City of Memphis

Continuing Sewer Assessment Program

July 3, 2014

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering such information, the information submitted is, to the best of my knowledge and belief, true, accurate and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Bobby D. Allen, P.E. _____ Date: July 3, 2014

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Section 1
Introduction

On September 20, 2012, the Consent Decree between the City of Memphis (Memphis or "City"), the United States, the State of Tennessee, and the Tennessee Clean Water Network was entered by the United States District Court for the Western District of Tennessee. Within the Consent Decree, a number of programs were set forth for the continued improvement of the City's wastewater collection and transmission system (WCTS). The WCTS is defined in the Consent Decree as the municipal wastewater collection, retention, and transmission system, including all pipes, force mains, gravity sewer lines, lift stations, pumps, manholes, and appurtenances thereto, which are owned or operated by Memphis and service Memphis and which flow to the M.C. Stiles and T.E. Maxson wastewater treatment plants (WWTPs).

A Continuing Sewer Assessment Program, or CSAP, is required in paragraphs V.10.f.(i) through V.10.f.(viii) of the Consent Decree. The CSAP is intended to provide a framework to assess and analyze the infrastructure of the WCTS, including the establishment of procedures for setting priorities and schedules to complete those assessment activities. The purpose of the CSAP is to collect data to be used in subsequent prioritization decisions. The CSAP does not commit Memphis to undertake any action other than the assessment work described herein.

1.1 Collection System Description

The City of Memphis provides sanitary sewer collection and treatment services to most areas within the city limits. Memphis also receives wastewater generated from municipal satellite systems, including the Horn Lake Creek Basin Interceptor Sewer District (Mississippi), the City of Germantown, portions of the cities of Bartlett, Collierville, Lakeland, and Millington, and from unincorporated areas of Shelby County. The WCTS is a separate sanitary sewer system that serves a total area of 442 square miles, with 314 square miles within the City limits and 128 square miles within suburban areas. The WCTS is divided into six major sewer basins: Loosahatchie River, Wolf River, Front Street, President's Island, Nonconnah Creek, and Horn Lake Creek.

The sewer system in the Memphis service area is predominately gravity based and currently consists of approximately 2,400 miles of sewer lines, including gravity sewers and force mains, 85,000 manholes, and 102 lift stations. This excludes privately owned laterals or private collection systems, such as those lines within gated communities and apartment complexes; these sewers are neither owned nor maintained by Memphis, and, therefore, are not covered by this CSAP program.

The Maynard C. Stiles WWTP, located near the confluence of the Mississippi and Wolf Rivers, serves the northern portion of the service area, including the Wolf River, Front Street, and Loosahatchie River sewer basins. This WWTP receives flow from two 96-inch diameter interceptors which generally follow the Loosahatchie and Wolf Rivers.

The T. E. Maxson WWTP, located near the confluence of McKellar Lake and the Mississippi River south of President's Island, serves the southern portion of the service area, including the Nonconnah Creek, Horn Lake Creek, and President's Island sewer basins. There are two main interceptors serving the T. E. Maxson WWTP. A 96-inch diameter sewer collects flow from the east, generally following

Nonconnah Creek. A second 90-inch diameter sewer serves the area to the south, including the Horn Lake Creek Basin Interceptor Sewer District in Mississippi.

Figure 1-1 is a schematic of the WCTS showing lift stations, treatment plants, and gravity sewers 15 inches in diameter and larger.

1.2 Background

The CSAP is one of several components required under the Consent Decree related to the Management, Operation, and Maintenance (MOM) of Memphis's WCTS. These MOM programs will ultimately include:

- Sewer Overflow Response Plan
- Fats, Oil, and Grease (FOG) Management Program
- Lift Station and Force Main Operations and Maintenance (O&M) Program
- Gravity Sewer O&M Program
- Interjurisdictional Agreement Program
- Continuing Sewer Assessment Program (CSAP)
- Infrastructure Rehabilitation Program (IRP)

The CSAP is the primary data collection process that provides structural and O&M related data on the WCTS. This data can be used when evaluating and prioritizing how Memphis will manage and respond to defects found in the WCTS. Additionally, information obtained through other programs, such as the Gravity Sewer O&M Program or the Lift Station and Force Main O&M Program, will be utilized to meet the CSAP target for assessment of approximately ten percent of the WCTS on average per year.

1.3 Purpose

The primary purpose of the CSAP is to provide decision-support information for implementation of the IRP, which describes the basis for evaluating and prioritizing how Memphis will manage and respond to defects found in the WCTS. As stated in paragraphs V.10.f.(i) through V.10.f.(viii) of the Consent Decree, the CSAP is intended to describe the approach to assess and analyze the infrastructure of the WCTS, including gravity sewers, manholes, lift stations, and force mains, by establishing procedures to be used in the assessment and a framework for prioritizing areas to be assessed. The goal of the CSAP is to assess an average of approximately ten percent (10%) of the WCTS annually (i.e., following EPA approval of the CSAP) using cost-effective technologies to gather condition and performance-related data to support decisions. The following will be accomplished through the CSAP:

