flow rate calculation
    - Other data as necessary to verify the appropriateness of the approach and quality of the results

- Installation report. A summary of the installation details associated with each meter location, including a sketch of the manhole, wet well and/or force main configuration details and identifying related installation information.
- A rainfall analysis that estimates the rainfall recurrence interval for significant rainfall events.

3.4.3 Data Storage Format and Warehousing

The metered data shall be stored in an open data format that can easily be accessed in an ODBC (Open data base connectivity) compliant format.

Data for each meter should be uniquely identified and shall be distinguishable from the data from other meters. Further, the data shall be labeled and stored in a manner that will allow ease of site location identification and determination of the dates on which the data were collected.

3.4.4 Instrument Maintenance

Instrument operation shall be checked periodically. Problems with the instrument shall be corrected as soon as possible to sustain data collection at the highest level.

3.5 SEWER FLOW EVALUATION

The primary objectives of the flow evaluation are to characterize sewer flow under a range of hydrologic conditions, quantify peak flow for the purposes of identifying SSES Basins, and to develop the hydrographs needed to calibrate a hydraulic model. The sewer flow evaluation shall include quantification of base sewage flow, dry weather infiltration (DWI) and rainfall-derived inflow/infiltration (RDII) using the following procedure:

- Separate periods of dry and wet-weather flow with respect to rainfall data
- Establish a typical 24-hour, dry-weather sewer hydrograph
- Estimate DWI by determining average flow rate during off peak hours
- Extract RDII by subtracting the dry-weather flow hydrograph from the wet-weather hydrograph for the event or events of interest (Water Environment Research Foundation, *Using Flow Prediction Technologies to Control Sanitary Sewer Overflows*, 1999)

3.5.1 Data Analysis

The first step in determining the I/I reduction potential is to quantify the base sewage flow, the DWI and the RDII. This is done by compiling and reviewing of historical water consumption records and then comparing the results to the actual wastewater flow meter data collected as described previously. The following sections describe processes for determining each component of the total wastewater flow.

3.5.1.1 Base Sewage Flow

Water consumption data for the previous two (2) year period shall be used for the base sewage flow determination by assuming 100 percent of the metered water consumption is returned to the sanitary sewer system as sewage flow. Where a Locality has more accurate information to support application of a percentage return value to the water consumption data to estimate base sewerage flow, the data shall be used in the base sewage flow estimation. This may include application of flow return values to account for specific usages, such as irrigation, where specific usage was known to occur during the flow-monitoring period.

3.5.1.2 Dry Weather Average Daily Flow (ADF)

The flow at each flow-monitoring site shall be used as the basis for determining the dry weather average daily flow (ADF) for the metered areas and for estimating the dry weather infiltration entering the sewers. In determining the ADF, days with rainfall (and the following 3 days) are normally to be excluded from the analysis. Dry day flows shall be recorded at each monitoring site and averaged to determine the shape of the average diurnal curve for each metered area. A comparison of average daily flows is suggested to identify anomalies in flow patterns. The diurnal curve for each metered area represents the dry weather ADF and shall be used as input to the hydraulic analyses.

3.5.1.3 Dry Weather Infiltration (DWI)

Dry weather infiltration for each metered area shall be estimated by subtracting the base sewage flow from the ADF. Engineering judgment shall be applied in the estimation of DWI.

3.5.1.4 Rainfall Derived Infiltration/Inflow (RDII) Evaluation

Flows occurring during and after rainfall events that are higher than the dry weather diurnal curve represent potential RDII. The extraneous flow quantity is estimated by subtracting the measured average daily flow diurnal pattern from the wet weather hydrograph. After taking into account temporal and usage variations, the accumulated extraneous wet weather flow volume can then be estimated. The extraneous wet weather flow quantity (in gallons) for each monitoring site can be divided by the total rainfall accumulation (in gallons) over the metered area to calculate an RDII factor, expressed as a percentage of the total accumulated rainfall that entered the sanitary sewer system. This evaluation shall be carried out to characterize the volumetric contribution of rainfall to the system for each significant rainfall event captured by flow metering.

The RDII volume and/or RDII factor shall be used in the prioritization of SSES Basins as described in Section 5.2.1, Identification of Areas for Inspection.

In addition to estimating the volumetric contribution of rainfall to the sanitary sewer system flow, peak one (1) hour flow shall be observed in conjunction with each rainfall event. The peak one (1) hour flow is critical for identifying basins that will require SSES activities as described in Section 5.1.

The rainfall-derived infiltration can be graphically observed in the receding portion of the wet weather hydrograph. After the rainfall event has passed and the peak flow response has passed, the slower decline of flow back to normal dry weather conditions may be an indicator of the wet weather infiltration. Volumetric quantification of this flow in the system can help determine the volume of I/I entering the system.

EXAMPLE

In a sanitary sewer basin with a service area of approximately 320 acres there was a total rainfall accumulation of 3-inches (0.25 feet) over the area, resulting in extraneous flows that were measured over a 24-hour period. The event generated a total flow volume of 4.15 million gallons (MG) in 24-hours. The average daily dry weather flow in the service area is 150,000 gallons per day. The RDII factor is calculated as follows:

Formula:

The extraneous wet weather flow is calculated by subtracting the average daily dry weather flow volume from the total flow volume generated from the rainfall event. The average daily dry weather flow used should be from the same general time period as the rain event, but using data from a typical dry week.
= 4.15 MG – (150,000 gallon/day/1,000,000) = 4.0 MG

RDII Factor, % = 100 x (Measured volume of extraneous wet weather flow)/(volume of rainfall accumulated over the service area)

Volume of Rainfall (million gallons) = Rainfall accumulation (ft) x Basin Area (Acres) x 0.325 (conversion factor)

Solution:

Volume of Rainfall = 0.25 ft x 320 acres x 0.325 = 26.0 million gallons

RDII Factor = 100 x (4.0 million gallons / 26.0 million gallons) = **15.4%**

3.5.2 Flow Evaluation Report

A summary report shall be prepared documenting the: 1) flow monitoring activities performed; 2) flow monitoring data collected; 3) flow analyses conducted; 4) findings; and 5) conclusions. These flow evaluation reports shall be used to determine SSES basins and to prepare the SSES Plan for the sewer system.

The evaluation report shall include the following information:

- TITLE PAGE

    Project Title
    Locality Contact Information

- EXECUTIVE SUMMARY

- INTRODUCTION

- FLOW AND RAINFALL MONITORING METHODOLOGY & APPROACH

    Use of Existing Data
    Monitoring Site Selection
    Monitoring Equipment Used
    Data Collection Activities
    QA/QC Procedures

- MONITORED FLOW CHARACTERIZATION AND ASSESSMENT

    Data Analysis Overview
    Water Usage for Base Flow development
    Dry Weather Flow Analysis
    Dry Weather Infiltration Analysis
    RDII and Rainfall Analysis

- FINDINGS and CONCLUSIONS

    Discussions of Findings
    Areas Meeting SSES Criteria

- APPENDICES

    Field Data
    System monitoring location maps

SECTION 4 CONDITION ASSESSMENT OF SEWERS AND PUMP STATIONS

4.1 OBJECTIVE

Condition assessment of specific sanitary sewer system assets shall be conducted in order to develop a prioritized rehabilitation program that addresses deficiencies, which contribute to SSOs or decrease the existing capacity of the sanitary sewer system. If system assets are to be completely replaced under Section 7, Rehabilitation Plan, condition assessment shall not be necessary or may be deferred. This section provides guidance on development of condition assessment programs to be incorporated into SSES Plans per Section 5 based on the background data review, flow monitoring, and specific problems that are identified.

4.2 DATA NEEDS AND DATA MANAGMENT

The initial flow monitoring and system data review will give an indication of the field investigations that are necessary to further assess the condition of assets within SSES Basins. Condition assessment requires that certain data be collected to describe the facilities in the SSES Basins and their condition. Various investigation methods can be used to assess the infrastructure components and collect asset information. An example of the types of investigative activities that may be used to assess a range of issues is presented in Table 4-1. The matrix provides general guidance as to appropriate field investigations that may be used to assess the various infrastructure elements.

Data collected during the field investigations will indicate the existing condition of assets within SSES Basins. That information should be compiled in an Information Management System (IMS), such as a computerized maintenance management system (CMMS), if available. The collected information can be managed within the IMS and GIS systems to facilitate rehabilitation planning and execution. At a minimum, the data shall be stored in an open data format that can easily be accessed in an ODBC (Open data base connectivity) compliant format.

Table 4-1 Example Field Investigation Data Needs Matrix

	Records Review	CCTV Mainline	CCTV Lateral	Manhole Inspection	Smoke Testing	Dye Testing	Night Flow Isolation	Pressure Monitoring	Flow Monitoring	Ground Water Monitoring	Rainfall Gauging	Hydraulic Modelling	Pumping Test	Wet Well Inspection	Pump Run Time Assessment
SERVICE LATERALS – PUBLIC SIDE															
Capacity															
Evidence of I/I			●		●	●		●		●					
SSOs			●		●	●		●							
Surcharging			●					●							
Structural Condition															
Material Stability			●												
Age	●														
Maintenance															
Roots	●		●												
Grease	●		●												
MAINLINE SEWERS															
Capacity															
Evidence of I/I	●	●			●	●	●		●	●	●	●			
SSOs	●	●			●	●	●		●	●	●	●			
Surcharging	●	●				●			●	●	●	●			
Min Slopes or Grade Reversal	●	●													
Structural Condition															
Line Failure	●	●			●	●									
Sags		●													
Joint Misalignment		●			●	●									
Defect Rehabilitation	●	●			●	●									
Age	●	●			●										
Maintenance															
Roots		●													
Grease		●													
MANHOLES															
Capacity															
Evidence of I/I						●	●		●	●	●	●			
SSOs						●	●		●	●	●	●			
Surcharging						●			●	●	●	●			
Structural Condition															
Material Stability						●									
Age						●									
Maintenance															
Roots	●			●											
Grease	●			●											
FORCE MAINS															
Capacity															
Excessive System Pressure	●							●		●	●	●	●		●
Surcharging	●								●	●	●	●			
SSOs	●								●	●	●	●			
Structural Condition															
Air Vents	●														
Pipe Failures	●														
PUMP STATIONS															
Capacity															
Excessive Pump Runtimes	●								●	●	●	●	●		●
Surcharging	●								●	●	●	●		●	
SSOs	●								●	●	●	●		●	
Structural Condition															
Material Stability	●													●	
Age	●													●	
Operations															
Air Entrainment	●													●	

4.3 FIELD INVESTIGATION APPROACH

The objective of the field investigation is to provide an appropriate level of system information to support sound rehabilitation and/or replacement decisions, and identify I/I sources that require abatement.

Field investigations shall be conducted in a comprehensive or phased approach to identify deficiencies in SSES Basins. A phased approach may be used to progressively evaluate and screen SSES Basins. For example, if an SSES Basin has been so designated due to excessive pump run times, it may be beneficial to evaluate the pump station operating conditions prior to initiating a detailed investigation of the tributary gravity sewer system. Table 4-2 depicts an example of how a phased investigation approach may be planned.

Table 4-2 Example of Phased Field Investigation Approach

I Initial Field Reconnaissance & Records Review
- Manhole Checks
- Pump Station, Wet Well, and Force Main Evaluation
- Critical Location Inspection Determination

II Limited Field Inspection
- Manhole Inspections
- Smoke/Dye Testing
- Limited CCTV/Digital Imaging Inspection Associated with Dye Testing
- Night Flow Isolation

III Comprehensive Field Evaluation
- Comprehensive CCTV/Digital Imaging Inspection
- Comprehensive Manhole Inspections

IV Prompt Attention to Identified Severe System Deficiencies
- Find and Fix Level of Identification and Repair

Various types of investigations can be used to identify where rehabilitation or repair work should be performed and to determine the type and extent of rehabilitation. In SSES Basins that have known I/I problems or defects that have resulted in SSOs, a comprehensive condition assessment of the gravity sewer system may be initiated without the need for a phased approach. The field investigation techniques described herein may be undertaken as a comprehensive field evaluation or may be focused on a specific field activity where known problems exist. The field reconnaissance program should be based on the background data review, flow monitoring data, pump run time analysis, existing condition assessment and SSES reports, evaluation of SSO history, sewer service call history; and review of engineering and operations information.

