5 Assessment of Existing Facilities and Risks

5.1 Purpose

This chapter provides an assessment of existing facilities to identify the risks that may impact MMSD's ability to meet its future goals. The definition of "existing facilities" varies for each asset system but in general refers to facilities in place as of 2017 to 2019. The assessment of each asset system establishes the date that defines "existing facilities." The purpose of this chapter is to provide a summary of potential risks in the four failure modes—capacity, physical mortality, level of service, and economic efficiency—for each asset system for the planning period from 2020 to 2050. Assets identified to fail beyond 2050 generally are not included in the potential risks presented. The intent of the failure mode analysis is to provide a summary of risks based on the available information at the time of the assessment, as provided within this chapter. The chapter includes details on the number of assets within each asset system and describes the asset information used to evaluate possible asset system failures. The information evaluated under each failure mode has been used to identify potential asset system risks.

A functional description of each asset system is provided in Chapter 1. The level of service risks are identified and evaluated based on the level of service objectives presented in Chapter 3. The capacity risks that are identified and evaluated in this chapter are based on the future demand projections presented in Chapter 4. Chapter 6 presents an alternative analysis for each potential risk and outlines the recommended projects to address these risks.

Intent of Risk Assessment

Assets exist to help deliver organizational goals and risks are anything that MAY prevent this. The risk assessment process serves as an essential tool to help an organization prioritize its investments and identify the best practices to mitigate risk. The risks discussed in this chapter were identified in part by MMSD and 2050 FP project team staff and are informed by engineering judgment. When reading these assessments, it is important to note that these are identified as ***potential*** risks. The projected timing of risks is based on the risk assessment. Not all of the risks outlined in this chapter are actually occurring, nor may they ever occur.

As with Chapter 4, this chapter provides an overview of all four asset systems. In addition, this chapter provides a summary of the systemwide assessments that were conducted for those risks that impact multiple asset systems. The details for these assessments are discussed in the following chapter appendices:

- Appendix 5A, Conveyance and Storage Asset System Assessment of Existing Facilities
- Appendix 5B, WRFs and Biosolids Asset System Assessment of Existing Facilities
- Appendix 5C, Watercourse and Flood Management Asset System Assessment of Existing Facilities
- Appendix 5D, Green Infrastructure Asset System Assessment of Existing Facilities
- Appendix 5E, Energy Reduction Alternatives for 2050 FP Review

5.2 Overview of Asset System Risk Assessments

The asset system assessments conducted in the 2050 FP are summarized at different levels of the asset hierarchy, which are presented in Chapter 1. Each asset system was evaluated at the appropriate asset level for that asset system, as follows:

- **Conveyance and Storage**: The Conveyance and Storage Asset System is divided into eight subsystems. Subsystem eight consists of the inline storage system (ISS) or "Deep Tunnel" and the inline pump station (IPS). Within each subsystem, assets are broken down into a hierarchy that consists of legs, branches, and criticality sections.[1] Conveyance assets are further divided into manholes, sewers, and facility assets, which are those assets associated with pump stations or some other type of monitoring or control structure. In this chapter, the Conveyance and Storage Asset System is summarized at the system level. Subsystems are explained in more detail in Appendix 5A, Conveyance and legs are summarized in leg maps as part of that appendix.
- **Water Reclamation Facilities (WRFs) and Biosolids**: The WRFs and Biosolids Asset System includes the Jones Island Water Reclamation Facility (JIWRF), the South Shore Water Reclamation Facility (SSWRF), and the interplant solids pipeline (ISP), each of which are summarized in this chapter. Within the two WRFs are biosolids processing, liquid treatment, and support systems. Within those categories are major processes (MPs) and unit processes (UPs). There are 19 MPs, under which are 83 active UPs, that are explained in more detail in Appendix 5B, WRFs and Biosolids.
- **Watercourse and Flood Management (WCFM)**: The WCFM Asset System is divided into six watersheds and the risk assessment is performed at the watershed level and explained in more detail in Appendix 5C.
- **Green Infrastructure (GI)**: The GI system is also divided into six watersheds. However, due to the more programmatic nature of GI assets, they are evaluated at the overall system level, not the watershed level. The GI risk assessment is explained in more detail in Appendix 5D.

5.3 Risk-Based Approach

Risk identification, prioritization, and mitigation is a core conceptual process in asset management. Risks are assessed based on desired service levels and performance, projected demands, and changes in customer needs and expectations. For each significant risk, mitigation measures or management approaches must be selected and implemented.

To accomplish the risk identification, prioritization, and mitigation in the 2050 FP, the following risk assessment methodologies were used:

- Asset-level risk assessments
- Risk registers
- Systemwide assessments

[1] A criticality section is a section of metropolitan interceptor sewer (MIS) or near surface collector (NSC), the extents of which are defined by how critical a pipe failure would be. Criticality sections are determined for each leg and branch of the MIS. The length of a criticality section can range from a few feet to several thousand feet.

MMSD ultimately will populate all risks identified in the asset-level risk assessments in the risk registers so that risk ratings can be calculated for all potential risks. During the development of the 2050 FP, the risk registers had been only partially populated. Therefore, the 2050 FP project team used the results from the asset-level risk assessments and systemwide risk assessments in those instances where risk register data were not yet available.

Asset-Level Risk Assessments

Asset-level risk assessments used for failure mode assessments were conducted using available data from the AssetView database and other sources, including hydraulic analyses, mass balances or spreadsheet analyses, as identified in Section 5.4. These assessments defined the risk based on the predicted year/time period of failure, which is defined for each asset system. The development of asset-level data is a work in progress. Even though the AssetView data are not complete and need to be updated and verified by MMSD as the asset management program moves forward, there is enough data to provide meaningful assessments that identify potential risks.

Risk Registers

Risk registers are used to track information about identified risks, such as the nature and severity of risk, as well as proposed, planned, or ongoing actions to manage those risks. MMSD has developed risk registers for each asset system to record higher-level risks that could apply to multiple levels of the asset hierarchy (e.g., system, facility, process). Risks in the risk registers were generally developed based on input from MMSD and Veolia Water Milwaukee, LLC (Veolia) staff familiar with the assets and systems. Each risk was categorized according to failure mode (described in Section 5.4) and assigned a consequence of failure (COF) and a likelihood of failure (LOF). Definitions of COF and LOF were developed in a series of workshops to provide a consistent rating scale for each asset system and to allow comparison of risks between asset systems. Refer to Appendices 5A to 5D for details regarding the risk register for each asset system. The COF and LOF definitions were developed as follows:

- Consequence of failure: COF ratings were assigned based on unique COF definitions defined for each asset system. See Appendices 5A to 5D for details. These definitions provided a basis for MMSD staff and the 2050 FP project team to assign ratings of very low, low, medium, high, and very high to each risk in the risk registers.
- Likelihood of failure ratings were assigned according to the following scale:
  - Very high: event has, is happening, or may occur within 1 year (before 2020)
  - High: event may occur within 5 years (2020 to 2024)
  - Medium: event may occur within 25 years (2025 to 2044)
  - Low: event may occur within 50 years (2045 to 2069)
  - Very low: event is expected to occur after 50 years (2070 or later)

The LOF and COF ratings have associated numeric scores that were multiplied to determine the risk score. An overall risk level (high, moderate, low, minimal) was assigned to each risk based on the risk score as shown in Figure 5-1.

Likelihood of Failure						
Very High	75	75	450	1,875	16,500	75,000
High	25	25	150	625	5,500	25,000
Medium	5	5	30	125	1,100	5,000
Low	2	2	12	50	440	2,000
Very Low	1	1	6	25	220	1,000
		1	6	25	220	1000
Consequence of Failure		Very Low	Low	Medium	High	Very High

	Score Range
High Risk	>10,001
Moderate Risk	1,001 ≤ 10,000
Low Risk	101 ≤ 1,000
Minimal Risk	0 ≤ 100

FIGURE 5-1: RISK MATRIX

Source: MMSD Asset Management team

Systemwide Assessments

Systemwide assessments (i.e., across all asset systems) were also conducted to evaluate MMSD's performance towards meeting regulatory/permit and internal goal targets for the performance indicators (PIs) and key performance indicators (KPIs) identified in Chapter 3.

Summary

For the 2050 FP, the availability and quality of data vary depending on the asset system and the failure mode. Assessments identify risks from MMSD asset systems as of the dates noted for each assessment. Therefore, all significant risks need to be verified to confirm the risk is accurate and has not been identified because of missing or poor-quality data. Insignificant risks should also be verified in the future. Further evaluation of all risks – whether significant or insignificant – is in progress through implementation of the ongoing asset management program, including identification of new or emerging risks as well as modifications based on data verification and clean-up. This is inherent to the process of asset management as assets are constantly changing as is the data associated with them.

5.4 Assessed Failure Modes and Data Sources

Failure Modes

Asset risks were assessed based on four strategic failure modes: capacity, physical mortality, level of service, and economic efficiency. These failure mode assessments can be used to determine the most appropriate investment strategies relevant to the asset. The predicted timing for each failure mode determines the timing of the investment as well as the approach and the cost of asset renewal (evaluated in Chapter 6). The following failure modes were considered for each asset (general asset management definitions provided with more detail provided for each asset system in Section 5.5 through 5.9).

- **Capacity:** the asset or asset system fails to provide the required capacity under projected conditions, as identified in analyses presented in Chapter 4. Capacity analyses were conducted for each asset system.
    - o **Conveyance and Storage:** capacity analyses were based on hydraulic analysis using the final version of the 2014 Comprehensive System Model (CSM) model and on a 5-year recurrence interval for

Conveyance Baseline, Conveyance Future, and Conveyance Buildout Conditions as defined in Appendix 4A, Conveyance Future Demand.