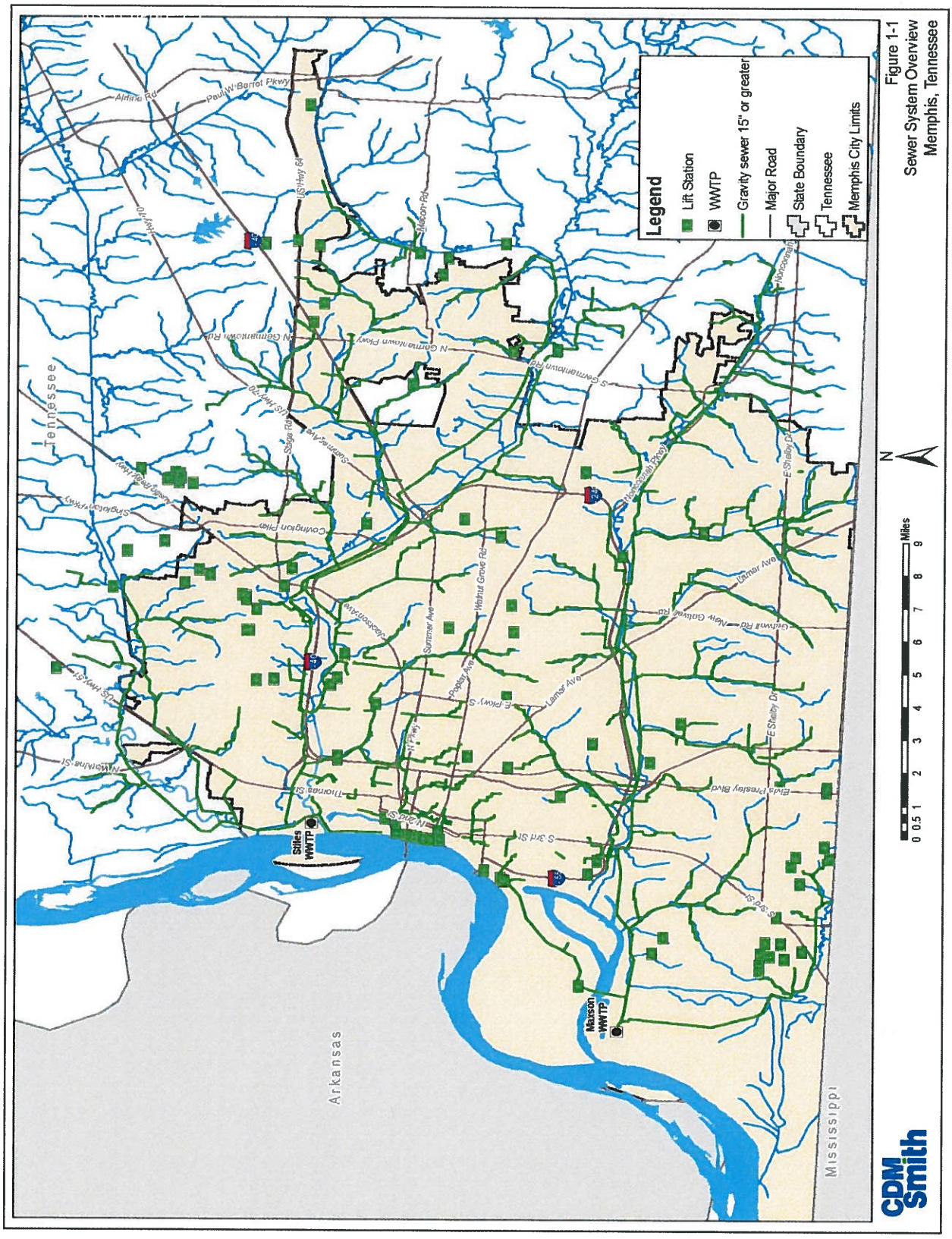


Figure 1-1
Sewer System Overview
Memphis, Tennessee

- Development of a prioritization scheme for determining other assessment areas, taking into consideration data, such as the nature and extent of customer complaints, flow monitoring (including flow isolation studies) if undertaken, location and cause of SSOs (including those identified pursuant to other approved MOM programs required by the Consent Decree), remedial measures already undertaken, field crew work orders, any preliminary sewer assessments (such as midnight flow monitoring), and any other information Memphis finds relevant for the purposes of the CSAP.
- Geographic data collection of the WCTS as it is assessed, with the ultimate goal of building a Geographic Information System (GIS) of the Memphis WCTS. This GIS of the WCTS can provide an efficient way of viewing and cataloging data on any part of the collection system, including pipe diameters, manhole depths, pipe material, pipe age, etc. GIS work, however, will be undertaken pursuant to Appendix J of the Consent Decree (State Project). As provided by Appendix J, GIS work undertaken by Memphis beyond that required by Appendix J is subject to the City's sole discretion.
- Assessment of the structural condition and O&M condition of the WCTS. This includes gathering data through a number of methodologies and cataloging the data in a database so that it may be used. The CSAP establishes procedures, as necessary, for the following components using best professional judgment:
  - Dye water flooding
  - Corrosion defect identification
  - Manhole condition assessment
  - Flow monitoring
  - Closed circuit television (CCTV) inspection
  - Gravity sewer line and force main defect analysis
  - Smoke testing
  - Lift station performance and adequacy evaluations

1.4 Implementation

In order to effectively and efficiently implement the CSAP, Memphis will utilize a combination of internal staff and contractual support. The CSAP will be administered through the Division of Public Works, with the Administrator for Environmental Construction responsible for direct oversight of the CSAP. Memphis has contracted with Black & Veatch to serve as Program Manager for implementation of the Consent Decree. Through this role, Black & Veatch will utilize trained personnel, including subcontractors, to collect condition assessment data following specifications approved by Memphis. Additionally, Memphis will conduct assessment activities through the Gravity Sewer O&M Program or the Lift Station and Force Main O&M Program, which will contribute to the goal of assessing approximately ten percent of the system per year on average.

These resources are anticipated to be adequate for the implementation of the CSAP; however, Memphis will continue to monitor resources.

Additionally, unless Memphis believes there is a need to reevaluate the CSAP earlier, Memphis will conduct an initial review of the CSAP following the first full year of implementation of the approved IRP. Once rehabilitation prioritizing decisions are made, this will provide the City the requisite information to determine whether changes to the assessment methodology should be undertaken. To the extent that Environmental Protection Agency (EPA) approval is required under the Consent Decree, any proposed modifications to the CSAP resulting from that review will be provided to EPA as described in the Consent Decree. Reviews of the CSAP will be subsequently conducted at a minimum of once every two years.

1.5 Organization of the Document

This document is organized as follows:

- **Section 1 – Introduction:** Provides background information, describes the existing system, and summarizes the Consent Decree requirements.
- **Section 2 – Definitions:** Provides definitions of commonly used terminology referenced in the document.
- **Section 3 – Approach for Assessment Prioritization:** Provides methodology for prioritizing portions of the WCTS for assessment and discusses the areas chosen for assessment in Years 1 and 2 of the CSAP.
- **Section 4 – Gravity Sewer Assessment Techniques:** Provides a discussion of the different techniques to be considered for assessment of the gravity sewer system.
- **Section 5 – Force Main Assessment Techniques:** Provides a discussion of the different techniques to be considered for assessment of the force mains within the WCTS.
- **Section 6 – Lift Station Assessment Techniques:** Provides a discussion of the different techniques to be considered for assessment of the lift stations within the WCTS.
- **Section 7 – CSAP Information Management System:** Provides a discussion of the data management and data packaging of the CSAP so it can be brought into the IRP.

Section 2
Definitions

This section is designed to help familiarize readers with common terms and acronyms used in this document.

Building Backup: A wastewater release or backup into a building or private property that is caused by blockages, flow conditions, or other malfunctions in the WCTS. A wastewater backup or release that is caused by blockages, flow conditions, or other malfunctions of a Private Lateral (as defined in the Consent Decree) is not a Building Backup.

Closed-circuit Television (CCTV): Technology by which Memphis and/or its outside contractors use a video camera to visually inspect the internal condition of pipes and sub-surface structures.

Continuing Sewer Assessment Program (CSAP): The Consent Decree deliverable that sets forth the procedures for assessing and analyzing the infrastructure of the WCTS, including the establishment of procedures for setting priorities and schedules.

Environmental Protection Agency (EPA): United States Environmental Protection Agency and any of its successor departments or agencies.

Fats, Oils, and Grease (FOG) Program: "FOG" refers to fats, oils and grease, which are generated by residents and businesses processing or serving food and other products. A FOG program aims to prevent FOG accumulation in sewer systems.

Force Mains: Any pipe that receives and conveys, under pressure, wastewater from the discharge side of a pump. A force main is intended to convey wastewater under pressure.

Geographic Information System (GIS): A system consisting of hardware, software, and data that is designed to capture, store, and analyze geographically-referenced information.

Gravity Sewer Line or Gravity Sewer: Pipes that receive, contain, and convey wastewater not normally under pressure but are intended to flow unassisted under the influence of gravity.

Gravity Sewer Operations and Maintenance (O&M) Program: The Consent Decree deliverable that sets forth the protocols and procedures associated with the gravity sewer system.

Inflow and Infiltration (I/I): The total quantity of water from inflow, infiltration, and rainfall-induced infiltration without distinguishing the source.

Infrastructure Rehabilitation Program (IRP): The Consent Decree deliverable that describes the basis for evaluating and prioritizing how Memphis will manage and respond to defects found in the WCTS.

Lift Station: A facility in the WCTS (not at the WWTPs) comprised of pumps which lift wastewater to a higher hydraulic elevation, including all related electrical, mechanical, and structural systems necessary to the operation of the lift station.