4.4 PROCEDURES FOR ASSESSMENT ACTIVITIES

The following procedures for sanitary sewer assessment activities define available and consistent techniques to be used in field investigation. Performing these activities in a consistent manner will aid in the evaluation of data, and can provide a regionally common basis for condition assessment.

The following sections provide guidelines for conducting field investigation of sanitary sewer systems. Activities that may be implemented include:

- Gravity Sewers
  - Manhole Inspections
  - CCTV Inspections
  - Smoke Testing
  - Dye Testing
  - Night Flow Isolation
- Pump Station Inspection
- Force Main Assessment

4.4.1 Gravity Sewers

Gravity sewers shall be inspected for structural conditions, capacity problems and maintenance issues, which may negatively impact performance. Gravity sewer inspections shall include manhole inspections, CCTV inspections, smoke testing, dye testing, and night flow isolation, as appropriate.

4.4.1.1 Manhole Inspections

One of the most useful methods to determine sanitary sewer system condition is to perform and document inspections of manholes. Manholes have the potential to allow significant quantities of I/I into the sanitary sewer system (such as when manhole lids are lower than the surrounding surface and drain storm water when streets are flooded during wet weather). Manhole inspections can also provide indication of surcharged conditions in mainline sewers. Manhole inspections should be conducted to obtain information on manhole conditions and to observe sewer flow conditions, including indications of unacceptable surcharging. Manhole inspections shall be conducted in SSES Basins that potentially have I/I problems. Manhole inspections shall be conducted in accordance with NASSCO standards.

In conjunction with manhole inspection activities, manholes and cleanouts in areas subject to flooding, ponding, or submerged tidal conditions should be observed and noted. It should be noted if the cleanout is broken or if the manhole cover allows ponded water to enter the manhole.

A topside (or non-entry) manhole inspection should be conducted to determine overall structural condition of the manhole. The surrounding area should be observed and noted if the manhole is located in an area that is conducive to flooding over the top of the manhole.

Manholes found to be surcharged may need to be re-inspected during a lower flow period. If a topside manhole observation provides evidence of the manhole being a significant I/I source, an internal manhole observation (i.e., pole camera or manhole entry) should be made to specifically determine what defects exist in the manhole and its connecting pipes. This information should be used to determine what corrective measures will be needed to correct the observed deficiencies.

Each manhole shall be assigned a unique identifier. The manhole identifier will be used to identify each manhole where an inspection is performed. Information and condition ratings should be collected on the manhole cover, frame, adjustment rings, cone, steps, wall, bench and channel as well as connecting influent and effluent pipelines.

4.4.1.2 CCTV Inspections

CCTV inspection should be used to assess the condition of sewer lines by identifying structural problems, points of inflow and infiltration, capacity issues, and system blockages. The data collected should be compatible with and easily integrated by the Utilities' IMS. The CCTV inspection shall be conducted and recorded in accordance with NASSCO PACP© standards.

4.4.1.3 Smoke Testing

Smoke and/or dye testing should be conducted as part of the evaluations in areas that are suspected to have inflow problems. Limited CCTV inspections should be used in conjunction with smoke testing to verify the location of cross connections and inflow sources that are identified.

Smoke testing shall be carried out in conformance with widely used industry guidance such as EPA Handbook 625/6-91-030 "*Sewer System Infrastructure Analysis and Rehabilitation*" Section 4.3.6, and WEF Manual of Practice FD-6 "*Existing Sewer Evaluation and Rehabilitation*".

The entire section being tested should be visually inspected by walking along the route of sewer line watching for smoke leaks. The location of smoke leaks should be marked, noted, numbered and photographed. The photograph number corresponding to each leak should be noted. Cleanouts and failures that are observed to produce smoke should also be noted if they are in an area subject flooding.

4.4.1.4 Dye Testing

Dyed water testing may be used to verify connectivity, direction of flow, sources of I/I, as well as illicit connections to the system. Dye testing may be used to complement smoke testing to verify these sources.

Prior to dye testing, the line to be tested should be cleaned. The down stream manhole should be monitored to observe if dyed water passes through the system and the estimated quantity noted. If sufficient dye water passes through the downstream manhole, a CCTV inspection may be performed to identify the location and magnitude of the source of flow.

4.4.1.5 Night Flow Isolation

Nighttime flow isolations may be used to trace sources of infiltration. Night flow isolations may be used to locate and quantify the amount of infiltration entering a sewer system. Night flow isolations are typically performed to narrow down and identify reaches that have excessive infiltration that can be pinpointed for further investigations.

Night flow isolations typically are performed during low flow periods, between the hours of midnight and 6 AM. The flow measurement should be conducted with a weir structure that is suitable for the size pipe being isolated. The upstream reaches should be plugged, whenever flow conditions warrant, to provide a quantification of infiltration in each reach of line. When flow conditions do not allow for plugging, differential measurements should be used upstream and downstream for the section of pipe being investigated. Any known sewage flows that contribute flow normally under nighttime conditions in the line under investigation should be noted for the section of line under investigation.

4.4.2 Pump Stations

Pumping stations shall be inspected for structural conditions, capacity problems and maintenance issues, which may negatively impact performance. Typical maintenance issues include, but are not limited to:

- Grease: Grease buildup interferes with station operation by inhibiting the operation of level sensors.

- Impeller wear: Entry of sandy soil and grit into the wet wells by way of structural defects in the gravity sewers reduce effective wet well capacity and cause excessive impeller wear.

- Mechanical and electrical failures: Inadequate preventive maintenance increases the risk of mechanical and/or electrical failures.

- Excessive pump run times can be an indicator of capacity issues or equipment wear.

- Influent surcharge: Improper "pump on" set point or inlets constructed close to pump centerline can lead to influent pipeline surcharge.

- Wet-well surcharge, SSOs: System head on manifolded networks exceeds the pumping capability of the pumping station or influent flow that exceeds pumping capacity can lead to overflows and excessive pump runtimes.

Pumping station inspections and evaluations shall be conducted in a consistent manner. Visual inspections should be made of various features of the pumping station, and the results documented. Some of the key information that should be obtained during the inspection is outlined below.

Building Condition: Visually inspect the interior, exterior and roof of the building for physical or structural problems and record defects that may lead to SSOs.

Pumps and Motors: From the manufacturer's data plates and any up-to-date maintenance information, record the pump head in feet, the capacity in gallons per minute and the impeller diameter in inches for each pump. Record the horsepower and listed RPM for the motors. Observe the pumps and motors for vibrations, sounds, temperature and odor. The operating logs should be reviewed. The operations staff should be consulted to determine under what conditions and how long all pumps operate at the same time.

Wet Well: Inspect the wet well in a dewatered state to ensure a complete and proper visual inspection. Accumulation of debris, sediment and grease buildup should be removed when the wet well is drained for the inspection. The walls should be observed for coating condition, spalling or softness of concrete, erosion of concrete and the condition of bottom fillets.

Corrosion of Ancillary Equipment: While the wet well is in a dewatered state and after cleaning, inspect the ventilation system ducts and fans, access hatch, interior railing, access ladder and platforms, pump control system, pump rails, and interior piping for corrosion.

Dry Well: Inspect the dry well for structural conditions of concern.

Piping: Visually inspect the piping, valves (check, isolation, surge relief and air relief) and other fittings for corrosion, leakage, coating system condition, and proper operation.

Emergency Generator/Pump: Observe the generator/pump while running under load to verify its operation, noting excessive noise, dark exhaust, and ease of generator/pump starting. Test to ensure that the device will automatically start upon loss of power.

Air Entrainment: Air entrainment into the pumping system and force main can create hydrogen sulfide buildup and corrode system piping and appurtenances. This corrosion can lead to system failures and create SSOs. Air entrainment can also create a loss of capacity. Several activities can be performed to reduce the potential for air entrainment into the system. These include:

- Minimum wet well levels should be set to a point where pumps do not entrain air.
- Pump packing and stuffing box should be adjusted so air is not entering the pump.
- Piping including inlet, bleed-off, sump pump piping and relief flows should be plumbed to avoid cascading into the wet well causing excess agitation.
- Screening systems that catch debris should be inspected and cleaned regularly to ensure that excess build up does not create cascading of wastewater into the wet well.
- Air bubbler lines should be located away from pump inlets.
- Wet well mixer level settings should be verified to confirm that they are below the low water level and that they do not create vortexes.

- Air release valves should be inspected and maintained to ensure proper operation.

Pump stations and force main systems should be routinely inspected to make sure these potential sources of air are minimized to avoid excessive air entrainment. Corrections required to avoid these conditions should be noted and prioritized.

Pump Draw-Down Tests. Pump draw down tests provide a simple, accurate, and direct method to measure total pumping rate. Pump drawdown tests are conducted by measuring the volumetric change in the wet-well due to pump action. The test often requires temporary flow measurement on the influent sewer to account for the effects of incoming flow. This step may not be necessary if the wet-well can be isolated.

4.4.3 Force Main Condition Assessment

Force main routes, air vents, and aerial line crossings of streams and ditches shall be inspected for signs of leakage or failures. Aerial crossings shall also be visually inspected for debris accumulation, erosion of soil around pipe and supports, and structural support condition.

Force main condition assessments shall be conducted if a review of existing information indicates a history of failures. Force mains should be evaluated based on pipe material, age, reported condition, and occurrence of SSOs. Inspections should include air vents, mainline valves, aerial crossings and other key ancillary items.

4.4.4 Vacuum System

Several vacuum systems exist within the regional sanitary sewer system. Generally vacuum systems do not pose a major source of I/I unless illicit connections are made at the service tap. Because the system is constantly under negative pressure, failures are usually realized when a loss of vacuum occurs. Vacuum systems will be excluded unless there are unresolved overflows.

4.5 ASSESSMENT STANDARDS FOR GRAVITY SEWER SYSTEM

4.5.1 National Association of Sewer Service Companies (NASSCO)

In an effort to standardize sewer pipe defect coding and ratings in the United States, NASSCO has developed industry-accepted standards. NASSCO has also developed rating standards for manhole and lateral defects as well. The following programs have been developed by NASSCO:

- A standard coding system
- A training and certification program
- Standardized data format
- A certification for data collection software vendors
- Mapping symbology standards

- A standard condition rating system

All defect coding and condition assessment shall be based on NASSCO standards to provide consistency.

4.5.1.1 Pipeline Assessment Certification Program (PACP)

The PACP establishes standards for the assessment of sewer mains using information obtained through CCTV inspections. This standard will be used to assess, evaluate and categorize gravity mains within the sanitary sewer systems.

4.5.1.2 Manhole Assessment Certification Program (MACP)

The MACP uses the established defect coding system found in the PACP and incorporates many of the American Society of Civil Engineers (ASCE) manhole standards as well. The MACP standard will be used to assess, evaluate and categorize manholes within the sanitary sewer systems.

4.5.1.3 Lateral Assessment Certification Program (LACP)

The LACP uses the same defect coding system found in the PACP because of the similarities between main line systems and laterals. This standard will be used to assess, evaluate and categorize lateral systems within the sanitary sewer systems.