  - **WRFs and Biosolids**: capacity analyses were conducted for each unit process for WRF Baseline, WRF Future, and WRF Buildout Conditions as defined in Appendix 4B, WRFs and Biosolids Future Demand.
  - **Watercourse and Flood Management**: capacity analyses were not explicitly evaluated but instead relied on risks identified in the WCFM Risk Register.
  - **Green Infrastructure**: capacity analyses were not conducted for GI, since, as a newer asset system, capacity data are not readily available, especially for assets installed prior to 2012. In addition, capacity risk for GI is expected to be very low because the flow and load demands placed upon GI assets are not expected to change significantly.

- **Physical Mortality:** the asset physically fails or becomes obsolete due to lack of repairability. Where available, asset mortality was based on predicted remaining useful life as estimated in condition assessments. Where condition assessments were not available, the predicted remaining useful life was based on asset age and a typical useful life for the asset.
- **Level of Service:** the asset fails to meet a defined level of service, as defined for each asset system in Chapter 3. Generally speaking, limited data were available to relate asset-level performance to the KPIs and KIs identified for each asset system. Therefore, level of service failure risks were identified for each system using the risk registers based on institutional knowledge. The WCFM Asset System also included an assessment of failure in operation of an engineered asset and flood-prone structures identified in MMSD Watercourse Management Plans.
- **Economic Efficiency:** the asset is no longer the lowest cost alternative to meet desired service levels. Limited data were available to calculate economic efficiency at the asset level. Therefore, economic efficiency risks were identified in the risk registers based on institutional knowledge of known inefficient assets.

Failure modes were assessed and are presented as four separate evaluations; however, the risks identified under the different failure modes are evaluated together when identifying an asset or asset system investment strategy in Chapter 6. Failures by the different modes described above are projected to occur in different time frames; therefore, it is necessary to understand the projected timing of potential failures. Each failure mode may also have different consequences that need to be considered when developing investment strategies to mitigate the predicted failure.

Words of Caution

The demand for Future Conditions was calculated by interpolating data points between the Baseline Conditions and Buildout Conditions. Interpolation is the process of ***estimating*** unknown data points between two quantities, which in this case are Baseline and Buildout Conditions, where Buildout Conditions are based on MMSD municipalities' projections of growth as documented by the Southeastern Wisconsin Regional Planning Commission (SEWRPC).

All forecasting models rely on historical data and relationships to produce a best estimate about future circumstances. It is important to note that forecasting is an uncertain business and the presence of uncertainty is inherent when making planning, management, or policy decisions. Forecasts invariably turn out to be different than the actual numbers that occur and these forecast errors increase with increased length of the forecast horizon. Therefore, forecasts should be updated when new data, such as 2020 census data, become available.

When reading these projections, it is important to note that the presented numbers are ***estimates*** of future demand conditions at the time of publication of the 2050 FP based on assumptions and—where noted—on planning judgment and should not be considered precise expectations of future conditions. Actual conditions will almost certainly deviate from these estimates.

Data Sources

Table 5-1 provides a summary of the specific risk assessment methodology used for each asset system for each failure mode.

TABLE 5-1: RISK ASSESSMENT DATA SOURCES USED BY ASSET SYSTEM AND FAILURE MODE

	Failure Mode			
Asset System	**Capacity**	**Physical Mortality**	**Level of Service**	**Economic Efficiency**
Conveyance and Storage	Hydraulic Model	AssetView Data Ad Hoc 211 Study	Risk Register Technical Memoranda Ad Hoc 206 Study	Conveyance Risk Register
WRFs and Biosolids	Mass Balance Analysis Hydraulic Analysis Veolia Input Risk Register	AssetView Data Risk Register	Risk Register WDNR Regulations	WRF Risk Register
Watercourse and Flood Management	Risk Register	Spreadsheet Data Risk Register	Spreadsheet Data Risk Register SEWRPC Floodplain Analyses	WCFM Risk Register
Green Infrastructure	Not Applicable	Spreadsheet Data Various MMSD Planning Docs	Risk Register	GI Risk Register
Systemwide	Not Applicable	Not Applicable	KPI/PI Targets vs. Performance	Not Applicable

Source: Chapter 5 Appendices 5A-5D

5.5 Conveyance and Storage Asset System Assessments

Capacity Failure Mode

A conveyance asset can fail if the demand for the asset exceeds its design capacity, which can be caused by pipe deterioration, economic growth, climate changes, conveyance system changes, and increases in infiltration and inflow (I/I). Pipe deterioration is addressed under the physical mortality failure mode assessment. The hydraulic capacity assessment used the hydraulic model to assess demand from economic growth, climate change, and conveyance system changes.

As noted in Chapter 4, the 2050 FP analysis assumes that I/I from the currently-served areas (Conveyance Baseline Conditions) will remain constant and that the only I/I increase will be due to future economic growth. As of this assessment, MMSD had not completed a separate project to perform a full system flow calibration of the hydraulic model. Therefore, to identify potential capacity risks due to increases in I/I not captured in the hydraulic capacity assessment completed for the 2050 FP, an assessment of the status of "enforcement metersheds" was conducted using data from MMSD's Wet Weather Peak Flow Management Program (WWPFMP), which has more current data.

Capacity failure mode assessments in the Conveyance and Storage Asset System are largely based on the ability of the pipelines to convey the anticipated flows described in Chapter 4. There are 329.7 total miles of pipe in the Conveyance system as documented in MMSD's geographic information system (GIS) of 2019. For purposes of the capacity failure assessment, a pipeline is defined to fail when the 5-year level of protection (LOP) is exceeded.

An LOP is a risk-based design criterion that can also be expressed as the probability of occurrence of an event in a given time period (e.g., a 5-year LOP can also be expressed as the 20 percent probability that an event would occur in any one year). For the 2050 FP, MMSD has established a 5-year LOP for protection against the occurrence of two types of events: SSOs and exceedance of critical elevations. The 5-year LOP was specified for these events because:

- SSOs and exceedance of critical elevations can significantly impact water quality and cause severe property damage.
- It is typical practice for municipalities and wastewater utilities to manage the possibility of SSOs by establishing a minimum LOP. Note: Although SSOs are not allowed under MMSD's 2019 Wisconsin Pollutant Discharge Elimination System (WPDES) permit, there are times when SSOs are necessary to prevent severe property damage, including basement backups and significant damage to municipality conveyance systems.
- Exceedance of critical elevations could inhibit free flow from the metropolitan interceptor system (MIS) or local conveyance systems, possibly resulting in basement backups. The 2050 FP uses the pre-defined critical elevations that MMSD has established in conjunction with municipalities within its planning area.
- The 2020 FP has determined for overall system design that a 5-year LOP was acceptable and it would cost 50 percent more to further reduce the risk of SSOs from a 5-year recurrence to a 10-year recurrence while only providing a minimal improvement in water quality. [1].

The purpose of capacity assessments is to identify pipe segments that are predicted to fail due to capacity over the planning period. The final version of the 2014 CSM model was used to conduct the Conveyance capacity assessments. Conveyance Baseline, Future and Buildout Conditions were all used as the basis for the capacity assessment. Conveyance Baseline Conditions were set at 2010, Conveyance Future Conditions at 2035, and Conveyance Buildout Conditions at 2049 for this assessment in order to project the year that assets could exceed design capacity. The following time periods were assigned: 2020 to 2024 (Baseline), 2030 to 2039 (Future), and 2040 to 2049 (Buildout). Data were not interpolated between these time periods. Capacity risks identified under Conveyance Baseline Conditions represent immediate risks that are already occurring or could occur shortly but are presented in the 2020 to 2024 time period to acknowledge that these risks have not been addressed as of the publication of the 2050 FP.

Figure 5-2 presents a summary of projected total risk in the Conveyance system over the planning period, represented as the total number of assets and miles of pipe projected to have capacity constraints under the 5-year LOP. Capacity failures are presented in terms of number of assets and miles of pipe that need to be replaced. The assets listed for each time period are additional assets over and above the assets listed for prior time periods. The capacity assessments only apply to pipeline assets, they do not apply to facility assets. No costs are presented in this chapter. Total project costs for identified projects are included as part of the Capital Repair and Replacement Evaluation in Chapter 6. Additional information on potential Conveyance capacity failures is provided in Appendix 5A, Conveyance.

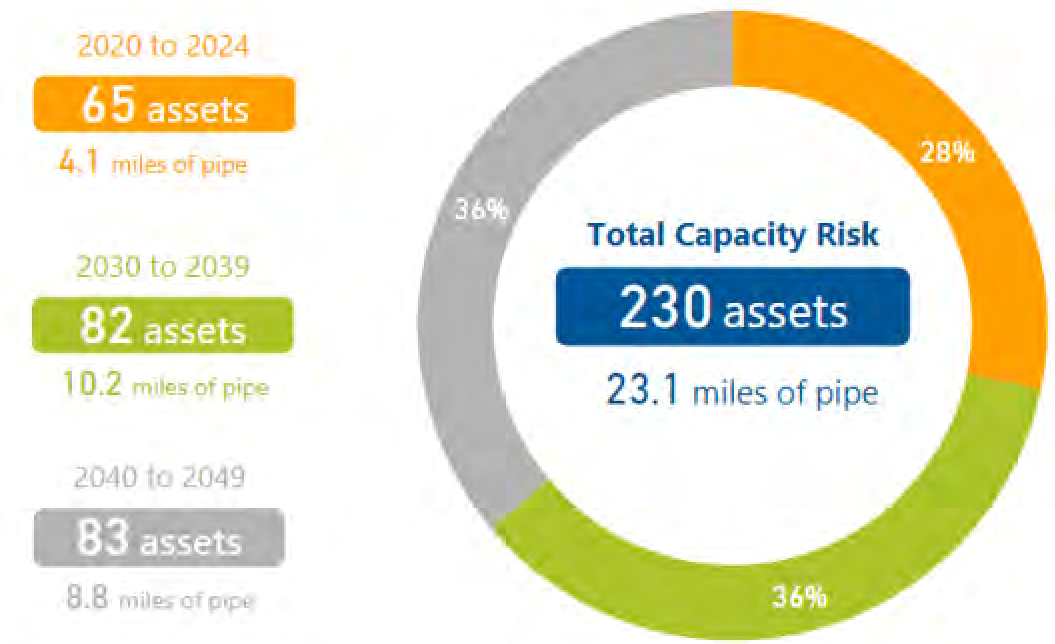

FIGURE 5-2: CONVEYANCE SYSTEM CAPACITY RISKS

Source: MMSD AssetView, assessed in PowerBI

The total capacity risk identified for the Conveyance and Storage Asset System through the year 2049 is 23.1 miles of pipe of the 329.7 miles of pipe in MMSD's GIS, representing 7 percent of the miles of pipe in the system. Figure 5-3, 5-4, and 5-5 indicate which pipe assets are projected to have capacity constraints under the 5-year LOP under Conveyance Baseline, Conveyance Future, and Buildout Conditions.