Lift Station and Force Main Operations and Maintenance (O&M) Program: The Consent Decree deliverable that sets forth the protocols and procedures associated with the operation and maintenance of lift stations and force mains.

Manhole or Junction Box: A structure which provides a connection point for gravity lines, private service laterals, or force mains, as well as an access point for maintenance and repair activities.

Manhole Assessment Certification Program (MACP): An industry standard system for coding defects and construction features of manholes.

Memphis: The City of Memphis, Tennessee, Public Works Division, and any successor thereto.

National Association of Sewer Service Companies (NASSCO): The North American trade organization that establishes industry standards associated with pipeline rehabilitation, including PACP and MACP.

Pipeline Assessment Certification Program (PACP): An industry standard system for coding defects and construction features of pipelines from CCTV inspections.

Sanitary Sewer Overflow (SSO): An overflow, spill, or release of wastewater from the WCTS or WWTPs, including: (a) unpermitted discharges; (b) overflows, spills, or releases of wastewater that may not have reached waters of the United States or the State; and (c) all Building Backups.

Sewer Overflow Response Plan (SORP): The SORP provides structured guidance, including a range of field activities to choose from, for a generalized uniform response to overflows.

Supervisory Control and Data Acquisition (SCADA) System: A system of automated sensory control equipment that monitors the operation of a portion of the lift stations within the collection system. The SCADA system is designed to convey alarms when predetermined conditions occur. Monitoring parameters may include, but are not limited to, power failures, high wet well levels, and pump failures that could potentially cause overflows.

Tennessee Department of Environment and Conservation (TDEC): Tennessee Department of Environment and Conservation and any of its successor departments or agencies.

Unpermitted Discharge: A discharge of pollutants which reaches waters of the United States or the State from (a) the WCTS, (b) WWTPs through a point source not specified in a National Pollutant Discharge Elimination System (NPDES) Permit, or (c) WWTPs which constitutes a prohibited bypass except if the criteria set forth at 40 C.F.R. § 122.41(m)(2) or 40 C.F.R. § 122.41(m)(4)(i)(A) – (C) are met.

Wastewater Collection and Transmission System (WCTS): The municipal wastewater collection, retention, and transmission system including all pipes, force mains, gravity sewer lines, lift stations, pumps, manholes, and appurtenances thereto, which are owned or operated by the City of Memphis and service the City of Memphis and which flow to the Maynard C. Stiles and T. E. Maxson WWTPs.

Wastewater Treatment Plant (WWTP): Devices or systems used in the storage, treatment, recycling, and reclamation of municipal wastewater. For purposes of this document and the Consent Decree, this definition shall refer only to the following treatment facilities: the Maynard C. Stiles WWTP located at 2303 N. 2nd St., Memphis, Tennessee, and the T. E. Maxson WWTP located at 2685 Plant Road,

Memphis, Tennessee, and all components of such sewage treatment plants but does not include the WCTS.

Waters of the State: Waters of the State shall have the same meaning as "Waters" defined at TCA § 69-3-103, whereby "Waters" means any and all water, public or private, on or beneath the surface of the ground, that are contained within, flow through, or border upon Tennessee or any portion thereof, except those bodies of water confined to and retained within the limits of private property in single ownership that do not combine or effect a junction with natural surface or underground waters.

Section 3

Approach for Assessment Prioritization

As outlined in the Consent Decree, Memphis is to assess approximately ten percent of the WCTS on average per year. This includes gravity sewers, force mains, and lift stations. The majority of this information will be collected through this CSAP, although additional information not discussed in this CSAP, such as operational performance data for lift stations, may be collected through the Lift Station and Force Main O&M Program or the Gravity Sewer O&M Program. When assessment of the WCTS is conducted through other MOM programs, Memphis will include that work towards the CSAP assessment goal. The assessment information collected will then be used through the IRP to provide a basis for evaluating and prioritizing how Memphis will manage and respond to defects.

The Consent Decree identifies two agreed-upon areas that will be assessed in the first two years of the CSAP. These areas and the rationale behind their selection are described in Section 3.1. The approach for prioritizing future assessment areas is discussed in Section 3.2.

In addition, the Consent Decree recognized that Memphis may undertake assessment work and be credited for such work undertaken earlier than required by the Consent Decree. For the purposes of calculating ten percent for the first year following EPA approval of the CSAP, Memphis will include any assessment activity conducted after April 1, 2011.