4.6 FIND AND FIX GUIDELINES

4.6.1 Conditions to Warrant Prompt Repairs

Certain asset conditions will warrant prompt corrective action when found during the course of the SSES work. Defects that pose an imminent risk of failure and warrant prompt repair under a Find-and-Fix approach may include, but are not limited to, partially collapsed pipe, pipe with holes (missing sections), pipe with extensive exposed rebar (concrete), joints that are displaced more than 10% of the pipe diameter, and pipe with displaced bricks, where such defects are determined to:

- Pose an immediate threat to the environment
- Pose an imminent threat to the health and safety of the public
- Create operational problems that may result in SSOs
- Contribute substantial inflow to the system

These assets may be operable at the time of discovery but could have potential for severe consequences and a high likelihood of failure.

4.6.2 Procedure

Conditions that warrant prompt repairs shall be considered under a "Find and Fix" rehabilitation approach. The Find and Fix methodology employs the concept that when failures or deficiencies are found, actions are taken to correct the problem either by internal maintenance personnel or an on-call contractor. Either should be capable of assessing the need for repair and of performing the repairs according to acceptable industry standards.

The Find and Fix concept provides a process by which system repairs can be made in a more timely fashion. Table 4-3 depicts the typical steps in a Find-and-Fix approach. Comparison to the traditional design-bid-build approach is shown to demonstrate differences in the approaches that may result in time and cost savings.

Table 4-3 Typical Find-and Fix Rehabilitation Steps

Sequence of Activities	Traditional Approach	Find and Fix Approach
Procurement	■ Procure Engineer and/or Field Investigation contractor	■ Procure contractors for on-call services
Field Investigation and Decision-Making	■ Review available information ■ Perform sewer condition assessment ■ Prepare study report	■ Review available information ■ Perform sewer condition assessment ■ Prepare rehabilitation justification and work orders
Planning and Engineering	■ Develop Capital Improvement Plan (CIP) projects and budgets ■ Prioritize projects ■ Perform engineering and create plans and specifications	■ Utilize standards specifications to conduct work
Rehabilitation Construction	■ Procure contractor(s) ■ Perform rehabilitation ■ Document and monitor results	■ Perform additional conditional assessment and rehabilitation ■ Document and monitor results

The types of repairs that are practical for Find and Fix programs include:

- Manhole reconstruction
- Pipeline reconstruction
- Point repairs and section liners
- Cured-in-place lining, slip lining and pipe bursting
- Manhole lining

4.6.3 Removal of Illicit Connections

Illicit connections that contribute substantial inflow to the sanitary sewer system warrant prompt corrective action when discovered. Illicit connections that are identified with the publicly owned portions of the sanitary sewer system shall be eliminated through a Find and Fix rehabilitation approach, where practical. Such connections may include storm drains and area drains that are directly connected to the sanitary sewer.

4.7 PRIVATE SOURCES OF I/I

Private property I/I sources may include roof drains, area and foundation drains, defective laterals, and private sewers. HRSD and the Localities shall develop and implement a Private Property I/I Abatement Program. The Private Property I/I Abatement Program will require, to the extent allowed by law, the correction of identified private system deficiencies.

4.8 CONDITION ASSESSMENT DOCUMENTATION

Upon completion of the field investigations, documentation shall be prepared that references the field procedures used and presents the investigation results, alternative analyses, findings, conclusions, and recommendations. These documents will be used to prepare the rehabilitation plan as described in Section 7. The documentation shall include the following minimum content:

- TITLE PAGE

  Project Title
  Locality Contact Information
  Vicinity Map

- TABLE OF CONTENTS

- INTRODUCTION

  Purpose
  Scope
  Background
  Vicinity Map

- METHODOLOGY AND INVESTIGATIVE APPROACH

- EXISTING FACILITY EVALUATION

  Inventory of Sanitary Sewer System
  Pumping Station Inspection
  Condition Assessment Evaluation

Field Investigation Results

- Manhole Inspections
- CCTV Inspections
- Smoke Testing
- Dye Testing
- Night Flow Isolations

• FINDINGS, CONCLUSIONS & RECOMMENDATION

• APPENDICES

Field Data (Compiled Raw & Analyzed)
System overview and detailed maps, for all project types

Note: This format is a general guideline to be used by in sewer basin investigations.

SECTION 5 SSES PLANNING

An SSES Plan shall be developed considering the results of sewer flow monitoring and other relevant information, including the SSO characterization analyses. The plan shall identify SSES Basins; the activities to be performed in those basins; and a schedule for conducting the SSES work. SSES Basins shall be selected based on the criteria presented in Section 5.1 in conjunction with utility personnel knowledge of the system.

5.1 SSES BASIN CRITERIA

Sewer basins that are known or suspected of meeting the following criteria shall be included in the SSES Plan:

- Basins with unresolved wet-weather SSOs, except where SSOs have only resulted during rainfall conditions in excess of a 10 year, 24 hour rainfall recurrence interval
- Basins with unresolved SSOs caused by infrastructure defects (pipe sags, offset joints, broken pipe, etc.)
- Basins exceeding an actual peak flow of 775 gallons per day per equivalent residential unit plus 3 times commercial water consumption plus actual major industrial flows, where this peak flow is estimated to occur during rainfall conditions up to a 10-year, 24 hour rainfall recurrence interval
- Basins served by pump stations that exhibit excessive pump run time

Because some sewers are considered less critical and the probability of wet weather SSOs are small, the following basin and system types may be excluded from SSES activities where appropriate, unless there have been preventable SSOs in the system:

- Vacuum systems
- Basins associated with small pump stations (25 gpm or less pumping rate at design pressure)
- Low pressure force main systems where the agency maintains the force main, but all contributing pump stations are privately owned

5.2 SSES PLAN DEVELOPMENT

An SSES Plan shall be developed to meet the following objectives:

- Identify and prioritize basins for investigation
- Establish baseline estimates of I/I
- Select the detailed approach to provide sufficient information for condition

assessment activities including hydraulic, corrosion and structural investigation
- Coordinate improvements to records and mapping that may be needed
- Establish a schedule of activities

Prioritization of basins for investigation may be based on the following:

- An initial estimate of potential volume of I/I reduction in each basin (i.e., gallons per day)
- The number and severity of SSOs that occur within the basins
- Historical information about the system such as number of repairs and operation and maintenance history (including pump stations and force mains)

The typical approach to detailed investigations is to perform preliminary evaluations as a basis for ascertaining the need for further detailed field investigations. For example, when the case can be clearly identified for replacement of certain reaches of sewer mains based on initial field reconnaissance, supplemental field investigations may not be cost effective or necessary. Conversely, there may be cases where the cost of further detailed investigations can potentially result in project cost savings through better defining the required scope of upgrade work.

Information from the field investigations is used to evaluate sanitary sewer system conditions. Field investigations to be used in the SSES are detailed in Section 4, and generally include:

- Gravity Sewers
  - Manhole Inspections
  - CCTV Inspections
  - Smoke Testing
  - Dye Testing
  - Night Flow Isolation
- Pump Station Inspection
- Force Main Assessment

A minimum investigative program in all SSES Basins shall include pump station evaluation, manhole checks, and determination of critical inspection areas. At a minimum, SSES Basins that exhibit wet weather flows in excess of the peak flow threshold shall be evaluated using smoke testing, and all gravity sewer locations that have identified unresolved dry weather overflows shall be investigated with CCTV.

5.2.1 Identification of Areas for Inspection

SSES Basins shall be selected based on the criteria established in Section 5.1 and best available information about the system. These areas need to be uniquely identifiable to track SSES activities and for ease of reference.

Each basin shall be inventoried to identify the specific facilities that will be investigated and scope of the investigation. Verification of system connectivity will also be necessary to trace sources of I/I. This shall include mapping of:

- Pipelines
- Manholes
- Pump Stations
- Pumps
- Force Mains
- Valves
- Air Release Valves
- Flow Control Structures
- Stream or Aerial Crossing
- Siphons

Once the areas are identified for SSES activities, priority should be given to the basins based on at least five (5) criteria. The criteria may be weighted based on relative factors of importance and criticality. Each criterion should have an established weighting and ranking system. The prioritization and ranking used by one Locality may not necessarily be appropriate for prioritization and ranking used in another Locality. SSOs and conditions leading to environmental, public health, or safety risks will be given the highest priority, regardless of the weighting factors that may be applied. The minimum criteria to be considered shall include:

- Number and severity of preventable SSOs
- I/I volume
- Peak one hour flow
- Operations and maintenance history
- Sewer basin criticality factors

An example of the use of a ranking scheme to prioritize basins for SSES activities is offered below. This example is for illustration of applying prioritization criteria. Individual localities may apply weighting criteria differently and/or may add additional criteria. In any case, the SSES Plan should establish a prioritization system that uses the above criteria as a minimum. This prioritization only impacts the sequence of SSES activities to be conducted. All SSES Basins shall be investigated within the overall timeframe set forth in these Standards.

EXAMPLE

In a sanitary sewer system "A" having 55 basins identified for SSES, the following ranking was given to a particular basin relative to the other basins. This is assuming 1st ranked is the highest priority and 55th ranked is the lowest priority of the 55 basins.

Ranking was determined as follows:

- Number of SSOs — 30 points
- Peak one hour flow — 30 points
- I/I volume — 20 points
- O/M history — 10 points
- Sewer basin criticality — 10 points

Total available Points: 100 points

Formula:

Parameter Weighted Ranking = ((Number of Basins +1) – Basin Rank for this Parameter) / Number of Basins x Number of Points for the Parameter

Basin 1			
I/I volume:	12th	((56 – 12)/55) x 20 points =	16.0
Peak hour flow:	1st	((56 – 1)/55) x 30 points =	30.0
The number of SSOs:	10th	((56 – 10)/55) x 30 points =	25.1
O/M history:	20th	((56 – 20)/55) x 10 points =	6.5
Basin criticality	30th	((56 – 30)/55) x 10 points =	4.7
		Basin 1 Total Points =	82.3

Basin 2			
I/I volume:	15th	((56 – 15)/55) x 20 points =	14.9
Peak hour flow:	8th	((56 – 8)/55) x 30 points =	26.2
The number of SSOs:	5th	((56 – 5)/55) x 30 points =	25.1
O/M history:	4th	((56 – 4)/55) x 10 points =	9.5
Basin criticality	40th	((56 – 40)/55) x 10 points =	2.9
		Basin 2 Total Points =	78.6

Therefore Basin 1 has a higher priority for SSES than Basin 2.

5.2.2 Implementation Schedule

All work related to the SSES Plan shall be completed prior to the submittal of the Rehabilitation Plan described in Section 7. A detailed schedule for conducting the SSES work shall be established in the SSES Plan, which shall be reviewed and approved by DEQ.

In general, the sequence of activities is as follows:

- Review of Existing Information to Characterize SSOs and Identify Data Gaps
- Flow Monitoring Program Development and Implementation
- Development and Submittal of the SSES Plan
- Execution of the SSES Plan
- Prompt Attention to Severe Defects
- Rehabilitation Planning
- Hydraulic Performance Assessment
- Preparation of the Regional Wet Weather Management Plan

A specific schedule outlining the activities to be conducted shall be established for inclusion in the SSES Plan. The schedule shall include the following milestones:

- Completion of Flow Evaluation Reports within 20 months of the effective date of the Order

- Completion of SSES Field Activities within 50 months of the effective date of the Order. Notification that field activities have been completed shall be submitted to DEQ within one month following completion of the work.