Enforcement Metershed Compliance

Another way to evaluate potential capacity issues is to review the maximum peak hourly flow of metersheds in the MMSD planning area. There are 146 metersheds within the MMSD planning area that have been identified as enforcement metersheds under MMSD's WWPFMP. [2] [3] MMSD assesses meter data from these enforcement metersheds on an ongoing basis to determine their status. The assessment as of 2019 is presented below:

- 48 Compliant Metersheds: A metershed is considered "compliant" if I/I is less than the maximum allowable peak hourly flow (as a function of the metershed area) as identified in MMSD Rules, Chapter 3, Subchapter 11.
- 21 Non-compliant Metersheds: A metershed is considered "non-compliant" if I/I is greater than the maximum allowable peak hourly flow. The governing units (i.e., municipalities) are responsible for reducing the peak hourly flow rates in their sewersheds associated with the non-compliant metersheds in order to be in compliance with MMSD Rules.
- 66 Not Analyzed: A metershed is considered "not analyzed" if, during the review of meter data, MMSD determined there is not enough data or that the data is very obviously unreliable.
- 11 Inconclusive Metersheds: A metershed is considered "inconclusive" if a calibration was attempted but there were either not enough storm events or enough reliable data to perform a successful calibration of the data.

The findings of the assessment of enforcement metersheds under the WWPFMP as of 2019 are presented in Figure 5-6. Because this assessment used more current data that the hydraulic model (which was not re-calibrated for the 2050 FP project), the 14 percent of metersheds identified as non-compliant indicates that there may be additional capacity risks above those identified by the hydraulic assessment. This information is taken into consideration when conducting alternative analysis to mitigate the capacity risks in Chapter 6.

The WWPFMP program is continuously collecting updated meter data and periodically assessing data to determine if enough meter data is available to update the classifications presented above.

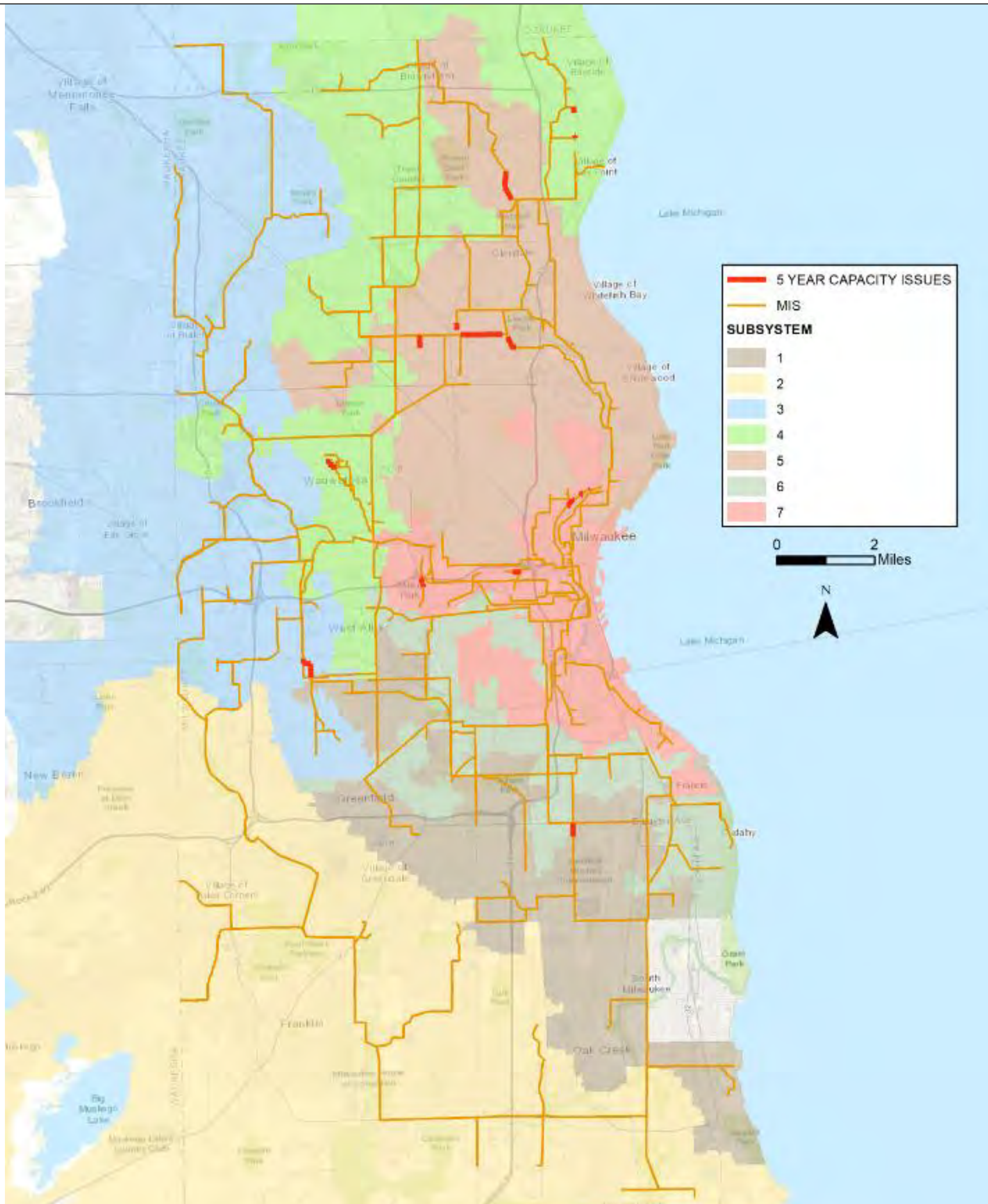

FIGURE 5-3: PROJECTED CONVEYANCE PIPELINE CAPACITY CONSTRAINTS UNDER CONVEYANCE BASELINE CONDITIONS

Source: MMSD GIS, from output from hydraulic model under Conveyance Baseline Conditions

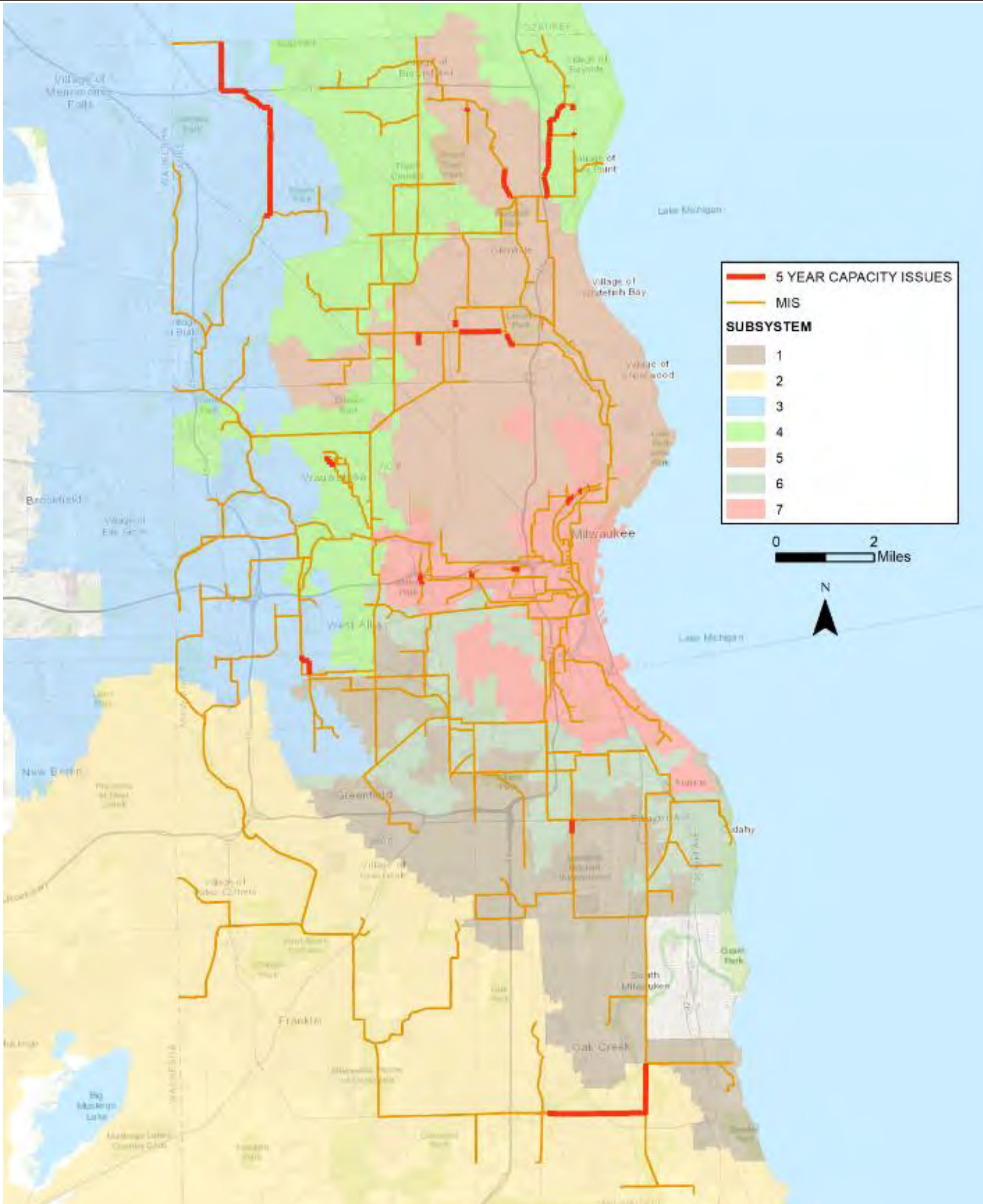

FIGURE 5-4: PROJECTED CONVEYANCE PIPELINE CAPACITY CONSTRAINTS UNDER CONVEYANCE FUTURE CONDITIONS

Source: MMSD GIS, from output from hydraulic model under Conveyance Future Conditions