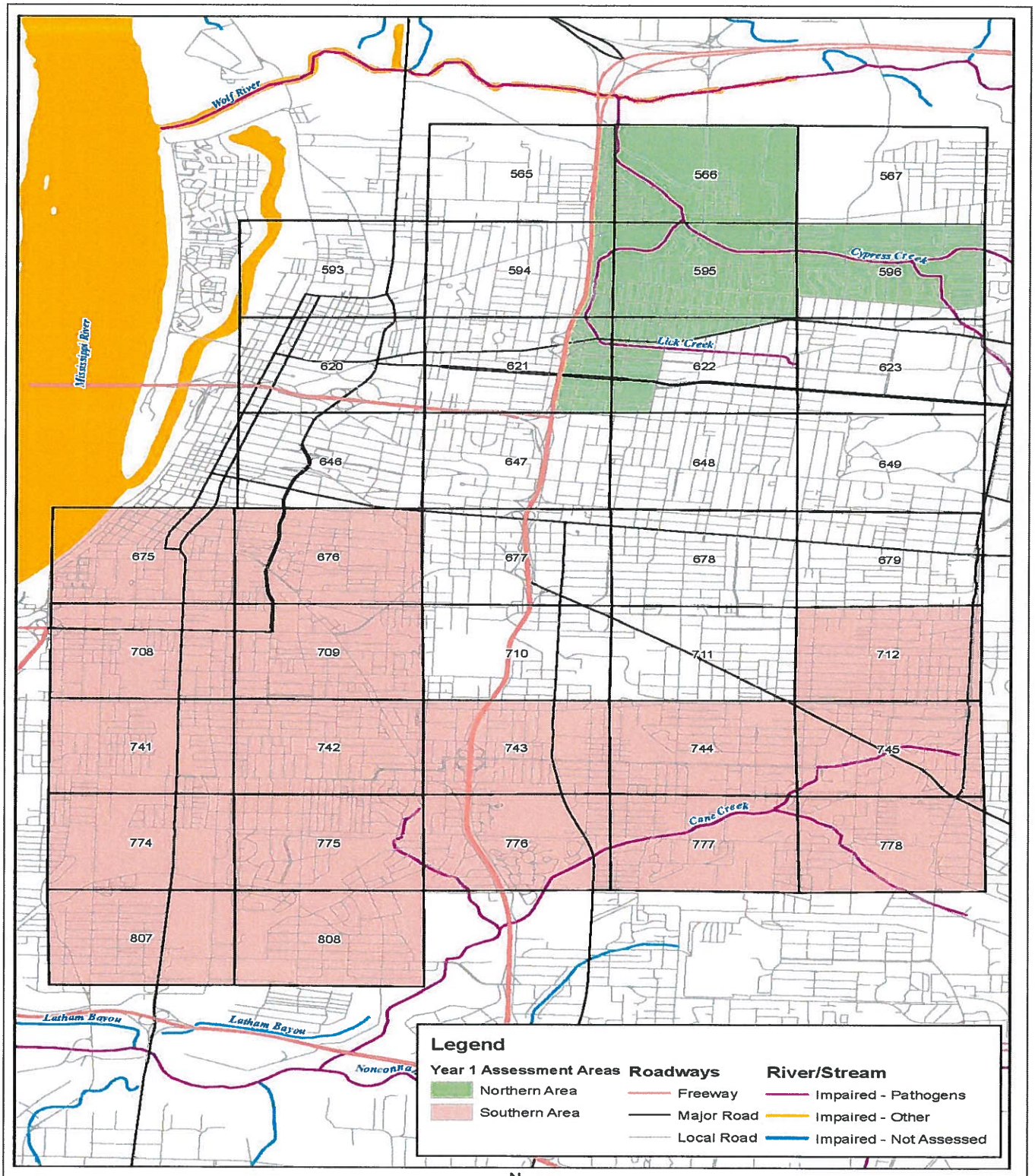
3.1 Assessment Areas for Years 1 and 2

As presented in Appendix E of the Consent Decree, Memphis has determined areas for condition assessment for the first year of the CSAP. These areas (identified as the Northern Area and Southern Area in Appendix E) were determined to be a priority based on the age of the system, SSO frequencies and volumes, proximity to surface waters that have been included on TDEC's Clean Water Act Section 303(d) list of impaired waters for pathogens, and proximity to environmental justice areas identified by EPA. In addition, Appendix F of the Consent Decree reflects the determination that the Lick Creek areas of the WCTS shall be assessed no later than the second year following EPA's approval of the CSAP.

In areas prioritized for assessment in Year 1 or Year 2 of the CSAP, manholes, gravity sewers, force mains, and lift stations will be assessed using the methods and approaches described in this document to the extent that they are required to understand the system's condition. For gravity sewers or force mains that are not entirely within the areas delineated, if the majority of the gravity sewer or force main is within the area delineated, then Memphis, subject to its discretion, may decide to assess the entire sewer or force main; otherwise, the assessment will be conducted as part of the adjacent area.

3.1.1 Year 1 Assessment Area

The area chosen for assessment in Year 1 of the CSAP is set forth in Appendix E of the Consent Decree and is shown as shaded map book pages in **Figure 3-1**. Overall, the area to be assessed in the first year includes approximately 230 miles of pipe with diameters from 8-inches to 36-inches, 3,400 manholes, and five lift stations, which represents approximately ten percent of the gravity sewers in the WCTS. This area also encompasses approximately 27,700 properties, although work under this CSAP will only include condition assessment on publicly-owned components.



CDM Smith

Figure 3-1
Year 1 Assessment Areas
Memphis, Tennessee

As shown in Figure 3-1, the areas are generally delineated by map book pages, which divide the WCTS into a grid-like system. Partial map book pages were selected in the northern area to encompass critical sewers in proximity to Cypress Creek and Lick Creek, which are listed as impaired for pathogens. The southern area also includes map book pages in proximity to Cane Creek, another creek listed as impaired for pathogens. The southern area also includes map book page 778, which is the location of the highest frequency of SSOs during the 2008 through 2009 period analyzed.

3.1.2 Year 2 Assessment Area

The area chosen for assessment in Year 2 is set forth in Appendix F of the Consent Decree and is shown as shaded map book pages in **Figure 3-2**. This area is also known as the Lick Creek Assessment Area due to its proximity to Lick Creek, a water body listed as impaired by pathogens. This area encompasses approximately ten map book pages.

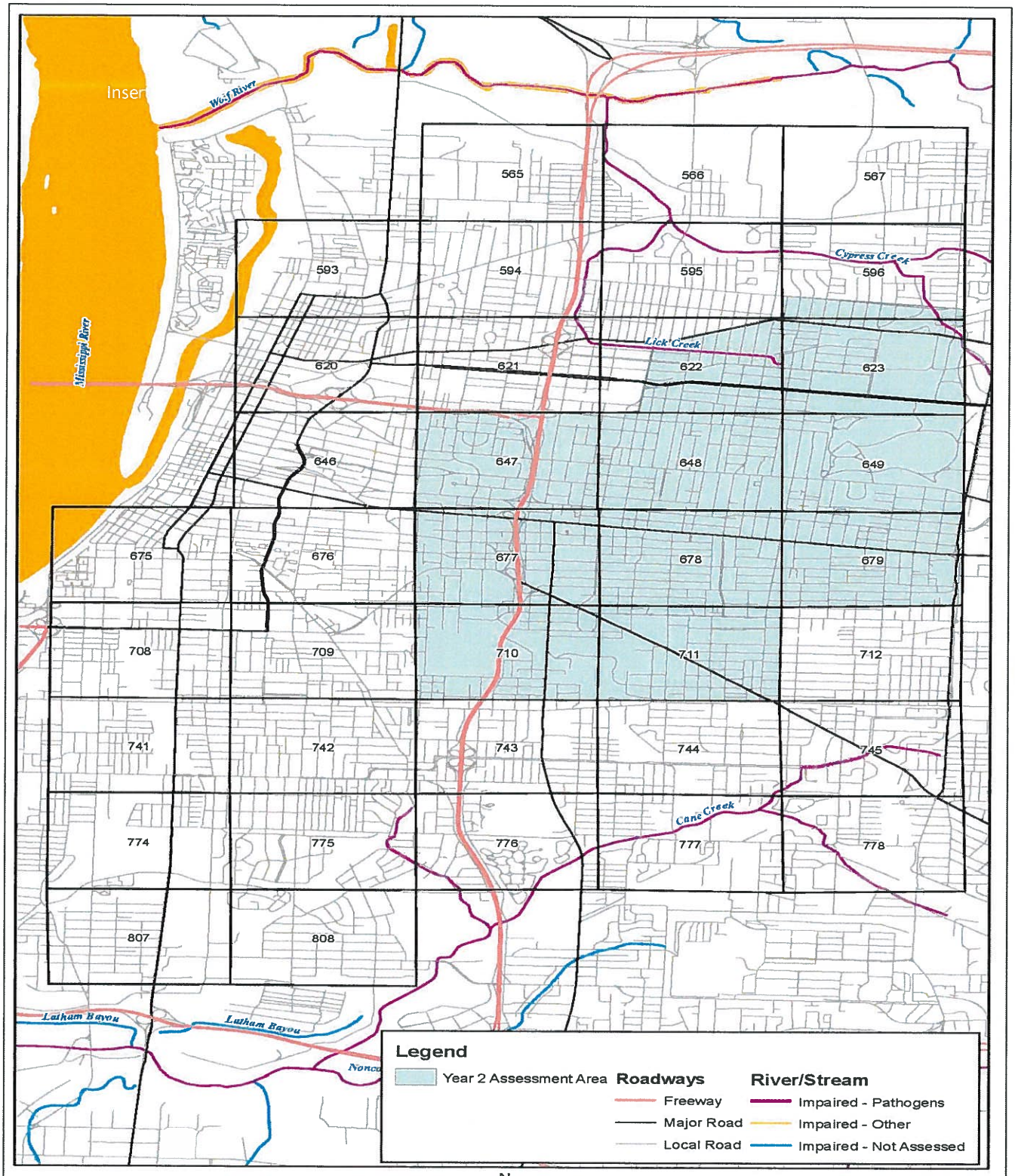
Additional areas will be included for assessment by Memphis in Year 2 of the CSAP, as needed, to meet the goal of assessing approximately ten percent of the WCTS on average per year. These additional areas will be selected, as needed, using the prioritization approach described in Section 3.2.