SECTION 6 HYDRAULIC PERFORMANCE ASSESSMENT

6.1 USE OF HYDRAULIC MODELS

Calibrated hydraulic model(s) of the Regional Sanitary Sewer System shall be used to support the following objectives:

- Assessment of the regional sanitary sewer system performance with respect to capacity
- Development of the Regional Wet Weather Management Plan, including:
  - Alternatives analysis
  - Operational scenario testing
- Design testing and optimization

6.1.1 Capacity Assessment

A capacity assessment shall be conducted to estimate the performance of the existing Regional Sanitary Sewer System under conditions of interest. The hydraulic model shall be used to perform the capacity assessment, and shall include the following minimum conditions of interest:

- Baseline dry weather flows, current conditions and 2030 population
- 2-year peak flow recurrence, current conditions and 2030 population
- 5-year peak flow recurrence, current conditions and 2030 population
- 10-year peak flow recurrence, current conditions and 2030 population

Current conditions refer to the state of the regional sewer system at the time of model development, inclusive of any sanitary sewer system construction projects that are currently underway at the time of the model development. Near term projects will be included in the "current conditions" where prudent and will be decided on a case-by-case basis.

The use of the model allows estimation of performance under conditions that may not have been observed and/or documented in the system. The capacity assessment shall be conducted within the extent of the hydraulic model as defined in Section 6.4. The capacity assessment shall:

- Identify pumping stations that do not have adequate capacity to convey the peak flow under the above defined conditions
- Determine the probable cause of identified pumping station capacity limitations
- Evaluate causes of known unresolved capacity related overflows
- Predict locations and extent of potential SSOs

- Predict locations and extent of potential sanitary sewer system surcharges that may result in SSOs or impaired system performance

6.1.2 Regional Wet Weather Management Plan

The regional hydraulic model shall be used to analyze capital and operating alternatives to improve system performance and address capacity limitations in the regional sanitary sewer system. The Regional Wet Weather Management Plan shall be developed in accordance with the guidelines established in Section 8.

6.1.2.1 Alternatives Analysis. The hydraulic model will be used as a tool for evaluating capacity enhancement projects, including conducting the following activities:

- Estimating the impacts of I/I reduction projects, assuming the effectiveness of rehabilitation in reducing peak flows
- Evaluating capital improvements which increase the capacity of the sanitary sewer system, including pipe replacements, pumping station capacity improvements, and flow equalization facilities
- Quantifying the effectiveness and estimated system performance for each alternative or groups of alternatives

6.1.2.2 Operational Scenario Testing. Areas of the sanitary sewer system with operational flexibility shall be managed to optimize wet-weather performance. The Regional Wet Weather Management Plan shall include short and long term operating plans to maximize available capacity in the system through effective and proactive operations. This may require diversion of wastewater flow to alternate downstream facilities (i.e. pumping stations, interceptors or wastewater treatment plants) or activation of flow equalization/attenuation facilities. These operational scenarios shall be tested and optimized using the hydraulic model under a variety of flow conditions.

6.2 MODEL DEVELOPMENT PROCESS

The steps in the model development process are:

- Data collection
- Model building
- Calibration
- Verification
- Model use
- Documentation

Guidelines and requirements for each of these activities are included in this section. Although documentation is depicted as the last step in this process, good record-keeping practices should be followed throughout the model development to facilitate documentation.

6.2.1 Model Requirements

The Regional Hydraulic Model shall possess the following capabilities:

- Fully dynamic hydraulic solution (i.e. model time-varying flows and depths representing the true nature of flow attenuation and translation)
- Minimal volume balance errors and numerical instabilities
- Model both gravity (i.e., open channel) and pressurized flows, simultaneously including the measurement of negative pressures and siphons
- Stable and robust solution for transitions between gravity and pressurized flows
- Stable pump controls including pump curves, switch on/off controls, variable speed pumps and real time control capabilities
- Model surcharged manholes with either storage of surcharged volume out of manhole lids and/or flow depth in excess of manhole depth predicted to overflow the manholes
- Capable of accepting diurnal curves and hydrographs as flow input

Locality models, as described in Section 6.2.4, shall use hydraulic analysis solutions that possess at a minimum, the ability to:

- Model both open channel and pressurized flows, simultaneously
- Predict locations of potential excess surcharge or overflows

6.2.2 Regional Model Development Process

Development of the Regional Hydraulic Model shall be a coordinated effort between HRSD and the Hampton Roads Localities. HRSD shall maintain the Regional Hydraulic Model. The Localities shall coordinate with HRSD to provide the necessary pumping station and pipeline information, as defined in Section 6.3, to construct the Regional Hydraulic Model. The Localities shall also provide HRSD with sewer flow hydrographs for the conditions indicated in Section 6.1.1 as inputs to the Regional Hydraulic Model.

It is recognized that model calibration may require the adjustment of input hydrographs provided by the Localities. HRSD and the Localities shall coordinate model development efforts to create a calibrated hydraulic model based on input data common and agreeable by both parties.

6.2.3 Physical Extent of Regional Hydraulic Model

The Regional Hydraulic Model shall be developed to the extent necessary to assess the performance of the system relative to capacity, and to develop the Regional Wet Weather Management Plan. At a minimum, the Regional Hydraulic Model shall include:

- All HRSD pipes, HRSD pumping stations, and HRSD pressure reducing stations, in the regional sanitary sewer system.
- Locality pumping stations and force mains that directly discharge into a HRSD interceptor sewer
- The gravity sewers extending one manhole upstream from each Locality pumping station that directly discharges to a HRSD interceptor sewer (Note that some pumping stations may receive discharge from multiple sewers; in theses instances, the first upstream manhole on each line will be included)
- Locality gravity sewers extending one manhole upstream from the point of connection to an HRSD gravity interceptor

6.2.4 Locality Model Development Process

The Locality shall develop and maintain models of the sanitary sewer system upstream of the Regional Hydraulic Model. The Localities models shall include sewers and related facilities extending from any pumping station or gravity sewer in the Regional Hydraulic Model up to the location where any unresolved capacity related overflows are known to have occurred or suspected to occur based on review of pump station or other background data. The downstream boundary conditions of the Localities' models will be provided by HRSD based on the results of the Regional Hydraulic Model.

6.3 DATA COLLECTION

The following data are beneficial for the development, calibration and use of hydraulic models:

- Physical system data
- Population, demographic, and land use data
- Geographic information system (GIS) data
- Water use records
- Rainfall records
- Sewer flow monitoring records
- Operational information
- Force main pressure records

6.3.1 Physical System Data

Physical system data is information needed to describe the physical components of the sanitary sewer system such as gravity sewers, pumping stations, force mains, manholes, and other system features in the hydraulic models. These data are used to develop representative system elements in a hydraulic model.

Sources for this information include GIS, record drawings, sewer system maps, sewer survey data, and sewer inspection records (e.g. condition information). A review shall be conducted of collected data to ensure that the physical system data are of sufficient detail and are up to date. Data of questionable reliability shall be field verified, where appropriate.

6.3.1.1 Pipe Data. The following data pertaining to pipes shall be used in the development of the hydraulic model:

- Network connectivity (i.e., the pipe data record must include unique identification numbers for manholes or other structures at both ends of the pipe)
- Pipe size (nominal diameter)
- Length between manholes and/or junction structures and pumping stations
- Invert elevations (upstream and downstream)
- Material
- Pipe condition
- Force main or gravity sewer

The selection of a pipe roughness coefficient shall be made following an evaluation of the pipe diameter, material, and condition using engineering judgment. Appropriate coefficients from industry recognized sources shall be used for modeling. Consideration shall also be given to pipe roughness conditions where known heavy silt, debris, or slimes are found in the system. In the absence of pipe material or condition information, engineering judgment shall be used for the selection of an appropriate roughness coefficient.

6.3.1.2 Manholes and Junction Structures. Manholes and junction structures are structures that connect segments of pipe in the system. The following data shall be used in the development of the hydraulic model:

- Manhole ID
- Diameter/size
- Locations
- Invert elevation
- Rim elevation
- Ground elevation
- Sealed or unsealed lid
- Manhole inserts or similar devices

Head losses present at the entry and exit locations of manholes shall be included in the pipe data. Trunk and interceptor manholes having significant bends (i.e. > 45 degrees) should be considered for increasing the head loss coefficients based on the local hydraulic characteristics.

6.3.1.3 Pumping Stations. The following information shall be used in the development of the hydraulic model:

- Wet-well physical attributes (i.e. dimensions)
- Pumping capacity (i.e. pump performance curves, draw down test results)
- Number of pumps
- Type of drive (i.e. Variable speed or constant speed pumps)
- Control logic (i.e. wet well elevations at which each pump turns on and/or reaches full speed, and turns off)
- Piping details
- Flow equalization/storage physical attributes and control strategy (in-line or off-line storage)
- Bypass pump information, if such pumps were used during the flow monitoring period used for calibration

It is important to accurately represent the physical attributes of the pumping station and to program the model with the same control logic used to operate the station. Control logic includes triggers for turning the pumps on or off and/or for changing the pump speed when variable speed pumps are used. Pumping stations equipped with off-line flow equalization structures require additional data regarding the dimensions and elevations of storage, as well as the control logic and facilities that divert flow to, and return flow from, storage.

6.3.1.4 Other Boundary Conditions. Other boundary conditions that shall be considered include:

- Wastewater treatment plant (WWTP) headworks characteristics
- Weirs
- Pumping station records including flow, discharge pressure and wet well elevation
- Pressure reducing stations
- Other flow controls such as high pipes in manholes
- Control gates
- Siphons
- Downstream discharge conditions

The headworks conditions of a WWTP are particularly important to quantify. Since many models terminate at a WWTP, the headworks establish the outlet condition for the model. The headworks may include pumping equipment and associated controls similar to a pumping station. Careful consideration should be given to how this type of outfall condition is developed in the model to provide an accurate representation of field conditions.

If present, weirs within the sanitary sewer system provide a method for controlling flow within the sanitary sewer system. Generally, weirs are located in manholes that join pipes between parallel sewers. These devices may not be conspicuous on sewer system maps or record drawings. When preparing a model, the modeler shall carefully examine all available records to identify the locations of weirs and connections between systems, such as short pieces of pipes between nearby manholes, which serve a similar purpose to weirs.

Inverted siphons present the situation where the flow depth is affected by the construction details of the structure. The elevations and sizes of all barrels of the siphon must be known for an accurate simulation. If flow to multiple barrels is controlled by weirs, the elevation of the weir crests must be known.

6.3.2 Population, Demographic, and Land Use Data

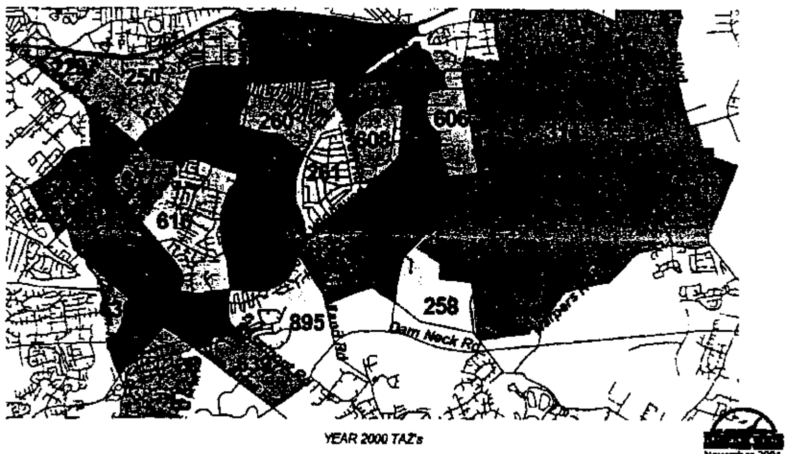
Population data are used to estimate existing and future sewer baseflows. These data are available from a number of sources, including:

- Transportation Analysis Zones (TAZ)
- Census data
- Land Use Planning and Zoning
- Parcel data

TAZ data shall be used as the primary source for population data. In situations where the study area is too small to effectively use these data, as discussed in this section, engineering judgment shall be used in conjunction with other population data sources to derive appropriate population data. TAZ data will not necessarily be used as the basis for final design of system improvements.