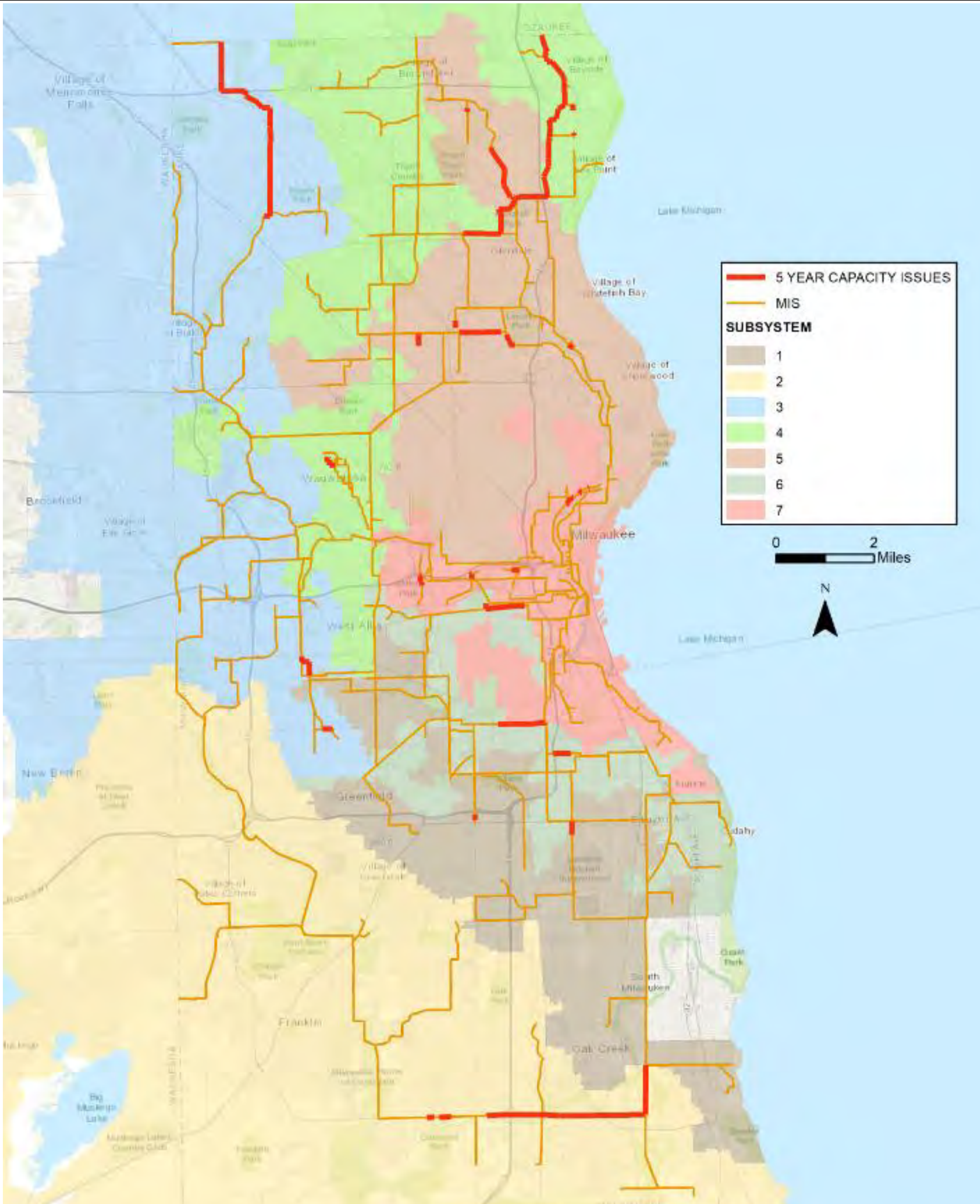

FIGURE 5-5: PROJECTED CONVEYANCE PIPELINE CAPACITY CONSTRAINTS UNDER BUILDOUT CONDITIONS

Source: MMSD GIS, from output from hydraulic model under Conveyance Buildout Conditions

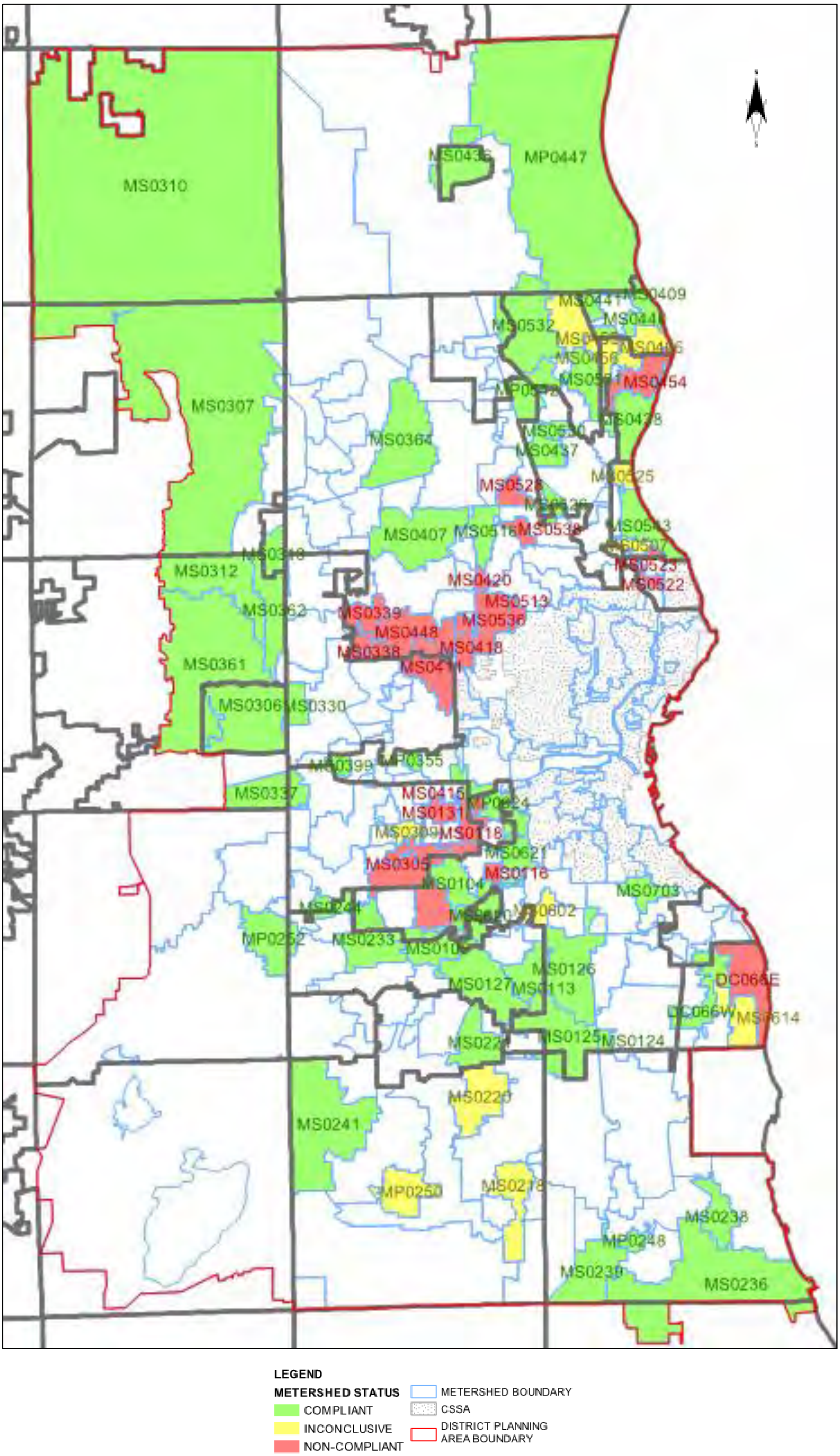

FIGURE 5-6: STATUS OF ENFORCEMENT METERSHEDS AS OF 2019

Source: MMSD WWPFMP

Physical Mortality Failure Mode

AssetView Analysis

Physical mortality failure mode assessments are performed to identify potential failure due to asset deterioration. The remaining life of an asset can be difficult to predict. MMSD has developed a methodology to estimate the remaining life of each asset based on progressively detailed investigations. The asset remaining life and the resulting predicted year/timing of failure, available from MMSD's AssetView system as of June 6, 2019, were used as the primary basis for this analysis. The physical mortality assessment applies to both pipeline and facility assets (pump stations, manholes, etc.). Figure 5-7 presents a summary of physical mortality risks identified in the Conveyance system over the planning period as the miles of pipe and number of assets that are identified for rehabilitation/replacement, with details below the figure. The assets listed for each time period are additional assets over and above the assets listed for prior time periods. Note that the predicted time of failure identified in this assessment does not indicate that a failure has actually occurred but rather it indicates which assets should be of highest priority to replace due to age. In addition, assets that are indicated to have reached their useful life "Before 2020" are based on the AssetView data and do not take into account any active projects that had not been documented in AssetView as of June 6, 2019. Additional information on potential mortality failures is provided in Appendix 5A, Conveyance.