Pursuant to the Consent Decree, if Memphis undertook assessment work in the Lick Creek area after April 1, 2011 but prior to the second year following approval of the CSAP, and Memphis has otherwise assessed ten percent of other portions of the WCTS in the first year following approval of the CSAP, during the second year following approval of the CSAP, Memphis can take credit for such earlier Lick Creek assessment work.

3.2 Prioritization for Assessment in Future Years

As the assessment work identified for the first two years of the CSAP is completed, Memphis will schedule additional portions of the WCTS for assessment. The following factors will be considered when selecting additional assessment areas, as identified in the Consent Decree:

- Location and causes of SSOs
    - Areas where other MOM programs have identified SSOs
    - Environmentally sensitive areas
    - Areas where SSOs could impact public health
    - Areas that have a potential of high volume SSOs
    - Areas with high frequency of SSOs
- Flow monitoring including flow isolation studies – Although flow monitoring (including flow isolation studies) is not required as part of the Consent Decree, if flow monitoring is conducted in the future, the results of those studies will be considered when prioritizing assessment areas.
- Nature and extent of customer complaints – The nature and extent of customer complaints, which may indicate potential deficiencies within the WCTS, will be considered when prioritizing assessment areas.



CDM Smith

Figure 3-2
Year 2 Assesment Areas
Memphis, Tennessee

- Remedial measures already undertaken – Locations where other remedial measures, as applicable, have been undertaken will be considered when prioritizing assessment work. For instance, if repair work to a lift station has recently been undertaken or is planned and is expected to resolve, in whole or in part, SSOs in the area, Memphis may elect to assign that area a lower priority until the benefits of that remedial measure can be evaluated.
- Field crew work orders – Locations of field crew work orders, as well as the nature of those work orders, will also be considered when prioritizing areas for assessment. If review of the work orders indicates conditions that warrant more immediate assessment, Memphis will prioritize assessment work in these areas.
- Preliminary sewer assessments – Where preliminary sewer assessment information is available, this information will be considered when prioritizing assessment areas.
- Other relevant information – Memphis, will also consider other information deemed relevant to prioritizing areas of the WCTS for assessment. This information will include the following:
  - Age of the sewer system
  - Large Capacity Sewers
  - Proximity to water bodies included on the TDEC 303(d) list as impaired for pathogens.
  - Input from other MOM Programs – Information obtained from other MOM programs
  - Environmental justice areas
  - Contiguous Areas – As a means to utilizing its resources, similar to the approach established for areas in Appendix E and Appendix F of the Consent Decree, the assessment areas may be limited to contiguous areas, such as map book pages, watershed sub-basins, or other geographic boundaries, rather than on individual line segments spread across the City. Memphis' decision regarding prioritization of areas for assessment may consider issues associated with having an assessment area focused on a defined, contiguous geographical area.

In the areas identified for assessment as shown in Appendix E and Appendix F of the Consent Decree, lift stations and force mains are assessed when the adjacent gravity sewer is assessed. In other assessment areas, lift stations may be prioritized and assessed separately from force mains by considering the above-defined list as the criteria relate to lift stations. Separate assessment may be conducted due to the fact that condition assessment requirements and technologies used for the lift stations (electrical, mechanical, structural, etc.) and force mains (overland survey, internal pipe inspections, etc.) are different requirements and skillsets employed by different vendors. Therefore, it is not necessarily advantageous to combine the assessments and perform these disparate activities simultaneously.

Section 4

Gravity Sewer Assessment Techniques

Section 3 discussed the methodology for prioritizing portions of the WCTS for assessment. This section will discuss the different techniques to be considered for assessment of the gravity sewer system. Standard procedures for these techniques are included in Attachment A. The gravity sewer system will be evaluated on its structural condition, as well as for operation and maintenance observations, such as roots or evidence of inflow and infiltration (I/I), with the goal of assessing approximately ten percent of the system each year on average. This information will be obtained and recorded through a variety of techniques. Some of these techniques will be utilized frequently in gravity sewer assessment, such as closed circuit television (CCTV) inspections and manhole inspections. Other techniques will be relied upon less frequently due to special circumstances in which they would be useful. The following techniques are available for use by Memphis in assessing the condition of their WCTS, and Memphis shall use its best professional judgment in determining which options to utilize. Additionally, Memphis will continue to evaluate other existing and emerging assessment techniques, as appropriate, for use as part of the CSAP.

4.1 Closed Circuit Television (CCTV) Inspections

CCTV inspection uses a color television camera inside the sewer to visually establish the pipeline conditions as the camera is propelled through the pipeline. Television inspections are conducted to locate pipe defects and potential I/I sources. Most CCTV cameras can also pan and tilt to locate and inspect the connection between the lateral and the main sewer along the pipe. CCTV inspection covers the entire pipeline from manhole to manhole and is one of the most accurate methods of determining the internal condition of a gravity sewer. However, CCTV may not be well suited if a significant portion of the pipe is below the water line, as the camera cannot determine the condition of the pipe below the water.

CCTV inspections and reports conducted as part of the CSAP will conform to the standards outlined in the National Association of Sewer Service Companies' (NASSCO's) Pipeline Assessment and Certification Program (PACP). PACP uses standardized codes to record defects in a gravity sewer segment. These include structural defect codes, operations and maintenance defect codes, and construction defect codes. Each code can have a rating of 1 through 5 which indicates the severity of the defect (5 is the highest, meaning the most severe defects). These codes and ratings will allow for standardized reporting of a pipe's condition and comparison of the condition among sewer segments inspected.

4.2 Manhole Condition Assessment

Manhole inspections provide basic information including pipe size, depth from rim to invert, and pipeline cover (i.e., street, yard, easement, etc.). Manhole inspections also provide data on defects in the manhole that could cause structural failure or contribute to I/I potentially causing SSOs, as well as identify portions of the collection system in need of cleaning.

Like with CCTV inspections, manhole condition assessments will be conducted with NASSCO's Manhole Assessment Certification Program (MACP). Like PACP for gravity sewer, MACP has a set of standardized defect codes that will be used to classify the condition of manholes.

For MACP, there are two levels of inspections. Level 1 includes basic assessment information that will evaluate the general condition of a manhole. No special equipment or entry into the manhole is required for a Level 1 inspection. Level 2 inspection gathers detailed information that documents the existing defects and determines the condition of a manhole through either manned entry of the manhole or through the use of cameras that are lowered into the manhole.

For each manhole condition assessment under the CSAP, whether a Level 1 or Level 2 MACP inspection is performed, a GPS location of that manhole will be recorded, if possible. If a GPS location cannot be obtained, the manhole location will be estimated from known GPS locations.

4.3 Smoke Testing

Smoke testing can be used to identify sources of I/I in the WCTS. The smoke testing procedure involves placing a blower at a manhole to force a non-toxic, non-staining smoke into the sewer. This smoke will then fill the sewer line, including adjacent private service connections, and follow available paths to the ground surface. Locations where smoke is observed at the surface are then documented through field reports and photographs. Smoke testing generally should not be performed during or immediately following rainfall events or when the ground appears to be saturated.