6.3.2.1 Transportation Analysis Zones (TAZ). The region is sub-divided into multiple TAZs. For example, the current TAZ mapping for the Holland-Oceana area of Virginia Beach is shown on Figure 6-1. Population and employment data are assigned to each TAZ. This information is disaggregated into multiple population categories such as residential, commercial, institutional (e.g. schools), and manufacturing.

Figure 6-1. Transportation Analysis Zones for the Holland-Oceana Area of Virginia Beach



Demographic data for each TAZ includes population projections for various horizon years (2010, 2020, etc). The most recent TAZ data includes population projections through the year 2030. TAZ data are developed and maintained by the Hampton Roads Planning District Commission (HRPDC).

In instances where modeling of areas smaller than those of TAZ areas are necessary, other, more granular data and engineering judgment shall be used to develop population estimates and projections. This data shall be verified for consistency with the TAZ population data.

6.3.2.2 Census Data. Detailed population data may be obtained (in GIS format) for census tracts and blocks that may provide finer coverage than TAZ data. These data are available for each Locality through the United States Census Bureau. These data do not generally provide a convenient breakdown of population into categories (i.e. residential, employment, industrial) or population projections. However, these data do provide spatial, baseline population data that may be used in conjunction with other data sources to estimate current and future populations.

6.3.2.3 Land Use Plans and Zoning. Land Use and Zoning Plans are maintained by the Localities to guide growth and development. These plans generally include future land use, which indicates the adopted zoning districts, and land uses for current and future development.

6.3.2.4 Parcel Data. Parcels refer to individual pieces of property. Where available in GIS format, parcel mapping is organized spatially and contains information regarding the land use of the specific property.

Parcel data may be used for developing highly detailed models of small areas, beyond the granularity available from other population data sources. These data provide spatial, baseline population data that may be used in conjunction with other data sources to estimate current and future populations.

6.3.3 Geographic Information System (GIS) Data

Readily available GIS data shall be used to support the data capture effort during the model building process. Specific uses of GIS include delineating sub-catchments, validating ground elevations, and identifying areas of flooding. Information of this type may include:

- Topographic mapping/digital terrain model
- Stream and hydrologic mapping
- Flood maps
- Sewer system maps (service areas, connectivity, accounts/billing information)
- Parcel information
- Land use information

This information is available from multiple sources including sewer system mapping, FEMA flood maps, and topographic maps that are maintained by various Localities.

6.3.4 Water Use Records

Water use data shall be used if available to validate baseflows calculated using population data. Water use data are recorded for each Locality's customer. It is possible to geocode the water consumption data based on the address of a meter to spatially distribute the water usage.

6.3.5 Rainfall Records

Rainfall data shall be used to estimate rainfall derived inflow and infiltration (RDII). Rain gauge data are available from both the U. S. Geographical Survey and efforts undertaken during the flow-monitoring phase. Hydraulic modeling generally requires rainfall data having a resolution of 1-hour or less. All data shall be reviewed for quality issues such as periods of missing data, or data from a defective rain gauge, before being used in hydraulic modeling.

Rainfall data are required that coincide spatially and temporally with the sewer flow data used to develop the model, as described in Section 3.3.5.

6.3.6 Sewer Flow Monitoring Records

Flow monitoring provides sewer flow data under known conditions. This information is used during model calibration, testing, and validation.

Flow monitoring data may be available from:

- Permanent flow monitors
- Temporary flow monitors
- Sewer system evaluation studies (SSES)
- Post sewer rehabilitation studies
- Wastewater treatment plant records
- Pumping station records including flow, discharge pressure and wet well elevation

Flow monitoring data collected in accordance with this Attachment shall meet the requirements presented in Section 3.3. The following locations shall be considered in the development of the flow-monitoring program:

- Sanitary sewer system outlet points
- Mid-points of large or complex sewer basins
- Branch sewers near the junction with a larger sewer where flow from the branch sewer is of concern
- Major sewers near the confluence of branch sewers
- Areas experiencing performance problems where modeling accuracy of such areas is important
- Specific points of concern such as siphons or weirs, where modeling accuracy of such points is important
- Points where ownership of sewer lines changes between HRSD and Localities

A series of data management activities are required to process and validate the flow, depth, velocity, and reaction to rainfall. These following activities support the model's calibration and validation:

- Preparation of a GIS layer, or alternative map, depicting flow meter locations
- Identification of the appropriate model node for each flow meter
- Conversion of the observed flow data into the model's flow data format

6.3.7 Operational Information

Operational records provide important qualitative and quantitative data about the performance of a sewer system. These data shall be considered for use during calibration to fine tune the model. The primary sources for these data are interviews with operation staff, SSO databases and maintenance logs. This data may also include records of pumping station discharge pressures. Operational criteria to consider include changes in system operation such as pump replacement, weir adjustments, surcharge, SSO volume, and frequency.

6.4 MODEL DEVELOPMENT

Model building is the construction of a hydraulic model using collected data. This process includes:

- Physical data entry
- Sub-basin delineation
- Baseflow estimation
- Rainfall derived inflow and infiltration (RDII) generation

6.4.1 Physical Data Entry

The data describing the collection system geometry will form the attributes and boundaries of the model. These data may be entered directly from GIS or from other database formats. Regardless of the data source, care shall be taken to ensure that the network connectivity and attributes are correctly represented in the model.

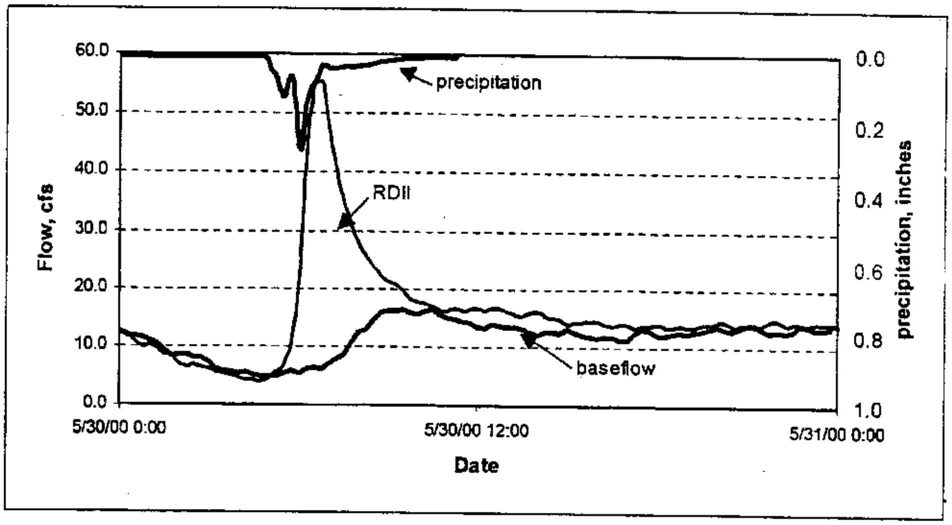
6.4.2 Sub-basin Delineation and Flow Assignment

Sub-basin delineation is the determination of tributary areas to various key points within the collection system. Flow assignment is the correlation of the flow from a tributary area to a specific node within the system. Sub-basins shall be delineated using a combination of sewer maps and topographic maps. Flow from tributary areas shall be assigned in a manner that represents the sewer systems characteristics.

6.4.3 Components of Flow

Sewer flow consists of baseflow and rainfall derived inflow and infiltration (RDII), as shown on Figure 6-2.

Figure 6-2. Components of Sewer Flow



6.4.3.1 Baseflow. Baseflow, also referred to as dry-weather flow, consists of domestic sewage flow and dry-weather infiltration. Domestic sewage flow is the sewage produced by individuals and businesses connected to the collection system. These flows shall be predicted based on population and per capita unit flow rates. DWI results from defects in the sanitary sewer system that are located below the water table that allow groundwater to enter the system.

DWI should normally be accounted for by applying a constant DWI rate above the population based domestic sewage flow.

6.4.3.2 Rainfall Derived Inflow and Infiltration (RDII). RDII is the component of total wastewater flow resulting from rainwater entering the sewer system.

RDII is generally a substantial portion of the total sewer flow that occurs during wet-weather. In many cases, particularly in older sewers, RDII may be the largest component of wet-weather flow. RDII varies with rainfall volume, rainfall intensity, antecedent moisture conditions, the condition of the collection system, and other factors, including storm driven tidal effects. The constituents of RDII are inflow and infiltration.

6.4.3.3 Separation of Base Flow and RDII. Total observed sewer flow shall be separated into baseflow and RDII using the following procedure:

- Separate periods of dry and wet-weather flow with respect to rainfall data
- Establish a typical 24-hour, dry-weather sewer hydrograph
- RDII is extracted by subtracting the dry-weather flow hydrograph from the wet-weather hydrograph for the event or events of interest

6.4.4 Baseflow Estimates and Projections

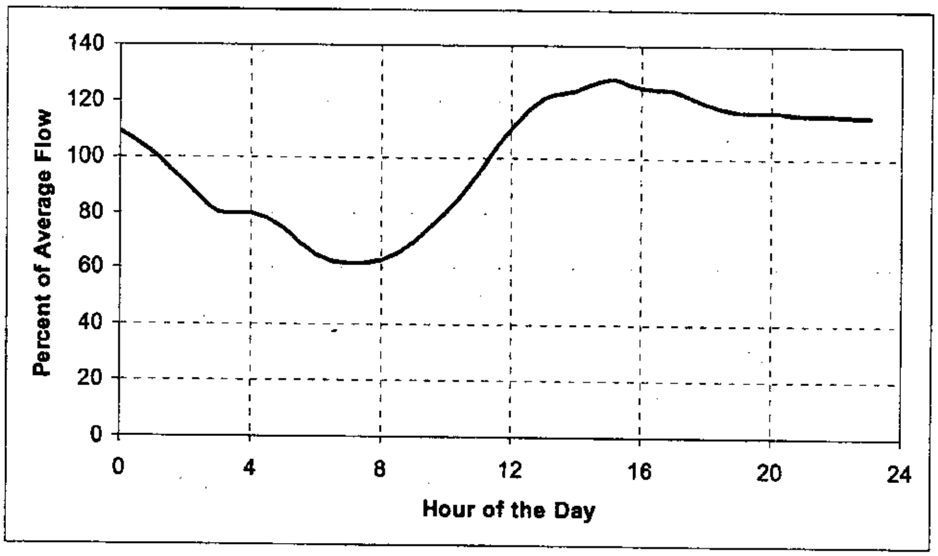
Baseflows are estimated by applying unit flow rates to population data plus the addition of DWI using the technique presented in Section 6.4.3.1.

Variability exists in all unit flow rates. Industrial unit flow rates, in particular, tend to have the greatest variation due to the volume of process water used in production, production schedule, and production methods. In the absence of industry specific information, consideration should be given to using flow monitoring to determine a suitable value based on engineering judgment.

It may be necessary during model calibration and testing to adjust the unit flow rates to match the observed baseflow.

6.4.4.1 Variations in Baseflow. Baseflow may vary daily, weekly, or seasonally. Daily variations in baseflow shall be accounted for using diurnal curves. Diurnal curves shall be normalized based on average daily dry-weather flow to produce a unit diurnal curve. Unit diurnal curves shall be used to develop dry-weather flow hydrographs based on observed or predicted average daily flow. Figure 6-3 illustrates a typical diurnal curve, normalized by average daily flow.

Figure 6-3. Example Diurnal Curve



Unit diurnal curves shall be created by:

- Developing a typical dry-weather hydrograph from a representative period
- Dividing the dry-weather flow hydrograph by the average daily dry-weather flow, for the representative period

This unit hydrograph can be multiplied by average daily flows for various population conditions. This provides a method to generate future hydrographs based on population projections. Ideally, several days of dry-weather flow data should be used for the development of the unit hydrograph, including weekdays and weekends.