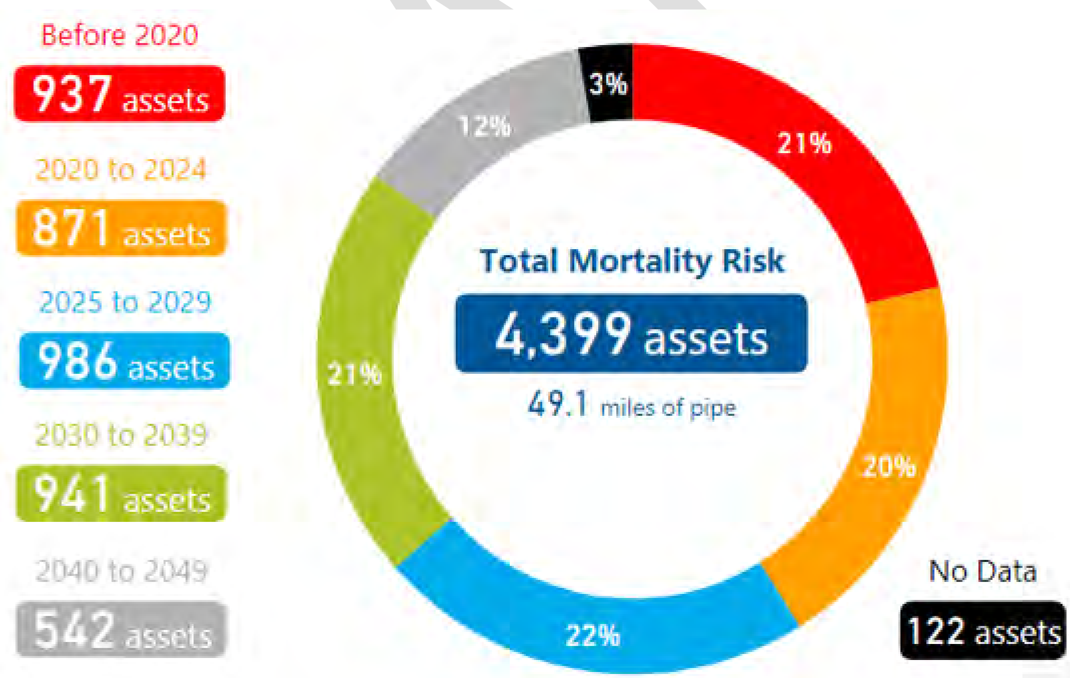

FIGURE 5-7: PROJECTED CONVEYANCE SYSTEM PHYSICAL MORTALITY RISKS

Source: MMSD AssetView, assessed in PowerBI

The total physical mortality risk identified for the Conveyance and Storage Asset System through the year 2049 is almost 4,400 assets and 49.1 miles of pipe of the over 9,900 assets and 284.4 miles of pipe reviewed, representing 44 percent of the assets and 17 percent of the miles of pipe in the system. The potential risks in each time period were identified as follows:

- 937 assets are predicted to fail due to physical mortality before 2020. As noted at the beginning of this section, this assessment is not stating these assets actually failed prior to 2020 but instead indicates that these assets should be the highest priority to replace due to age. The bulk of these assets are located in Subsystems 5, 7, and 8. In Subsystem 8, there are 346 assets identified as having reached the end of their useful life. Of these, 45 are mechanical, electrical, and instrumentation and control (I&C) system assets located at the ISS Pump Station (ISS PS), which is over 50 percent of the 82 assets identified at the ISS PS.
- 871 assets are predicted to fail due to physical mortality in the 2020 to 2024 time period. These are distributed between multiple subsystems, with Subsystem 5 indicating the greatest number of assets reaching the end of their useful life prior to 2024.
- 986 assets are predicted to fail due to physical mortality in the 2025 to 2029 time period. These are distributed between multiple subsystems, with Subsystem 5 and Subsystem 6 indicating the greatest need prior to 2029.
- 941 assets are predicted to fail due to physical mortality in the 2030 to 2039 time period. These are distributed between multiple subsystems, with the most assets identified in Subsystem 5. Subsystem 8 also has a number of assets identified, of which are 20 mechanical, electrical, and I&C system assets located at the ISS PS.
- 542 assets are predicted to fail due to physical mortality in the 2040 to 2049 time period. These are fairly well distributed across all subsystems, with the greatest renewal needs in Subsystems 3 and 4.
- 122 assets did not have data related to the predicted year/time period of failure. These assets, mostly located in Subsystems 4 and 5, present a potential mortality risk in the planning period.

Ad Hoc 211 Study

In addition to the physical mortality assessment completed with the AssetView data for this project, MMSD undertook a review of the impact on I/I due to the degradation of the system, which is documented in Ad Hoc Request 211. [4] The hydraulic analysis undertaken for the 2050 FP assumes an increase in I/I only due to new growth, which is consistent with WDNR facilities planning requirements. However, there is a risk that I/I will increase as pipes continue to age. Ad Hoc Request 211 reviewed the impact that ongoing pipe degradation would have on the likelihood of SSOs, assuming a 7 percent increase in I/I per decade due to pipe degradation, which equals a 14 percent increase in I/I from Conveyance Baseline Conditions to Conveyance Future Conditions. The Ad Hoc Request 211 study found that if pipes are not repaired or rehabilitated, baseline I/I flows by the end of the regulatory planning period (2040) would increase the risk of an SSO by 375 percent over and above the risks identified in the Capacity Failure Mode assessment.

Level of Service Failure Mode

MMSD and the 2050 FP project team developed initial risk registers to identify and track potential risks for each asset system. The Conveyance Risk Register developed in 2016 was used as the primary basis for assessing level of service failures using the level of service categories defined in Chapter 3. Figure 5-8 presents a summary of the level of service risks identified in the risk register for the Conveyance system. For purposes of this assessment, “Multiple Subsystems” refers to risks that apply to more than one Conveyance subsystem or the entire Conveyance system. A summary table of level of service risks in the risk register is provided in Appendix 5A-9, included in Appendix 5A. The level of service risks are broken down by subsystem and the level of service category in Table 5-2. For the 2050 FP, MMSD focused on the five high risks identified as Multiple Subsystem that applied to the entire Conveyance and Storage Asset System that are not already being address by MMSD strategies. These high Multiple Subsystem risks are summarized in Table 5-3.

In addition to the systemwide risks included in the Conveyance Risk Register, MMSD has identified one additional risk of concern, associated with Subsystem 6: High frequency of SSO at BS0603 (43rd & Lincoln) as it relates to SSOs.

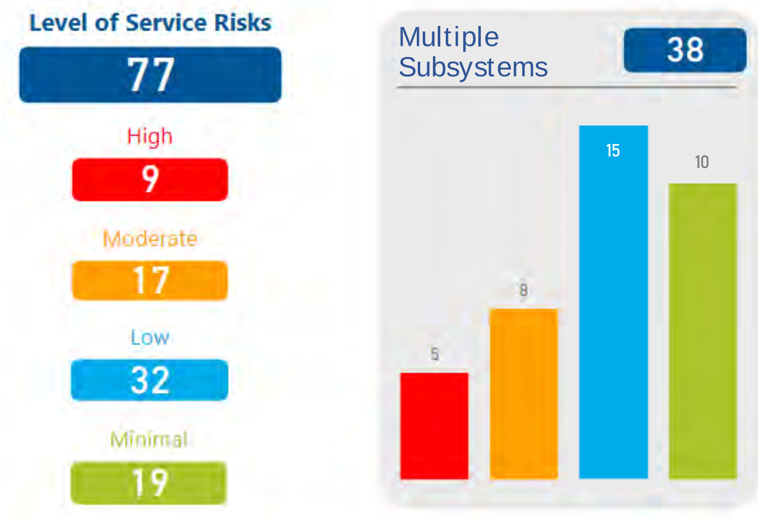

FIGURE 5-8: SUMMARY OF CONVEYANCE SYSTEM LEVEL OF SERVICE RISKS IDENTIFIED IN RISK REGISTER

Note: Level of Service risks listed on the left represent all risks in the Conveyance and Storage Asset System. Out of all of the risks, 38 are identified as "Multiple Subsystems" which are presented on the right.