Smoke observed at the surface may indicate that rainwater or other inflow sources have a pathway to enter the system and contribute to increased flow rates. These pathways may be a result of defects including breaks in the sewer, cross-connections with the storm drainage system, illegal connections such as roof drains, missing or broken cleanout caps, etc.

Prior to smoke testing, customers in the area to be tested and emergency responders will be made aware of the smoke testing activities occurring. Notifications to customers in the area will also instruct the customers to pour water into any drain that may be dry in order to reduce the likelihood of smoke entering their building.

4.4 Corrosion Defect Identification

Although sewer system corrosion may be the result of discharges of highly corrosive materials into the sewer system by industries, the majority of corrosion-related defects typically observed in sewer systems are caused as hydrogen sulfide (H_2S) gas is released from the wastewater and converted into sulfuric acid (H_2SO_4). This acid can damage metal, concrete, and mortar and potentially lead to material failures in the sewer system.

The release of hydrogen sulfide gas is most prominent anywhere turbulence exists in the system, such as at force main discharge locations. Based on historical observations by Memphis personnel, corrosion-related defects have not been observed in the majority of the Memphis system, however, large diameter interceptor sewers may be prone to deterioration caused by corrosion. Additionally, Memphis utilizes plastic-based, non-corrosive pipes, such as polyvinyl chloride (PVC) and high-density polyethylene (HDPE), for new sewer construction wherever possible.

Defects and deterioration caused by corrosion will be identified using CCTV inspection and manhole inspection techniques following PACP and MACP guidance, as described in the previous sections. Corrosion-related defect information will be included in the PACP and MACP electronic databases or otherwise recorded, where applicable. The information developed under the CSAP Corrosion Defect Identification system can be used in subsequent MOM programs, i.e. the IRP, to set forth a basis for evaluating and prioritizing how Memphis will manage and respond to defects found in the WCTS.

4.5 Flow Monitoring

Flow monitoring involves placing sensors into gravity sewer pipes to measure depth and velocity, typically in 5 to 30 minute increments, and using this information, along with the sewer geometry, to calculate the rate of flow. Pump station monitors can also be used for flow monitoring; these monitors log pump run times which can be used in conjunction with pump station drawdown tests to determine the flows discharged by the station. Rainfall data is collected in conjunction with flow monitoring data to determine the relationship between rainfall volume and rainfall-derived I/I volume into the sewers.

According to the Consent Decree, Memphis is not required to perform flow monitoring at this time. However, it may be used in the future for determination of flows or to identify capacity problems, if applicable.

4.6 Gravity Sewer Line Defect Analysis

As discussed in Section 4.1, gravity sewer defects observed through the CCTV inspection process and manhole defects observed through the manhole inspections will be analyzed using NASSCO's PACP and MACP coding, respectively. The PACP and MACP coding establishes standard defect codes to be used in identifying the defects in a pipeline or manhole, standard procedures and guidelines to identify the defects, and a standardized process for cataloging defects. The defect analysis will usually be conducted concurrently with CCTV data collection or manhole inspections.

4.7 Dyed Water Testing

Dyed water testing is primarily used to verify connectivity of the sewer system (e.g., illegal connections) or to locate potential pathways for I/I to enter the sewer system. These pathways can include both direct connections, such as cross connections with an adjacent storm drain system, and indirect connections, such as defects in the sewer system that would allow infiltration.

The dyed water testing procedure varies depending on the purpose of the test. For instance, if a cross connection with a storm drain is suspected, dyed water would be introduced into a catch basin near the line being inspected, and the downstream manhole or sewer is checked for the presence of dye. If dye is observed, then the catch basin may be directly or indirectly connected to the WCTS and additional investigation is warranted. Based on the CCTV and smoke testing results, dyed water testing will be conducted to better pinpoint the location of the defect. Structural defects will be identified using standard codes defined under PACP and MACP standards to the extent applicable.

4.8 Other Assessment Techniques

In addition to the assessment techniques described above, Memphis will utilize additional technologies as part of the CSAP when determined to be applicable and appropriate. This includes techniques that are either relatively new technologies or are applicable in only very limited circumstances. Some of these potential techniques for assessment include:

- Sonar Inspection

  Sonar inspection involves a robotic unit inserted into the pipe that uses sonar to measure the pipe cross section and determine any deviations from the pipe's ideal geometry. Sonar can determine the condition of the pipe by comparing the measured internal diameter of the pipe to the ideal diameter. This detects any deformations inside the pipe as well as the sediment levels in the sewer.

- Laser Profiling

  Laser profiling can be used to obtain a detailed picture of the pipe, including precise measurements of inside diameter, holes, ovality, joints, protruding rebar, etc. Continuous-spinning 3D technology for laser profiling is an accurate method for assessing the extent of corrosion, especially in large-diameter outfalls. This could be especially useful when assessing the large trunk lines that flow to the WWTPs.

- Zoom Camera Inspection

  This technology can be used as an initial screening tool to prioritize areas for subsequent CCTV and/or cleaning and maintenance. The benefit of using zoom camera technology instead of CCTV is that it is less costly than CCTV and can help identify problems more quickly and in a larger portion of the system. When used in conjunction with CCTV, it can provide a cost-effective means of focusing CCTV efforts on the highest priority areas in the system. Sewer Line Rapid Assessment Tool (SL-RAT)

  This proprietary technology by InfoSense allows for a cursory assessment of sewer line blockages. It has a transmitter that produces active acoustic transmissions through the pipe and a receiver that processes the acoustic signals and interprets where there may be blockages. SL-RAT is commonly used in pipes 6-inches to 12-inches in diameter but can be calibrated for larger pipes. It is a rapid assessment tool that only identifies pipes that are blocked. A more detailed inspection using CCTV may be needed if a pipe is identified by SL-RAT as blocked.

Section 5

Force Main Assessment Techniques

The Memphis WCTS consists of nearly 39 miles of force main, approximately half of which are less than one quarter of a mile long. As force mains are identified for assessment through the CSAP prioritization process, a variety of techniques may be selected to complete the assessment. Since force mains are designed to flow under pressure (designed to flow full), the investigation techniques are different from gravity sewers. This includes an initial desktop assessment step, which is followed by physical inspections, if deemed necessary. As provided by the Consent Decree, Memphis shall use its best professional judgment in determining which technique(s) to utilize.

5.1 Desktop Analysis

Force main assessments begin with an initial desktop analysis, which identifies the most likely locations for corrosion or other failures of the force main. Areas identified as potential failure locations will be further investigated in the field, as described in Section 5.2.

The desktop analysis is completed by examining the profile of the force main and identifying locations where the pipe may be partially full and where turbulence from connecting force mains may release hydrogen sulfide gas. If deemed necessary, surge modeling will also be performed as part of the desktop analysis to identify the transient pressure surges that can be found in the pipe under certain conditions, such as during a power failure. Severe pressure transients can have an adverse effect on the integrity of the force main and can cause pipe failure. If conditions warrant, desktop analysis will also include review of previous soil condition studies, investigation of groundwater levels, and investigation of surface conditions.

5.2 Physical Inspections

Depending on the results of the desktop analysis, field investigations can then be used to determine the condition of the force mains. These techniques vary depending on the size and material of the force main and will be selected by Memphis using its best professional judgment. Investigation techniques can be divided into those that require the force main to be taken out of service and those that can be performed while the force main remains in service. **Table 5-1** provides a summary of common force main investigation techniques and their applicability. Memphis may choose to utilize additional technologies as part of the CSAP when determined to be applicable and appropriate. These include techniques that are either relatively new technologies or are applicable in only very limited circumstances.