If seasonal or weekly variations exist in the area being modeled, specific unit diurnal curves should be developed for these periods using the same technique. Note that seasonal variations may also require an adjustment to the population data, such as during peak tourism, to accurately characterize seasonal variations in baseflow.

It is understood that flow-monitoring data will not be collected specifically for each individual sewer basin. For sewer basins that have not been individually monitored, diurnal curves shall be estimated based on diurnal curves from comparable basins with similar basin characteristics, particularly land use and area, using engineering judgment.

6.4.5 Rainfall Derived Inflow and Infiltration Generation

RDII generation techniques shall be limited to those which estimate the stormwater generated hydrograph, as described in this section. The modeler may use engineering judgment to select the RDII generation technique.

Note that some of these methods may not be available in all commercially available hydraulic modeling software. In order to apply a method not included in a given software package, sewer hydrographs will need to be developed outside of the software. Note that no method is more accurate or precise than the data, which are used to develop the RDII estimate.

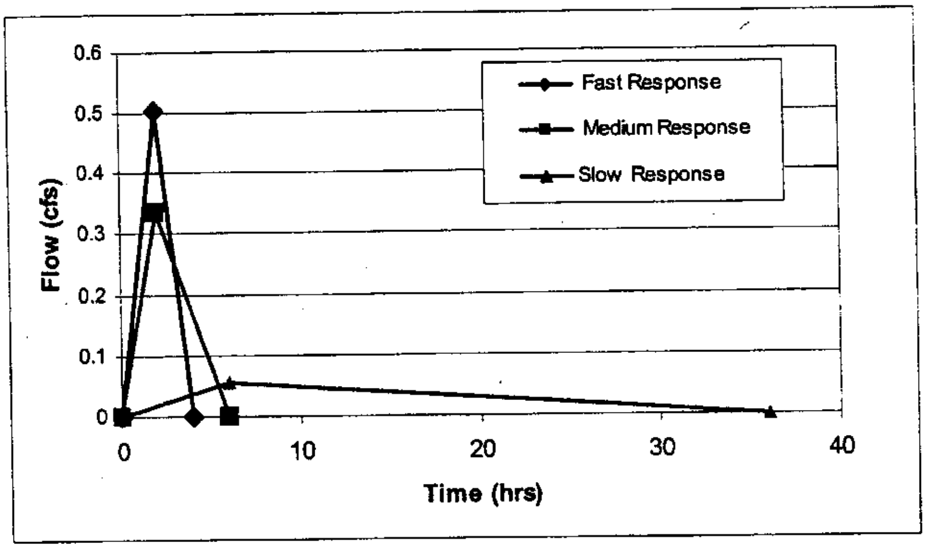
It is understood that flow-monitoring data will not be collected specifically for each individual sewer basin. For sewer basins that have not been individually monitored, RDII shall be predicted based on comparable results from monitored basins with similar basin characteristics using engineering judgment. The variables used to predict RDII shall be scaled as appropriate in non-monitored basins to develop proportional RDII as observed in the monitored basins of similar basin characteristics.

The modeler shall use engineering judgment when projecting RDII for future conditions. This assessment shall be made based on pipe age, condition, current versus future extent of sanitary sewer system, and experience.

RDII flow generated from models calibrated using a relatively short history of rainfall and flow records (i.e. less than the requirements in Section 3) should be used cautiously and more data should be collected to confirm the model results.

6.4.5.1 Synthetic Unit Hydrograph. This method follows a similar theory as used for developing unit hydrographs for stream hydrology. The shape of the unit hydrograph is a function of the basin's characteristics. Up to three unit hydrographs are commonly used to simulate the fast, medium and slow recession response of a sewer basin to rainfall as shown on Figure 6-4. Up to three unit hydrographs may be required to accurately predict RDII due to the fact that inflow and infiltration exhibit different responses to rainfall. Inflow typically exhibits a rapid reaction to rainfall while infiltration exhibits a more gradual response.

Figure 6-4. Synthetic Unit Hydrographs



6.4.5.2 Rainfall/Flow Regression. The rainfall/flow regression method develops a mathematical equation to relate rainfall and RDII. Once calibrated, this equation can be used to predict RDII quantities for selected rainfall events. This method requires a continuous (i.e., uninterrupted) history of both sewer flow and rainfall.

6.4.5.3 Hydrologic Methods. This technique simulates the hydrologic cycle including direct runoff, indirect inflow from sources such as foundation drains, ground water entry through system defects, and the impact of antecedent moisture conditions. Such methods, available in most commercial software, perform a mass balance on the rainfall, sewer flows and soil moisture to simulate RDII over all seasons and antecedent moisture conditions.

This RDII generation method can be made to match a measured flow hydrograph with a wide range of coefficient values; this may result in an inaccurate representation of RDII generation if these variables are adjusted improperly. Experience is needed to choose those parameter sets that will be most appropriate under different rainfall conditions.

6.4.5.4 RDII Prediction Components of Modeling Software. Most hydraulic modeling software includes methods for generating RDII based on parameters entered by the user. These may include one or more of the methods described earlier. Note that the software may use different terminology to describe these methods.

6.5 CALIBRATION AND VERIFICATION

6.5.1 Calibration

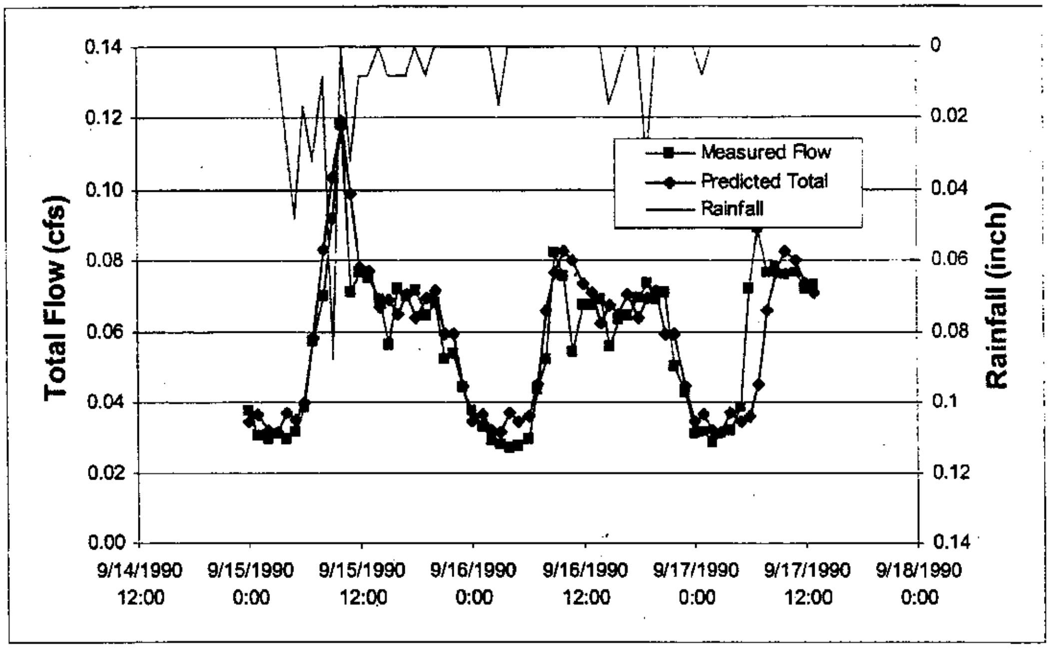
Calibration refers to the process of checking the predicted (modeled) flow against actual observed flow, given the rainfall conditions observed for the same period. This process includes double-checking initial input variables for reasonableness and adjustment of input variables. This process shall be followed by verification using a different set of data than was used for calibration.

The first step in model calibration is assuring network connectivity and boundary conditions (i.e. outlet conditions, pump control). Identification and correction of errors in network connectivity prior to variable adjustment will save labor during calibration.

Baseflow and RDII shall be treated as separate components during calibration. Baseflow shall be calibrated adequately before making adjustments to RDII. If baseflows were over predicted to match the total sewer flow, then the RDII would consequently be under predicted. This could produce gross inaccuracies in predicted flow, particularly in evaluation of future conditions when baseflows are extrapolated to account for population growth.

Adjustment of model variables can be guided by both graphical and statistical methods. During the initial iterations, it is convenient to use a graphical comparison of modeled and observed flow, as shown on Figure 6-5.

Figure 6-5. Modeled Versus Observed Flow



Graphing modeled and actual flows provides a quick analysis of model accuracy. This can be used early in calibration to identify large discrepancies and make broad adjustments to the model. Criteria for consideration during graphical analyses are hydrograph shape, peak flowrate, and peak and trough timing. This shall be applied to both baseflow and RDII.

Statistical methods provide quantitative comparisons to modeled and observed flows. Calibrated models shall meet the following statistical standards for dry and wet-weather flows. These standards will also be applied for model verification.

For dry-weather flow (i.e., baseflows), the following standards shall be met for calibration, in addition to matching general hydrograph shape. These standards shall be met for at least 2 dry-weather days.

- Predicted time of peaks and troughs shall be within 1 hour of the observed flow
- Predicted peak flowrate shall be within +/- 10 percent of the observed flow data
- Predicted volume of flow over 24-hours shall be within +/- 10 percent of observed flow

For wet-weather flow (baseflow and RDII), the following standards shall be met for calibration, in addition to matching general hydrograph shape. These standards are based on generally accepted practices, and conform to the guidance published in *Wastewater*

Planning Users Group (WaPUG) Code of Practice for the Hydraulic Modeling of Sewer Systems (2002). These standards are desirable for model calibration for the wet-weather events described in Section 3.3.3.

- Predicted time of peaks and troughs shall be within 1 hour of the observed flow
- Predicted peak flow rates shall be within -15 percent and +25 percent of the observed flow
- Predicted volume of the wet-weather event shall be within +20 percent and -10 percent of the observed flow
- Predicted pump discharge pressure within +/- 10% of observed pressures
- Predicted surcharge depth in manholes or other structures shall be within +1.5 feet and -0.3 feet of the observed depth
- Predicted non-surcharged water surface elevations shall be with in +/- 0.3 feet of the observed depth

Other parameters may be used to ensure accurate calibration. These include, but are not limited to:

- Reasonable agreement between predicted and actual pumping station wet well level and discharge
- Accurate prediction of known overflow location and volume
- Accurate prediction of observed discharge pressure in force mains
- Accurate prediction of duration and volume of flow equalization/storage systems
- Representative performance of flow control structures such as weirs
- Adjustment of C-factors and roughness coefficients

If a model cannot meet the calibration criteria, the model may be considered sufficiently calibrated using engineering judgment if:

- The reason for non-compliance has been identified but cannot be modeled, and has been determined to be unimportant to the model's purpose and use. This shall be supported by credible evidence.
- The reason for the discrepancy cannot be identified, but an assessment of the effect of likely causes on the accuracy of the model has shown that this will not be detrimental to the use of the model.

6.5.2 Verification

Verification is the process of checking a model against data that were not used for calibration. The calibrated model is run with different rainfall data than those used in the calibration, and the results compared against corresponding flow data. Verification standards shall follow the same criteria used to evaluate the model during calibration. An overall quality review of the input data, network connectivity, assumptions, and simplifications shall be conducted during model verification.

In the event that a model does not meet the verification criteria, the cause of the situation shall be carefully reviewed. This situation may warrant inclusion of additional flow monitoring data in the analysis, field studies to determine system anomalies (e.g., heavy sediment accumulations) not included in the model, or revisiting the data input.

If a model cannot meet the verification criteria, the model may be considered sufficiently verified using engineering judgment if:

- The reason for non-compliance has been identified but cannot be modeled, and has been determined to be unimportant to the model's purpose and use. This shall be supported by credible evidence.
- The reason for the discrepancy cannot be identified, but an assessment of the effect of likely causes on the accuracy of the model has shown that this will not be detrimental to the use of the model.