Source: Appendix 5A-9, Conveyance Risk Register

TABLE 5-2: CONVEYANCE SYSTEM LEVEL OF SERVICE RISKS BY CATEGORY

Level of Service Category	High Risks	Moderate Risks	Low Risks	Minimal Risks	Total
Permit Requirements	Multiple – 1 Subsystem 2 – 1 Subsystem 4 – 1 Subsystem 5 – 1 Subsystem 6 - 1	Multiple – 1 Subsystem 1 – 1 Subsystem 3 – 1 Subsystem 4 – 1 Subsystem 5 - 3	Multiple – 4 Subsystem 3 – 2 Subsystem 5 – 2 Subsystem 6 - 2	Subsystem 8 - 1	23
Energy		Multiple – 1			1
Environmental Improvements			Multiple – 1		1
Fiscal Responsibility		Multiple – 1	Multiple – 3	Multiple – 2 Subsystem 8 - 2	8
Management Effectiveness			Multiple – 3	Multiple – 3 Subsystem 1 – 1 Subsystem 6 – 1	8
Safety	Multiple – 2	Multiple – 5 Subsystem 6 – 1	Multiple – 2 Subsystem 2 – 1 Subsystem 3 – 2 Subsystem 5 – 3	Multiple – 2 Subsystem 4 – 1	19
Customer Service, Communication, and Employee Development	Multiple – 2		Multiple – 2 Subsystem 3 – 1 Subsystem 5 – 3 Subsystem 7 – 1 Subsystem 8 - 2	Multiple – 2 Subsystem 5 – 1 Subsystem 6 – 1 Subsystem 8 - 1	16
Multiple Categories				Multiple – 1	1
Total	9	15	34	19	77

Source: Appendix 5A-9, Conveyance Risk Register

TABLE 5-3: HIGH LEVEL OF SERVICE RISKS ACROSS MULTIPLE SUBSYSTEMS IDENTIFIED IN CONVEYANCE RISK REGISTER NOT ALREADY ADDRESSED BY MMSD STRATEGIES

Risk ID	Risk Level	Risk Description
C060	High	Risk of sediment accumulating due to low flows during dry weather, which may lead to odor and hydrogen sulfide (H_2S) issues in sewers as well as additional maintenance/cleaning. Low flows create other risks as well, such as increased volatile fatty acids and higher strength wastes to WRFs that may challenge treatment strategies.
C066	High	The methodology used during the 2020 FP for developing future flows creates challenges for municipal development once flow allocations for the planning horizon are met. Additionally, increased flows from new development lower the level of protection against separate sewer overflows (SSOs) and combined sewer overflows (CSOs). Future flows must be determined so that conveyance projects can be planned to accommodate the flows.
C085	High	Risk of too much clear water in the system and increase to conveyance, storage, and treatment costs as well as basement backups, SSOs, and negative public perception due to failure to achieve goals for I/I reduction.
C126	High	Risk of pipe damage and safety concerns H_2S present in MIS in various parts of the conveyance system.
C159	High	Community risk/cost of water in basements (WIB).

Source: Appendix 5A-11, Conveyance Risk Register – LOS Risks

Concurrent to the development of risks identified in the Conveyance Risk Register, MMSD identified several risks that could apply to the entire Conveyance and Storage Asset System for which additional assessments were conducted (risks that overlap with risks in the Conveyance Risk Register noted below):

1. The risk of potential corrosion issues and odor complaints due to hydrogen sulfide. (Risk C126)
2. Risks due to access limitations in pipelines, which prevent/limit sewer cleaning and emergency access.
3. Risks due to outfalls with limited free discharge, which can cause surcharging in the MIS and ultimately may lead to basement backups.
4. Risks due to low velocity in pipes, which can contribute to sediment buildup, associated odors, and can affect the capacity of the pipelines. (Risk C060)
5. Risks due to the potential presence of polychlorinated biphenyl (PCBs) in the Conveyance system.
6. The risk to the ISS if the ISS PS was inoperable.

Analyses 1 – 4 are included in leg maps, where applicable, and in Appendices 5A-13 through 5A-16 as a part of Appendix 5A, and are addressed further in Chapter 6. PCB presence, identified in the leg maps that are included as Appendix 5A1-7, will be further analyzed by MMSD outside of the 2050 FP. The risk to the ISS if the ISS PS was inoperable would be an increase in CSOs, with the risk that the ISS PS could be inoperable covered under

Physical Mortality in the Conveyance and Storage Asset System and Appendix 5B, WRFs and Biosolids, related to risk of power outage at JIWRF.

Economic Efficiency Failure Mode

The Conveyance Risk Register developed in 2016 was used as the primary basis for assessing economic efficiency failures. Figure 5-9 presents a summary of economic efficiency risks identified in the risk register for the Conveyance System. Eight risks were identified, but none of them was classified as high risk and therefore no economic efficiency risks are analyzed in Chapter 6. A summary table of economic efficiency risks in the Conveyance Risk Register is provided in Appendix 5A-9 as a part of Appendix 5A.

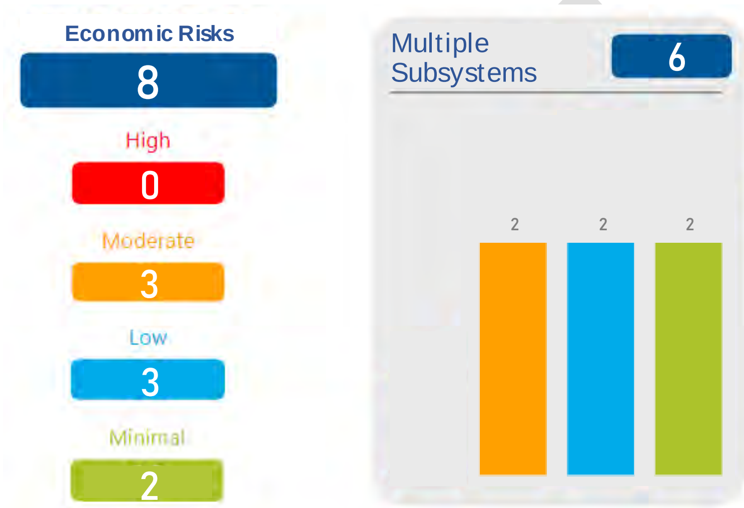

FIGURE 5-9: CONVEYANCE SYSTEM ECONOMIC EFFICIENCY RISKS

Note: Economic Efficiency risks listed on the left represent all risks in the Conveyance and Storage Asset System. Out of all of the risks, 6 are identified as "Multiple Subsystems" which are presented on the right.

Source: Appendix 5A-11, Conveyance Risk Register – Economic Efficiency Risks

Summary of Conveyance and Storage System Risks

Figure 5-10 presents the number of identified asset risks for the two failure modes with information on predicted timing of failure: the capacity and physical mortality failure modes. The figure shows that improvements driven by physical mortality account for the majority of the renewal needs, but significant capacity improvements may be required in the planning period. It should also be noted that some pipes were identified as both capacity and physical mortality risks, so the number of assets presented in Figure 5-10 does not necessarily match values in prior figures. In such cases, the count is assigned to the driving failure mode that is predicted to occur first.

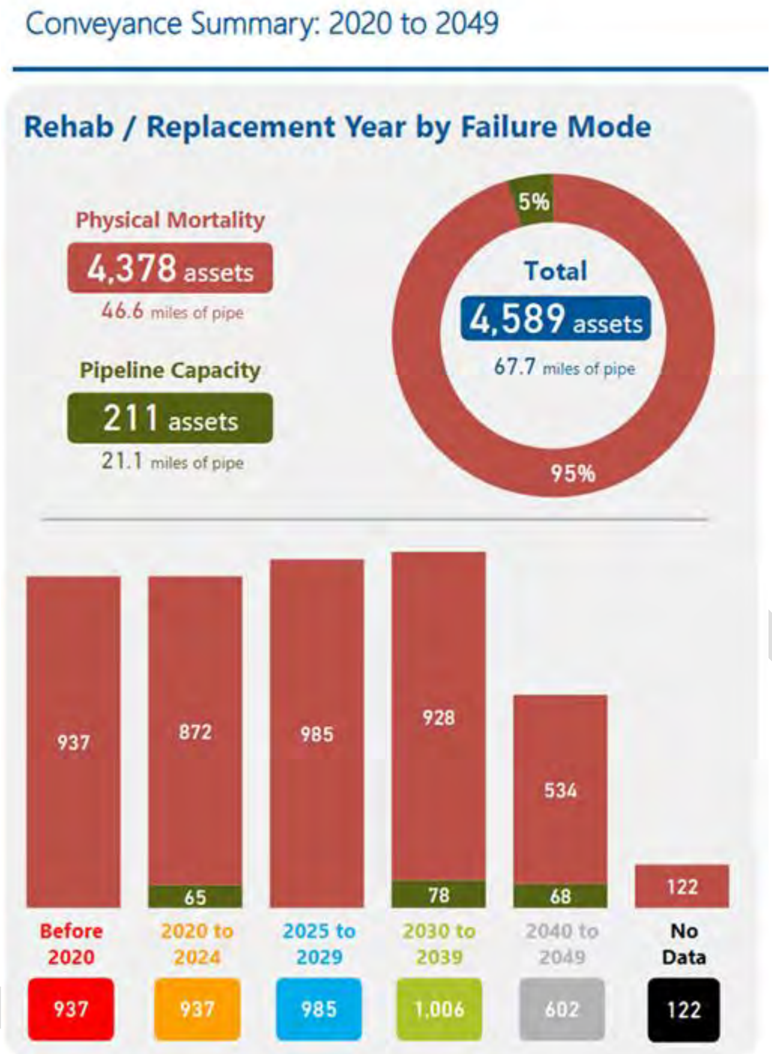

FIGURE 5-10: SUMMARY OF PROJECTED CONVEYANCE AND STORAGE SYSTEM CAPACITY AND PHYSICAL MORTALITY RISKS BY TIME PERIOD

Source: MMSD AssetView, assessed in PowerBI

The following summarizes the identified Conveyance and Storage Asset System risks:

- **Capacity Risks:** There are 211 assets within the 2020 to 2050 planning period that are driven by capacity constraints, with 65 identified in the 2020 to 2024 time period. Following are some considerations when reviewing these risks.
  - The bulk of the capacity risks under Conveyance Baseline Conditions are identified in Subsystem 5, with smaller quantities in Subsystems 1, 3, 4, and 7. By Buildout Conditions, all subsystems are projected to have capacity risks.