Table 5-1 Summary of Force Main Assessment Techniques

Investigation Technique	Can Pipe Remain in Service?	Entire Length of Force Main, or Isolated Spot Testing?	Pipe Materials	Size
Internal Visual Inspection, including CCTV	No	Entire Length	Any	4-inch or greater
Sonar Inspection	No	Entire Length	Any	Any
ARV Inspection	Yes	Spot Testing	Any	Any
Leak Detection	Yes	Entire Length	PCCP, Ductile & Cast Iron, Steel, PVC	12-inch or greater

Pipe Coupons	Yes – Excavation Required	Spot Testing	Any	Any

A more detailed description of the force main investigation techniques listed in the table is provided, as follows:

- Internal Visual Inspection

  Internal visual inspection requires the pipe be dewatered and that physical access to the force main is available. It is applicable to any pipe material. This technique is typically used for very large diameter pipes (48 inches and up in diameter) where people will enter the pipe to perform the inspection. This also could be done with a CCTV camera in a smaller diameter pipe similar to how gravity sewer is inspected. The requirement for access and dewatering makes this method expensive for most force mains.

- Sonar Inspection

  Sonar inspection involves a robotic unit inserted into the pipe that uses sonar to measure the pipe cross section and determine any deviations from the pipe's ideal geometry. Sonar can determine the amount of corrosion in the pipe by comparing the measured internal diameter of the pipe to the ideal diameter. If the measured diameter is greater than the ideal diameter, this indicates that corrosion is taking place. Sonar inspection can also measure the amount of grease build up and sediment levels in the force main. The pipe does not have to be dewatered for sonar inspection but it is typically taken out of service. Sonar inspection can be performed on any pipe material.

- ARV Inspection

  Air release valve (ARV) inspection can be done while the force main remains in service. ARVs are normally located in manholes, and therefore can be visually inspected for signs of corrosion without the need for excavation. ARV inspections are regularly conducted as part of the Lift Station and Force Main O&M Program.

- Leak Detection

  Leak detection testing has historically been used successfully in water transmission main testing. This technology can be used to pinpoint leaks in pipes and estimate the magnitude of the leak. The system is inserted into an in-service force main through any tap larger than 2-inches. The probe is carried along the pipe by the flow of water and locates leaks by distinctive acoustic signals generated by the leaks in pipe walls, joints, or welds. Leak detection does not require excavation unless a new insertion point must be constructed.

- Pipe Coupons

  Coupons can be taken from selected locations to determine the amount of internal or external corrosion in any pipe material. However, use of pipe coupons will be limited to taking direct pipe thickness measurements. The disadvantage of taking coupons is that it provides information only at the location where the coupon was taken, and often, corrosion is not uniform.

Additional techniques for force main investigations, such as electromagnetic testing or internal hammer sounding, can also be used in limited circumstances depending on the material and diameter

of the force main. These additional techniques are not described herein but will be considered by Memphis, if needed, to complete the required condition assessments.

5.3 Corrosion Defect Identification

Corrosion is one of the most significant defects that can occur in force mains as it can lead to material failures that eventually can cause an SSO. Corrosion is a result of hydrogen sulfide (H_2S) gas accumulation that is transformed into sulfuric acid (H_2SO_4), which can corrode the pipe material. Hydrogen sulfide is released at air-water interfaces where turbulence occurs, which are commonly seen at force main discharge points, downstream of vacuum valves, or at high points along the force main if an air release valve is not installed.

Based on historical observations of the City staff, force mains within the WCTS have typically not shown evidence of deterioration caused by hydrogen sulfide corrosion, and newly-installed force mains are constructed of non-corrosive materials.

One additional component of the desktop analysis for force mains is the corrosion defect identification process. This is done by examining the profile of the force main and identifying locations where the pipe may be partially full and where turbulence from connecting force mains may release hydrogen sulfide gas. These locations can then be targeted for condition assessment investigations, as described in Section 5.2.

Manholes that serve as force main discharge locations and gravity sewers immediately downstream of force main discharges will be inspected as described in Section 4. Visual inspection of the force main discharge point will be conducted to the extent possible as part of manhole inspection activities.

5.4 Force Main Defect Analysis

Force main defect analysis is dependent upon the condition assessment techniques utilized. As discussed in Section 4.1, defects observed through the CCTV inspection process will be analyzed using NASSCO's PACP coding. The PACP coding establishes standard defect codes to be used in identifying the defects in a pipeline, standard procedures and guidelines to identify the defects, and a standardized process for cataloging defects. The defect analysis will usually be conducted concurrently with CCTV data collection. If other techniques are utilized to assess the force main, defect analysis will occur, as appropriate, for the technology implemented.

Section 6

Lift Station Assessment Techniques

When a lift station is identified for assessment through the CSAP, a variety of techniques will be used to complete the assessment. These assessment techniques are intended to evaluate not only the station's structural integrity but also the station's capacity relative to its anticipated flows and the station's failure history. As provided by the Consent Decree, Memphis shall use its best professional judgment in determining which technique(s) to utilize.

This assessment work will be in addition to the regularly-scheduled lift station inspection and maintenance activities described in the Lift Station and Force Main O&M Program. Information collected through that program will also be used when assessing lift stations as part of this CSAP and in the IRP evaluation and prioritization process. When information described herein is collected through other MOM programs, it will be considered towards the CSAP assessment goal.

6.1 Physical and Mechanical Condition Inspections

As part of the Lift Station and Force Main O&M Program, lift stations undergo inspections to confirm that the station is operating properly and includes several maintenance activities. Personnel will inspect instrumentation and controls for anomalies and inspect mechanical and electrical equipment for proper operation. When a lift station is targeted for assessment through the CSAP, inspection reports for the previous five years, as available, will be reviewed to determine if the station has a history of deficiencies.

Furthermore, a review of a lift station's operating and mechanical failure history in the last five years will be included as part of the physical inspection. This will allow for a historical look at the lift station's condition and can help pinpoint any persistent problems with its operation.

6.2 Capacity Evaluation

When being assessed under the CSAP, an evaluation of lift station capacity will be conducted to determine if that station's capacity is adequate to convey the flows received. As described in the Consent Decree, the capacity analysis of each lift station will be evaluated relative to the guidance in the Pumping Systems chapter of WEF's *Manual of Practice FD-4: Design of Wastewater and Stormwater Pumping Stations*. Because this document primarily provides guidance for the design of new lift stations, the use of the guidance when evaluating existing stations needs to recognize that important distinction. The capacity criteria listed in that document include:

- The station should be designed to discharge the design peak flow, which is the maximum flow that the station will be required to discharge during the design life of the station. However, station design should consider approaches that allow the station to operate efficiently during initial, interim, and design year average flows.
- Pumps installed in a lift station should be capable of discharging the peak flow with the largest pump out of service, while accounting for age in the discharge force main.

- System curves, which are a combination of the system head-capacity curve and the pump curve, should be developed to understand how the system will operate under average and peak flow conditions. These curves also allow an assessment of the efficiency of the pump operation.