6.6 LONG TERM FLOW SIMULATIONS

Long-term flow simulation shall be used to assess recurrence frequencies for peak flows or volumes. Specific recurrence frequencies are established using probabilistic analysis discussed in this section. Long-term flow simulation takes into account the range of historical antecedent rainfall patterns, and provides sufficient data with which to define the recurrence interval of peak flows.

Flow monitoring data may not be available for a sufficient period of record or for the location of interest to perform a probability analysis. Therefore, flow records may be synthetically generated using a calibrated model and a historic rainfall record. Generally, rainfall data is available for a much longer period of record than typically found in sewer flow monitoring.

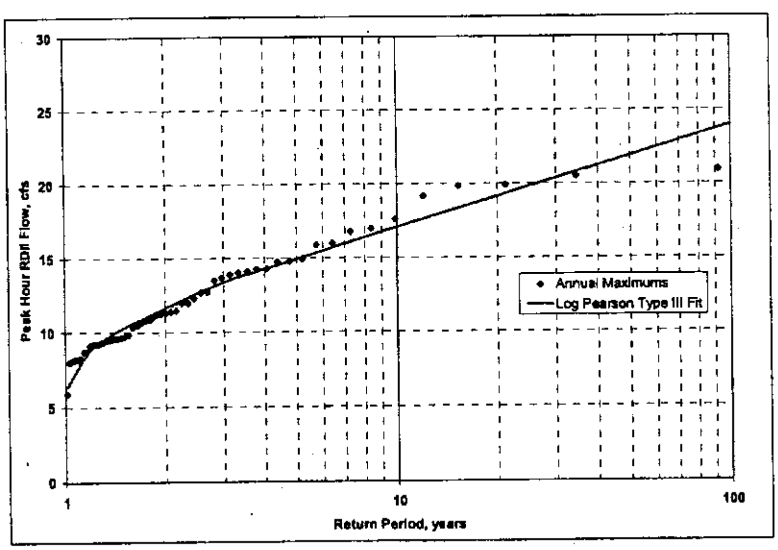
Long–term flow simulation begins with the development of a calibrated model. Once a calibrated model has been developed, a long history of rainfall shall be applied to the model to generate a long-term history of sewer flows. The resulting modeled sewer flows provide an estimation of the actual sewer flows under the same rainfall conditions for the same period of record as the rainfall. Following the long-term simulation, the predicted sewer flow shall be subjected to probabilistic analysis to determine the recurrence interval for various events.

Any representative rainfall record for the area can be used for long-term simulation. To provide regional consistency, long-term historical rainfall data shall be used from the Norfolk International Airport (Airport Code ORF) for long-term simulations for the South Shore portion of the regional sanitary sewer system. Historical rainfall Data from the Newport News/Williamsburg International Airport (PHF) shall be used for the North Shore portion of the regional sanitary sewer system. The South Shore includes the portion of the regional sanitary sewer system south of the James River. The North Shore includes the regional sanitary sewer system to the north of the James River. Each of these rain gauge stations contains several decades of data, dating to the 1940s.

For event frequency analyses, the length of the rainfall record required shall be at least twice the frequency of the peak flow recurrence being evaluated. For example, to confidently predict the 5-year peak flow recurrence event would require 10-years of rainfall data.

Probabilistic analysis shall be used to determine event recurrence intervals and can be applied to both peak flow and volume. This method is detailed in most hydrology textbooks. Examples of probabilistic methods include Normal (Gaussian) distribution and Log-Pearson Type III distribution. An example of a peak flow probability graph is shown on Figure 6-6.

Figure 6-6. Example of Probability Plot



The peak flow recurrence frequency is based on long-term sewer flow data for the system (actual or synthesized data) that statistically represents the probability of achieving specific flow values. The peak flow recurrence frequency does not directly correlate to the peak flow resulting from the same rainfall recurrence interval. For example, springtime rainfall events may have higher sewer flow volumes than would result from the same rainfall volume that occurs in summer due to differing soil moisture conditions and groundwater levels. A 2-year peak flow recurrence may occur during a 2-year, 24-hour rainfall event when soils are dry and groundwater is low, while the same sewer flow may be realized during a one-year 24-hour rainfall when the ground is saturated and the groundwater table is high. Resultantly, it is more accurate and defensible to utilize peak flow recurrence than rainfall recurrence as a basis for evaluating sanitary sewer system performance under wet-weather flow conditions.

6.7 HYDRAULIC MODEL DEVELOPMENT DOCUMENTATION

Modeling work shall be documented to support the model and the conclusions drawn from its use as well, as to provide a record for assessment the model's suitability for other projects.

Modeling documentation shall be developed which includes the following information:

- Model development, including data sources
- Model calibration and verification results

HRSD and the Localities shall develop model documentation for their respective models.

6.7.1 Model Development Documentation

This section of the model documentation shall document work from project inception through calibration, including:

- Project definition and purpose
- Data description, sources, reliability and location of data storage
- Assumptions and simplifications
- Naming conventions for manholes, pipes, structures, etc.
- Flow estimation methodology
- Calibration records including initial variable assumptions and justifications for variable adjustments outside of accepted ranges

The record of data shall be as specific as possible, referencing firm or agency of origin, date, format, modifications, and any commentary regarding data quality or assumptions about the data.

6.7.2 Model Verification Documentation

The purpose of the model verification section of the model documentation is to document the accuracy of the model against data other than that used for calibration. This section shall include:

- Metrics indicating the models compliance with verification standards
- Description and justification of changes to the model during verification
- Graphs comparing predicted to actual flow both for the verification period and the original calibration period
- Comments of the model's suitability for the intended use, particularly if the model does not meet one or more verification standards
- Analysis used to evaluate the suitability of a model not conforming to the verification standards
- Limitations of the model

SECTION 7 REHABILITATION PLANNING

7.1 PURPOSE

A Rehabilitation Plan shall be developed to address deficiencies identified in the SSES Basins; system-wide improvements including control of I/I sources; and improvements needed to ensure sustainability of the regional sanitary sewer system and protect water quality, human health, and the environment. Rehabilitation shall be considered the repair or replacement of existing sewer assets to restore or improve the performance of the regional sanitary sewer system. Correction of capacity deficiencies in the Regional Sanitary Sewer System up to, but not including, the Locality pump station that discharges directly to the HRSD system shall be addressed in the Rehabilitation Plan.

Factors to be considered in the development of the Rehabilitation Plan include:

- Location, cause and frequency of SSOs
- Structural condition of assets
- Hydraulic capacity of existing assets versus capacity needs (level of service requirement)
- I/I reduction potential
- Criticality of the pump station, sewer basin, or sewer
- Technical feasibility of rehabilitation
- Durability and useful life of various remedies
- Economic feasibility of rehabilitation
- Affordability of the Rehabilitation Plan in relation to the implementation schedule

The structural conditions of the assets shall be identified in the Condition Assessment documentation described in Section 4.8. The durability, useful life, and I/I mitigation effects of rehabilitation measures shall be considered when comparing asset repair versus asset replacement alternatives.

The criticality of individual assets shall be considered during the prioritization of projects in the Rehabilitation Plan. The prioritization shall consider the risk and consequence of failures that may be prevented or mitigated by each project. Projects that mitigate chronic SSOs and conditions leading to environmental, public health, or safety risks will be given the highest priority.

Consideration shall be given to the technical and economic feasibility of individual rehabilitation projects, particularly with regard to I/I reduction. In cases where rehabilitation or replacement is not projected to reduce peak flow to within the peak flow threshold, an alternatives analysis shall be conducted cooperatively between the Locality and HRSD to identify cost-effective capacity enhancements. Such enhancements shall be included as part of the Regional Wet Weather Management Plan described in Section 8. The construction of capital improvements and modified operational schemes to increase the capacity of the regional sanitary sewer system and manage peak flows shall be coordinated between the Locality responsible for the improvement and HRSD.

7.2 GOALS

The goals of the Rehabilitation Plan are to:

- Prevent SSOs by addressing localized significant defects and bottlenecks in the sanitary sewer system
- Reduce I/I and thereby peak flows
- Ensure sustainability of the infrastructure assets by addressing identified deficiencies
- Identify means and methods to remedy the problems
- Establish prioritization of rehabilitation efforts for inclusion in the Locality's Capital Improvement Program

7.3 I/I REDUCTION APPROACH

Engineering judgment should be used to estimate the percent I/I that can be removed within an SSES Basin based on observed defects, general pipe/manhole condition, material of construction, and estimated I/I contributions within the sanitary sewer system exclusive of contributions from private sanitary sewer connections. Consideration shall be given to the "fluid" nature of the I/I sources, particularly if rehabilitation is limited to specific components in the total system. A common error in estimating the effectiveness of rehabilitation is to assume net sewer service area effects will be equal to the sum of the I/I values initially allocated to specific rehabilitation components. Rehabilitation in one area can result in raising the groundwater level, increasing leakage in previously adequate sewers because of increased hydraulic head. Historically, peak flows represent a surcharge condition, in which rehabilitation efforts will not register any overall reduction until peak flows have been reduced below the capacity of the limiting conveyance segment of the surcharged section. Understanding the effectiveness of the sewer rehabilitation I/I control program is essential to making the right decisions regarding rehabilitation versus increasing conveyance capacity. Additional guidance information may be found in the WEF Manual of Practice FD-06 – "*Existing Sewer Evaluation and Rehabilitation*", and WERF Publication 99-WWF-8 - "*Reducing Peak Rainfall Derived Infiltration/Inflow Rates – Case Studies and Protocols.*"

Various rehabilitation and replacement methods have differing levels of effectiveness, maintenance impacts and life spans. These variations should be considered when evaluating the costs and benefits of alternatives.

For each SSES Basin, the Locality shall assess the cost and feasibility of using rehabilitation to reach the Peak Flow Threshold Criteria. The estimated peak flow in the basin (as determined per the procedures outlined in Section 6) associated with a 10-year rainfall recurrence interval shall be compared to the Peak Flow Threshold Criteria. One of the following two outcomes of this analysis shall be identified:

1. If the projected peak flow in the SSES Basin exceeds the Peak Flow Threshold Criteria under current development conditions, the Locality shall assess the cost and feasibility of reaching the Peak Flow Threshold. If after appropriate analysis and collaboration with HRSD, the Locality deems that it is not cost-effective and/or it is not feasible to achieve the Peak Flow Threshold in a particular SSES Basin, the Locality shall develop costs, and estimate the reduced peak flow levels that can be achieved, for the planned level of rehabilitation in that SSES Basin. Any SSES Basins in which the planned rehabilitation is estimated not to reach the Peak Flow Threshold must be addressed within the Regional Wet Weather Management Plan.

2. If the projected peak flow in the SSES Basin is less than the Peak Flow Threshold Criteria then the Locality shall develop a rehabilitation plan to correct significant defects and reduce I/I to the extent that is cost effective and feasible. The Rehabilitation Plan will provide for the cost, schedule and estimated peak flow resultant from the rehabilitation.

In any case, the Locality shall make an affirmative commitment, which will be relied upon in the RWWMP in terms of post rehabilitation peak flow in all SSES Basins at the specified level of service. All costs developed in the Rehabilitation Plan shall be stated in the dollar value in the year the plan is submitted.

7.4 PRIORITIZATION OF PROBLEMS AND IDENTIFIED DEFECTS

The prioritization of significant defects is needed in order to develop a plan to systematically reduce I/I, and ultimately reduce SSOs, that occur in the system. The prioritization shall focus on the most severe defects and areas with the majority of SSO occurrences. In addition, there are several other factors that need to be considered when working through the prioritization. Items to consider when prioritizing rehabilitation activities include:

- Number and severity of system defects
- Number of SSOs that could be avoided if the system were rehabilitated
- Operation and maintenance history and costs
- Quantity of I/I entering the system and potential for I/I reduction
- Probability and consequence of failure of the sanitary sewer system
- Available capacity
- Estimated cost of the proposed rehabilitation

- Technical complexity of the rehabilitation activities and potential secondary impacts

A ranking system shall be developed that accounts for factors that influence the prioritization of system improvements. Individual utilities may weight the criteria differently and/or may add additional criteria based on their need and desired priorities. In any case, the prioritization shall consider the above criteria as a minimum.