  - Identified capacity needs are based on model simulations. In some cases, the model may have overestimated flows in particular branches, which could affect the timing and need for these improvements. It is recommended that flow monitoring be performed to verify that the estimated flows from the model occur and that capacity is truly an issue.
  - Capacity needs were identified based on the simulation year used in the analysis. For example, improvements associated with the Conveyance Future Conditions simulation were placed in 2035. In reality, these improvements would need to be in place prior to 2035 if the projected population and land use growth is realized. Although this is not conservative, it was considered to be reasonable to offset conservatism in other aspects of the capacity analysis.
  - Capacity needs identified in the Conveyance Baseline Conditions model simulation were assigned to the year 2020, so these improvements appear in the 2020 to 2024 time period in this analysis.
  - Needed capacity at JIWRF to maintain the baseline CSO frequency is reviewed in Appendix 5B, WRFs and Biosolids.
  - The assessment of enforcement metersheds indicates that at least 14 percent of the metersheds are identified as non-compliant, indicating that there may be even more capacity risks than those identified under the hydraulic capacity assessment.
- **Physical Mortality Risks:** In total, 4,378 pipeline assets are projected to have physical mortality risks within the 2020 to 2050 planning period, with 937 predicted to occur before 2020. As noted at the beginning of this section, this assessment is not stating these assets actually failed prior to 2020 but instead indicates that these assets should be the highest priority to evaluate to determine whether they need replacement due to age. Following are some considerations when reviewing these risks.
  - The bulk of the physical mortality risks predicted to occur before 2020 are located in Subsystems 5, 7, and 8. In Subsystem 8, there are 346 assets identified as having reached the end of their useful life. Over 50 percent of mechanical, electrical and I&C system assets located at the ISS PS are identified as having reached their useful life.
  - The physical mortality-driven needs include some pipes that are also projected to need capacity improvements, so those pipes are instead identified for replacement under the capacity assessment. Chapter 6 provides guidance regarding actions to take if system flows do not increase as predicted.
  - There are 122 assets that have unknown physical mortality risks since there are no data on the predicted year/time period of failure either due to not having an installation year or not having an assigned design life. It is recommended that the asset age be determined and, if possible, the condition of these assets be evaluated to develop an estimated rehabilitation or replacement year due to physical mortality.
  - There are 45 mechanical, electrical, and I&C system assets located at the ISS PS projected to need replacement or rehabilitation prior to the year 2020, which is over 50 percent of the 82 assets identified at the ISS PS.
  - The findings from Ad Hoc 211 study indicate that if pipes are not maintained to address the ongoing degradation of the sewer system over time and I/I is assumed to increase by 14 percent during the regulatory planning period of 2020 to 2040, the risk of an SSO will increase by 375 percent over and above the risks identified in the Capacity Failure Mode assessment.

- **Level of Service Risks.** There are five high level of service risks that apply to multiple subsystems, along with one risk associated with SSO concerns in Subsystem 6. The additional analyses that were conducted identified the following risks:
  - Risks associated with hydrogen sulfide, access limitations, outfalls with limiting free discharge, and low velocity.
  - The risk of the ISS PS being inoperable is also related to power outage at JIWRF, which is a risk identified in Appendix 5B, WRFs and Biosolids.
- **Economic Efficiency Risks.** There were no high-level economic efficiency risks identified for this asset system.

While significant potential improvement needs are identified in the next 10 years, a significant majority of potential needs are identified in the 2030 to 2050 time period, when estimates are considered to be less reliable. As more data are collected as part of MMSD's asset management process, these estimates are expected to be refined.

Note that there is some overlap between the risks identified under each failure mode. Chapter 6 identifies potential alternatives to mitigate the risks, presents total project costs for each alternative, and identifies recommended projects.

5.6 Water Reclamation Facilities and Biosolids Asset System Assessments

Capacity Failure Mode

Capacity assessments in the WRFs and Biosolids Asset System used mass balances to determine the ability of the UPs in each MP to process and treat the projected flows and wasteloads. The focus of the capacity assessment is on liquid treatment and biosolids processing facility divisions; therefore, although the MPs that fall under support systems are presented for each facility, they were not assessed. A UP is projected to be at risk of failure (or capacity-deficient) when the projected flow, wasteload, or other key parameter exceeds its design capacity as established O&M Manuals as of 2018. [6] [7] All UPs were also assessed against 2017 Wisconsin Administrative Code Chapter NR 110 (NR 110) requirements[2] and 10 States Standards guidance. [8] [9] The purpose of this assessment is to identify projected gaps between design capacity and future flows and loads over the planning period. An additional risk for some of the gaps is that if the gap is not addressed MMSD's 2019 WPDES permit limits could be exceeded. Confirmation of the risk, including more detailed analysis, and timing of recommended projects to address confirmed capacity gaps prior to exceeding design capacity is addressed in Chapter 6. Tables 5-4, 5-5, and 5-6 provide a summary of identified capacity deficiencies and which time period they are first projected to occur within the planning period at JIWRF, SSWRF, and ISP respectively. Where the tables indicate a projected capacity risk "Before 2020," this does not mean the UP has failed or is about to fail, but instead indicates a risk that warrants further analysis in Chapter 6.

Additional capacity assessments were also completed, including identification of potential single-point failures and redundancy limitations, and capacity risks documented in the WRF Risk Register. Additional information regarding these capacity risks and the analyses development for the assessment is provided in Appendix 5B.

[2] Current (2017) NR 110 requirements were reviewed to provide an additional perspective for assessing the capacity risk of a major process. In instances where NR 110 requirements differ from projected values, MMSD is not in violation of the NR 110 requirements, which are applicable to new and modified facilities.

JIWRF Mass Balance Capacity Assessment

The results of the capacity assessment are documented in the WRF Capacity Assessment, which is provided in Appendix 5B-9 as a part of Appendix 5B. The assessment identified nine UPs at JIWRF where projections indicate they may have deficient capacity within the 2020 to 2039 regulatory planning period, as shown in Table 5-4. The projected timing of these potential capacity deficiencies are as follows:

- 3 UPs are projected to exceed capacity before the year 2020
- 2 additional UPs (5 total) are projected to exceed capacity by the year 2024
- 2 additional UPs (7 total) are projected to exceed capacity by the year 2029
- 2 additional UPs (9 total) are projected to exceed capacity by the year 2039
- No additional UPs are projected to exceed capacity by the year 2049

Details about the three UPs that are projected to have deficient capacity by 2020, grouped by associated MP, are as follows:

- MP04 – Aeration: One UP is projected to have deficient capacity. An increase in the primary effluent biochemical oxygen demand (BOD) load is projected to exceed the volumetric loading rate of UP05 – Secondary Flow Control/Aeration by the year 2020. Note that anecdotal information from MMSD staff indicates that JIWRF secondary treatment does not have capacity issues. Design parameters do not include the large volume of aerated channels provided at JIWRF, which may be providing more treatment than the original design conditions specified. Further analysis of secondary treatment at JIWRF is included as part of the evaluation of this risk in Chapter 6.
- MP05 – Secondary Clarification: One UP is projected to have deficient capacity. UP06 – Secondary Clarification is projected to exceed solids loading rate design parameters by the year 2020 due to projected biosolids loadings to the UP. The same note regarding the aerated effluent channels stated under MP04 above applies to this MP.
- MP08 – Sludge Thickening: One UP is projected to have deficient capacity. UP10 – Sludge Thickening appears to be exceeding its maximum month tons of solids per day processed design parameter under WRF Baseline Conditions, even with all four gravity belt thickeners in service.

Interim Level of Service Target to Maintain Baseline CSO Frequency

In addition to the capacity assessment presented in Table 5-4, a separate assessment was completed to determine the potential risk of JIWRF UPs not being able to maintain the baseline CSO frequency of 3.25 CSOs per year, as defined in Chapter 4). The ability to maintain the baseline CSO frequency under WRF Future and Buildout Conditions would require JIWRF to increase peak hourly flow capacity up to 425 MGD under WRF Future Conditions and up to 490 MGD under Buildout Conditions. Depending on whether wastewater is processed through full peak hydraulic capacity or through use of blending,[3] the following UPs are projected to have deficient capacity under WRF Future and Buildout Conditions:

- Full Peak Hydraulic Capacity (11 UPs): all three UPs in MP01, Preliminary Treatment; UP04, Primary Clarification under MP02, Primary Treatment; both UPs under MP04, Aeration; the UP under MP05, Secondary Clarification; both UPs under MP06, Activated Sludge; and both UPs in MP07, Plant Effluent
- Blending (3 UPs): blending under MP02, Primary Treatment and both UPs in MP07, Plant Effluent

This assessment assumes the amount of wastewater processed through JIWRF would increase. This increase in wastewater increases the risk of exceeding wasteload allocation (WLA) limits imposed as part of MMSD's 2019 WPDES permit on total suspended solids (TSS) (monthly and weekly limits) and total phosphorus (TP) (monthly limits).