To complete this capacity evaluation, the remaining design life of an existing station will be estimated, taking into consideration the year the station was built, any recent improvements to the station, the structural condition of the station, etc. Existing flows and projected future flows at the end of the station's remaining design life will be estimated using available information, such as land use, water use data, existing and projected populations, etc. These flows, which will consider both average and peak wet weather flows, can then be compared to the station's existing capacity.

Alternately, the capacity analysis can proceed by comparing the station's existing capacity to the existing average and peak wet weather flows. If the existing capacity is determined to be adequate, projected future flows can be estimated in five to ten year increments. Using that information, the projected date where the station's existing capacity is anticipated to be exceeded can be determined.

For stations where a pump curve or sufficient pump manufacturer and model data to adequately find a curve, is not available or for locations where it is suspected that the station is not performing as designed drawdown tests can be conducted to identify the pump performance and establish the station's existing capacity.

Additionally, limited pump capacity at a lift station may become evident as other assessment techniques discussed are completed. For instance, excessive pump run times, high nominal average pump operating time (NAPOT), and in extreme circumstances, SSOs upstream of the lift station may suggest the station's capacity is inadequate. SCADA, pump run times, pump start counters, or other information that is collected as part of the Lift Station and Force Main O&M Program, can also be used to analyze station capacity, as well as whether stations can handle peak flow with the largest pump out of service. The results of the analysis will be documented in the lift station inventory or in separate reports.

6.2.1 Nominal Average Pump Operating Time

The nominal average pump operating time (NAPOT), which is only determined for fixed-speed pumps, represents the daily average pump operating time and can be determined over one or more months. NAPOT can be developed using pump run times obtained from the SCADA system or as part of lift station inspections. It is calculated by summing the total hours of pump operation over a given time period and dividing that value by the number of days included in the assessment period. The resulting number is then divided by one less than the total number of pumps installed at the lift station.

For lift stations undergoing assessment through the CSAP, NAPOT can be used as an indicator of whether the lift station's capacity is adequate. Lift stations determined to have a NAPOT greater than 10 hours per day will be targeted for additional investigations through the CSAP and other subsequent evaluations/decisions. NAPOT, however, is not a suitable analysis technique for lift stations with pumps of different sizes or for pumps with variable speed drives. The adequacy of these stations can be determined through an evaluation of pump operating times.

6.3 Evaluation of Station Design

For lift station assessments under the CSAP, the Consent Decree also requires that the design of the station be evaluated, including pump redundancy, electrical power supply, and other equipment

installed, based on the guidance set forth by Chapter 40, *Wastewater Pumping Stations* of the most recent edition of *Recommended Standards for Wastewater Facilities* by the Great Lakes-Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers (commonly known as the "Ten State Standards").

Because this document primarily provides guidance for the design of new lift stations, recommendations described in the "Ten States Standards" may not be applicable to the evaluation of existing stations. When assessed, the following items will be considered, and deficiencies will be noted for consideration in subsequent evaluations/decisions.

- Pumps should have capacity such that, with the largest pump out of service, the remaining pumps will have capacity to handle the design peak hourly flow.
- Pump stations should have appropriate protection from clogging. Stations receiving flow from 30-inch diameter sewers or larger should have bar racks installed.
- Pumps should be capable of passing a 3-inch solid. Pump suction and discharge openings shall be 4-inches in diameter or greater.
- Pumps should be so placed that, under normal operating conditions, they will operate under a positive suction head.
- When in operation, the design pump rate should maintain a minimum velocity of 2 feet per second in the force main.
- Structures and electrical and mechanical equipment should be protected from damage by the 100-year flood and be accessible during the 25-year flood.
- Emergency pumping capability should be provided at a lift station unless overflow prevention is provided by storage. Emergency pumping capability can be accomplished by connection of the station to at least two independent utility substations, through provision of an in-place or portable generator, or by provision of portable pumping equipment. Equipment should be adequate to maintain the total rated capacity of the station.

6.4 Critical Response Time

The critical response time is the time between the activation of the high wet well level alarm and the first SSO under peak flow conditions. Memphis has previously calculated this criterion for the largest 18 lift stations under average, dry-weather flow conditions, as described in the Sewer Overflow Response Plan. As a station is identified for assessment under the CSAP, the station's critical response time will be calculated through a desktop analysis using the estimated peak flow rate into a station and the station's wet well geometry. This resulting critical response time will be compiled as part of the lift station inventory. A comparison between the critical response time and the ability of the City's staff to take corrective action within that time will be one of the factors considered for subsequent action.

6.5 Root Cause Failure Analysis

A root cause failure analysis is a problem-solving technique that attempts to identify and correct the root cause of the event instead of focusing on the event itself. This process recognizes that most failures involve a progression of events and consequences that lead to the failure. In many cases, it is

not necessary to prevent the root cause from occurring; it is only necessary to prevent the chain of events that precede the failure from occurring. For example, if a pump station experiences chronic lift failures due to blockages by rags, it is not necessary to prevent rags from entering the sewer. Instead, redesign of the system to include a screen or grinder may be more appropriate, unless a single source of rags can be identified.

For lift stations identified for assessment under the CSAP, if the station has a history of failures, a root cause failure analysis may be conducted to determine the root cause of the failures. As with the results of other assessment techniques, the result of this analysis is one of the factors considered in subsequent evaluations.

Section 7

CSAP Information Management System

An information management system, consisting of two primary components, will be used to compile and track the data collected in this program. These two components include a Geographic Information System (GIS) and CCTV inspection software.

7.1 Geographic Information System (GIS)

Although limited GIS data to describe portions of the WCTS has been developed, Memphis does not have a comprehensive GIS. A representation of their sewer system is maintained in a collection of 11-inch by 17-inch paper maps, commonly known as the "Sewer Bible." Appendix J of the Consent Decree provides for Memphis to conduct additional GIS work, although it is recognized that any GIS work undertaken by Memphis beyond that required by Appendix J is subject to the City's sole discretion.

Generally, GIS displays map data geographically as well as data that is associated with each feature. For example, a manhole can be shown in GIS in the location it corresponds to in the field relative to other mapped features, including roads and other planimetric features such as building footprints, water body boundaries, and parcel boundaries. In that manhole's data table, it can include attributes such as depth, manhole diameter, etc., if that information is entered by the GIS technician. The sewer system can be digitized easily by recording each manhole with a GPS device as they are inspected by field personnel, importing the manholes captured with GPS into the GIS, and entering any relevant data for that manhole. Additionally, a schematic of the WCTS can be developed by digitizing gravity sewer connectivity by cross-referencing the Memphis paper maps and through evaluation of the data collected through the CSAP.

Memphis will decide the extent to which the GIS work, undertaken pursuant to Appendix J of the Consent Decree, will integrate the data generated under the CSAP program into the GIS program. As noted in Appendix J, the GIS work undertaken pursuant to the Consent Decree will not fully fund the complete translation and integration of all sanitary sewer data into the GIS.

7.2 CCTV Software

CCTV software used in condition assessment of gravity sewers and manholes will provide for a data input structure that is standardized to make review and comparison of the data more straightforward. PACP-certified software, which adheres to PACP Standard Data Format export and import guidelines will be utilized. CCTV inspections will generally consist of tabular inspection data, linked still photos, and digital videos incorporated into a database.

7.3 Other Data Management Methods

Maintaining data electronically with links to the GIS may not be possible depending on the type of assessments conducted or may not otherwise be undertaken as provided for in Section 7.1. In some cases, individual reports describing the assessment and results may be required.