7.5 REHABILITATION ALTERNATIVES EVALUATION

Alternative approaches to rehabilitation shall be considered in the development of the Rehabilitation Plan. This may include rehabilitation, capacity upgrades, flow diversions, and/or replacement. Key factors in deciding a rehabilitation method for various facilities will include the: structural condition, mechanical condition, capacity requirements, type of material, accessibility, conflicting utilities and other facilities, extent of repair needed, remaining useful life and cost of rehabilitation or replacement.

7.5.1 Rehabilitation vs. Replacement

It will be necessary to determine if failing portions of the system can be rehabilitated or if they will require replacement. Factors affecting this decision include:

- Available capacity
- Structural condition
- Remaining useful life
- Estimated rehabilitation effectiveness
- Future needs
- Change in system functionality or operation
- Pipe slope
- Restoration requirements
- Cost

7.5.2 Methods of Rehabilitation

Several technologies are available for consideration in developing the Rehabilitation Plan, and new technologies are routinely emerging in the sanitary sewer industry. The Rehabilitation Plan shall consider the application of commonly used rehabilitation and replacement methods, advantages and limitations of the technique. The full range of available rehabilitation methods should be considered at the time the Locality develops the Rehabilitation Plan as described in Section 7.6.

7.6 REHABILITATION PLAN

7.6.1 Rehabilitation Plan and Schedule

Rehabilitation Plans shall be developed to define specific measures that will be taken to reduce SSOs, the cost associated with the proposed rehabilitation, and the planned timeframe for rehabilitation activities. The Rehabilitation Plan shall be submitted to DEQ for review and approval within 62 months of the effective date of the Consent Order. In addition, each Locality shall submit their estimated post rehabilitation peak flows to the Regional Wet Weather Management Planning Group, which will rely upon these in the completion of the RWWMP.

7.6.2 Report on Work Completed

Progress on rehabilitation projects that are implemented between the execution date of the Special Order by Consent and the submittal of the Rehabilitation Plan shall be described in the Annual Report to DEQ.

SECTION 8 REGIONAL WET WEATHER MANAGEMENT PLAN DEVELOPMENT

8.1 BACKGROUND AND PURPOSE

HRSD and the Hampton Roads Localities are entering into a collaborative process to address sanitary sewer overflows (SSOs). One component of this challenge is the provision of adequate capacity to collect, convey and treat peak flows in the Regional Sanitary Sewer System during wet weather. HRSD owns, operates and maintains the backbone infrastructure generally consisting of pump stations, pressure reducing stations, interceptors and treatment works for the region. The Localities generally own, operate and maintain sanitary sewer facilities that collect and convey wastewater to HRSD. During some wet weather conditions, facilities owned by the Localities and HRSD are strained to convey peak flows without experiencing SSOs.

The purpose of the Regional Wet Weather Management Plan (RWWMP) is to define improvements in the Regional Sanitary Sewer System necessary to achieve a mutually agreed upon level of service. Procedures are identified in Section 6 for evaluating the hydraulic performance assessment of the Regional Sanitary Sewer System under a range of hydrologic conditions. The hydraulic performance assessment will identify hydraulic deficiencies for each condition analyzed. This output will be used as input to the RWWMP.

Three types of improvements shall be defined and analyzed: .

- Large scale strategies to address major systemic hydraulic deficiencies
- Improvements to the pump stations, force mains, sewer mains and interceptors
- Improvements needed to ensure adequate capacity in SSES Basins where the Locality's or HRSD's individual Rehabilitation Plans are not expected to reduce the peak flow at the agreed upon level of service to within the Peak Flow Threshold.

Alternatives for addressing the hydraulic deficiencies will be developed and analyzed. Cost, feasibility, operations and maintenance issues, risk, performance, flexibility and local impacts will be considered in the analysis of alternatives. The preferred set of alternatives necessary to achieve the mutually agreed upon level of service will be identified along with their associated costs and implementation schedule.

During the process of actually providing and rehabilitating needed infrastructure, operational considerations shall be analyzed and coordinated between HRSD and the localities to help reduce the effects of high I/I and in turn reduce associated overflows where possible.

8.2 CAPACITY ASSESSMENT

HRSD and the Localities shall develop and document capacity assessments that describe the conclusions regarding capacity deficiencies and hydraulic performance of the Regional Sanitary Sewer System. Conclusions shall include, but not be limited to identification of areas that do not have adequate capacity, as defined in Section 2, to manage peak flows under the following conditions:

- Baseline dry weather flows, current conditions and 2030 population
- 2-year peak flow recurrence, current conditions and 2030 population
- 5-year peak flow recurrence, current conditions and 2030 population
- 10-year peak flow recurrence, current conditions and 2030 population

Operational and structural conditions contributing to capacity deficiencies shall also be identified. If a sewer basin is deemed to have adequate capacity under the 10-year peak flow recurrence conditions, additional analysis at lower levels of service may not be required. Any conclusions shall be supported by the modeling output (e.g. graphs, surcharge depths, peak flow), or other appropriate data.

8.3 LEVEL OF SERVICE SELECTION

A key concept in development of the RWWMP is establishing a level of service that will form the basis for planning capacity enhancements. Level of service in this context is defined as the peak sewer flow that the Regional Sanitary Sewer System can convey without resulting in a capacity-related SSO. Level of service in the RWWMP shall be quantified as a peak sewer flow recurrence interval.

Level of service equates to risk of system failure. For example, a sewer that performs at a 2-year level of service would have a probability of overflows being 50% in any given year; at a 10-year level of service, the probability of overflows would be 10% in any given year. The probability of overflow can be estimated based on monitoring and analysis of the flowrate and level of flow in a wastewater collection system, and through analysis of the SSO history. The cost of providing a 10-year level of service (or protection against overflows) is generally significantly greater than providing a 2-year level of service. The cost of service and risk of overflows are inversely proportional.

The costs, benefits and risks associated with achieving various levels of service for the defined capacity enhancements shall be defined in the RWWMP. These costs, benefits and risks shall be analyzed to reach a consensus on the selected level of service. The selected level of service will generally apply across the Regional Sanitary Sewer System although exceptions may be possible on a case by case basis provided that these can be adequately justified by their associated benefits and risks.

8.4 DEVELOPMENT OF CAPACITY ENHANCEMENT SOLUTIONS

After a level of service is selected, alternatives to achieve that level of service will be developed and analyzed in order to optimize the solutions needed to ensure adequate capacity. Alternatives shall be developed to address the capacity deficiencies identified per Section 8.2. These alternatives shall consider approaches such as removal of RDII, providing additional hydraulic capacity to convey and treat peak flows, storage options, operational schemes, and satellite treatment. These approaches can be used alone and/or in combination and should follow the Operating Guidelines set forth in Exhibit B. The life cycle costs, constructability, operations and maintenance impacts, water quality benefits, local impacts and risks associated with each alternative shall be described.

8.5 AFFORDABILITY

An affordability analysis shall be conducted for the selected plan with the results to be used as input to the development of an implementation schedule. The affordability analysis shall use a multifaceted approach which describes affordability in terms of such factors as total annual wastewater costs as a function of median household income, Localities' financial capability, total annual wastewater costs as a function of household income for vulnerable populations, impacts to homeownership and renter housing cost burden and impacts to the local economy and business health. The purpose of the affordability analysis is to provide input to the development of an implementation schedule, which will result in an affordable program for the Hampton Roads region.

8.6 RWWMP CONTENT

The following is a preliminary outline describing the anticipated content of the RWWMP. This outline is intended to provide general guidance for the preparation of the RWWMP. It is anticipated that some deviation from this outline will occur in the development of the RWWMP.

1. **Introduction**
1.1 Background
1.2 Purpose and Format of Regional Wet Weather Management Plan

2. **Consent Order Requirements**

3. **Public Participation and Agency Coordination**

4. **Characterization Report**
4.1 Sanitary Sewer System
    4.1.1 Localities Sanitary Sewer Systems

4.1.2 HRSD Sanitary Sewer System
4.1.3 Service Areas
4.1.4 Historical Wastewater Flow Projections
4.2 HRSD Wastewater Treatment Works
4.2.1 North Shore Facilities
4.2.2 South Shore Facilities

5. Planning Process
5.1 Methodology
5.1.1 Large Scale Strategies
5.1.2 SSES Basins
5.1.3 Wastewater Treatment Plant Wet Weather Optimization
5.2 Sewer System Capacity Definitions

6. Population Forecasts
6.1 Planning Horizon
6.2 Population and Employment Forecasts

7. System Evaluation
7.1 Model Framework
7.1.1 Dry Weather Flow
7.1.2 Wet Weather Flow
7.1.3 Peak Flow Reductions Expected from Localities' Rehabilitation Plans
7.1.4 Capacity Deficiencies
7.1.4.1 Deficiencies in the Regional Sanitary Sewer System
7.1.4.2 Deficiencies at the WWTPs
7.1.5 Modeled Conditions
7.2 Evaluation of Pump Stations, Main Trunk Sewers and Interceptors
7.2.1 Pump Stations, Main Trunk Sewers/Interceptors Studied
7.2.2 Level of Service Evaluation
7.2.3 Peak Flow Events
7.2.4 Methodology
7.2.5 Identification of Hydraulic Deficiencies
7.3 Wastewater Treatment Plants
7.3.1 Historical Flow Data
7.3.2 Evaluation for Extreme Events
7.3.2.1 Selection of Historical Events
7.3.2.2 Projecting to Future Conditions
7.3.2.3 Recurrence Frequency Analysis
7.4 SSES Basins Not Meeting Peak Flow Threshold
7.4.1 Methodology
7.4.2 Evaluation

8. Development and Evaluation of Capacity Enhancement Solutions

8.1 Large Scale Strategy Alternatives Evaluation and Selection
- 8.1.1 North Shore
- 8.1.2 South Shore

8.2 Pump Stations, Main Trunk Sewers/Interceptors
- 8.2.1 Analysis of 2, 5 and 10 year LOS
- 8.2.2 LOS Selection for Pump Stations, Trunk Sewer/Interceptors

8.3 SSES Basins Not Meeting Peak Flow Threshold
- 8.3.1 Mitigation Options
  - 8.3.1.1 RDII Abatement Options
  - 8.3.1.2 Operational Alternatives
  - 8.3.1.3 Conveyance Options
  - 8.3.1.4 Storage Options
  - 8.3.1.5 Satellite Treatment
- 8.3.2 Alternatives Analysis and Plan Selection

9. Wastewater Treatment Plant Alternatives

9.1 Hydraulic Assessment
- 9.1.1 North Shore
- 9.1.2 South Shore

9.2 Process Assessment
- 9.2.1 North Shore
- 9.2.2 South Shore

10. Optimization of Wet Weather Improvements

10.1 Description of Large Scale Strategy Alternatives

10.2 Sizing the Alternatives

10.3 Scoring Alternatives
- 10.3.1 Cost
- 10.3.2 Constructability
- 10.3.3 Operations and Maintenance
- 10.3.4 Water Quality
- 10.3.5 Local Impacts
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10.4 Selection of the Preferred Alternatives

11. Summary of Wet Weather Management Plan Components

11.1 Overview

11.2 Capital Improvement Plans

11.3 Operating Plans

11.4 Program Summary

12. Cost Analysis, Implementation Schedule and Risk/Benefit Analysis

12.1 Program Overview
12.2 Risk/Benefit Analysis
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12.5 Implementation Schedule
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