TABLE 5-4: NUMBER OF UNIT PROCESSES PROJECTED TO START BEING CAPACITY DEFICIENT AT JONES ISLAND WRF FOR EACH TIME PERIOD

Major Process	Before 2020	2020 to 2024	2025 to 2029	2030 to 2039	2040 to 2049	2050 or Later	Not Assessed	Total
MP01 - PRELIMINARY TREATMENT						3		3
MP02 - PRIMARY CLARIFICATION			1			2		3
MP03 - IRON MANAGEMENT							1	1
MP04 - AERATION	1					1		2
MP05 - SECONDARY CLARIFICATION	1							1
MP06 - ACTIVATED SLUDGE		1		1				2
MP07 - PLANT EFFLUENT						2		2
MP08 - SLUDGE THICKENING	1					1		2
MP10 - SLUDGE DEWATERING		1						1
MP11 - SLUDGE DRYING			1					1
MP12 - MILORGANITE PRODUCTION						1	1	2
MP13 - MILORGANITE STORAGE				1				1
MP14 - MILORGANITE WASTE PROCESSING & DUST CONTROL						1		1
MP15 - POWER GENERATION							3	3
MP16 - PLANT WATER AND DRAIN							1	1
MP17 - PLANT UTILITIES							4	4
MP18 - FACILITIES MANAGEMENT							3	3
Not Assigned							2	2
Total	3	2	2	2	0	11	15	35

Source: Appendix 5B-5, WRF Capacity Assessment

SSWRF Mass Balance Capacity Assessment

The results of the capacity assessment are documented in the WRF Capacity Assessment, which is provided in Appendix 5B-6 as a part of Appendix 5B. The assessment identified six UPs at SSWRF that projections indicate may have deficient capacity within the 2020 to 2039 regulatory planning period, as shown in Table 5-5. The

[3] *Full peak hydraulic capacity is the peak hydraulic flow that can be passed through all of JIWRF major liquid processes. Blending is the flow pumped from the ISS Pump Station to disinfection.*

review against current NR 110 requirements[4] identified one additional UP (UP08 under MP07), which is also included in the table. The projected timing of risks to these seven UPs is as follows:

- 5 UPs are projected to have deficient capacity or are projected to have parameters above 2017 NR 110 requirements (UP08 under MP07) before the year 2020
- 1 additional UP (6 total) is projected to have deficient capacity by year 2029
- 1 additional UP (7 total) is projected to have deficient capacity by the year 2039

Four of these UPs are related to primary and secondary treatment, which have had capacity issues in recent years and are the subject of a root-cause analysis study and a performance and aeration evaluation report, both of which were anticipated to be final in 2019.

The details for the five UPs projected to have deficient capacity by 2020, grouped by associated MP, are as follows:

- MP02 – Primary Clarification: One UP is projected to have deficient capacity. UP04 – Primary Clarification is projected to exceed the weir loading rate (WLR) design parameter by the year 2020 due to increased average day flow projections under WRF Future and Buildout Conditions. In addition, peak hourly surface overflow rate (SOR) is higher than the 2017 NR 110 requirements but does not exceed design parameters.
- MP04 – Aeration: Two UPs are projected to have deficient capacity. An increase in the primary effluent BOD load is projected to exceed the volumetric loading rate of UP05 – Aeration and RAS Pumping by the year 2020. In addition, in setting the mixed liquor suspended solids in the mass balance to calibrate the mixed liquor mass, the average food to micro-organism ratio would be exceeded under Buildout Conditions. This is further evaluated in conjunction with other UPs identified to have deficient capacity in Chapter 6. An increase in the primary effluent BOD and total Kjeldahl nitrogen (TKN) load, resulting in an increased oxygen demand within aeration, is projected to exceed the average day and maximum oxygen demand design parameters of UP 15 – Process Air by the year 2020.
- MP05 – Secondary Clarification: One UP is projected to have deficient capacity. The SOR, WLR, and solids loading rates are identified to exceed the design parameters of UP06 – Secondary Clarification under Baseline Conditions.
- MP07 – Plant Effluent: One UP is flagged as a risk based on 2017 NR 110 requirements. The contact time of 24 minutes for UP08 – Chlorination/Dechlorination does not meet the portion of NR 110 110.14.3.f that states that contact time shall be 30 minutes at maximum hour design flow.

[4] *Current (2017) NR 110 requirements were reviewed to provide an additional perspective for assessing the capacity risk of a major process. In instances where NR 110 requirements differ from projected values, MMSD is not in violation of the NR 110 requirements, which are applicable to new and modified facilities.*

TABLE 5-5: NUMBER OF UNIT PROCESSES PROJECTED TO START BEING CAPACITY DEFICIENT AT SOUTH SHORE WRF FOR EACH TIME PERIOD

Major Process	Before 2020	2020 to 2024	2025 to 2029	2030 to 2039	2040 to 2049	2050 or Later	Not Assessed	Total
MP01 - PRELIMINARY TREATMENT						3		3
MP02 - PRIMARY CLARIFICATION	1							1
MP03 - IRON MANAGEMENT						1		1
MP04 - AERATION	2							2
MP05 - SECONDARY CLARIFICATION	1							1
MP06 - ACTIVATED SLUDGE				1		1		2
MP07 - PLANT EFFLUENT	1					1		2
MP08 - SLUDGE THICKENING						1		1
MP09 - ANAEROBIC DIGESTION			1			1	1	3
MP10 - SLUDGE DEWATERING						1		1
MP15 - POWER GENERATION							2	2
MP16 - PLANT WATER AND DRAIN							1	1
MP17 - PLANT UTILITIES							3	3
MP18 - FACILITIES MANAGEMENT							4	4
Not Assigned							1	1
Total	5	0	1	1	0	9	12	28

Source: Appendix 5B-5, WRF Capacity Assessment

ISP Mass Balance Capacity Assessment

The analysis of the WRF Capacity Assessment identified one UP in the ISP facilities projected to have deficient capacity by 2049, which is outside of the 2020 to 2040 regulatory planning period. The UP is UP13 – IPS Pump Station, which is located at SSWRF.

TABLE 5-6: NUMBER OF UNIT PROCESSES PROJECTED TO START BEING CAPACITY DEFICIENT AT INTERPLANT SLUDGE PIPELINE FOR EACH TIME PERIOD

Major Process	Before 2020	2020 to 2024	2025 to 2029	2030 to 2039	2040 to 2049	2050 or Later	Not Assessed	Total
MP19 - LIQUID SLUDGE					1			1
Not Assigned							1	1
Total	0	0	0	0	1	0	1	2

Source: Appendix 5B-5, WRF Capacity Assessment

Additional Capacity Assessments

Two additional capacity assessments were completed: the identification of single-point failures that could present risks to operations and a review of medium and high capacity failures included in the WRF Risk Register. In a review with MMSD and Veolia staff, the 2050 FP project team determined that the single-point failure assessment did not identify any capacity risks for any additional UPs beyond those identified in Tables 5-4 through 5-6. The review of the WRF Risk Register determined that MMSD does not already have a strategy to address three capacity risks, as summarized in Table 5-7. Details of the single-point failure assessment are included in Appendix 5B-5, WRF Capacity Assessment. Details of the capacity risks from the WRF Risk Register are presented in Appendix 5B-6, WRF Risk Register – Capacity Risks.

TABLE 5-7: MODERATE AND HIGH CAPACITY RISKS IDENTIFIED IN WRF RISK REGISTER NOT ALREADY ADDRESSED BY MMSD STRATEGIES

Risk ID	Risk Level	Risk Title
JIWRF		
R240	High	Risk of conveyance system overflows by not maximizing ISS pump out blending at the JIWRF
R039	Moderate	Risk of necessity to implement emergency operations and the corresponding cost impacts due to the insufficient capacity of the D&D sludge cake bypass belt to process all dewatered biosolids in the event that the south side system goes offline
SSWRF		
R190	Moderate	Risk of insufficient solids processing and disposal capacity at SSWRF during a JIWRF D&D extended or short-term shutdown

Source: Appendix 5B-6, WRF Risk Register – Capacity Risks

Physical Mortality Failure Mode

Physical mortality failure mode assessments are performed to identify potential failure due to asset deterioration. The replacement year of an asset can be difficult to predict. MMSD has developed a methodology to refine its AssetView data based on progressively detailed investigations. While that effort is ongoing, an interim methodology was developed to estimate the replacement year for assets that had missing information as applicable (described in Appendix 5B). The projected year/time period of failure, as recorded in MMSD's AssetView system as of June 6, 2019, was used as the primary basis for this analysis. Figure 5-11 summarizes predicted asset physical mortality by planning period for each facility in the WRFs and Biosolids Asset System, based on the available data. The assets listed for each time period are additional assets over and above the assets listed for prior time periods.

The total mortality risk identified for JIWRF, SSWRF, and ISP through the year 2049 is over 9,900 assets of the almost 12,000 assets reviewed, representing 83 percent of the system. The ISP facility has significantly fewer assets identified for replacement (280 assets compared to 5,853 assets for JIWRF and 3,779 assets for SSWRF); therefore, the physical mortality assessment focused on JIWRF and SSWRF. The potential risks in each time period were identified as follows, and as presented in Figure 5-11:

- 4,620 assets are projected to be overdue for renewal by the year 2020. The bulk of these assets are located at JIWRF, which is projected to have a total of 3,291 assets up for renewal by the year 2020. A significant number of these assets fall into the "Not Assigned" category. At SSWRF, MP18, Facilities Management has the largest number of assets identified for replacement. The MPs at JIWRF with the second and third largest set of assets overdue for replacement are MP16, Plant Water and Drain and MP04, Aeration.
- 2,345 assets are projected to need renewal in the 2020 to 2024 period. The bulk of these assets are located at SSWRF, where the MP with the most assets identified is MP18, Facilities Management. At JIWRF, the "Not Assigned" category has the largest number of assets identified for replacement.

- 788 assets are projected to need renewal in the 2025 to 2029 period. Over half of these assets are located at JIWRF. Most of these assets are in MP11, Sludge Drying. At SSWRF, MP04, Aeration has the largest number of assets identified for replacement.
- 1,614 assets are projected to need renewal in the 2030 to 2039 period. Most of these assets are located at JIWRF. Most of these assets are in the "Not Assigned" category. At SSWRF, MP16, Plant Drain has the largest number of assets identified for replacement. The MP at JIWRF with the second largest set of assets identified for replacement is MP11, Sludge Drying.
- 494 assets are projected to need renewal in the 2040 to 2049 period. Most of these assets are located at SSWRF, with the greatest renewal needs in MP16, Plant Water and Drain. At JIWRF, the MP with the highest number of assets identified for replacement is "Not Assigned."
- 51 assets do not have an install year but may need renewal in the planning period. Most of these assets are located at JIWRF, where the MP with the highest renewable needs is "Not Assigned." At SSWRF, the MP with the greatest renewal needs is MP04, Aeration.

These risks are evaluated in Chapter 6 to determine total project costs to address physical mortality concerns.

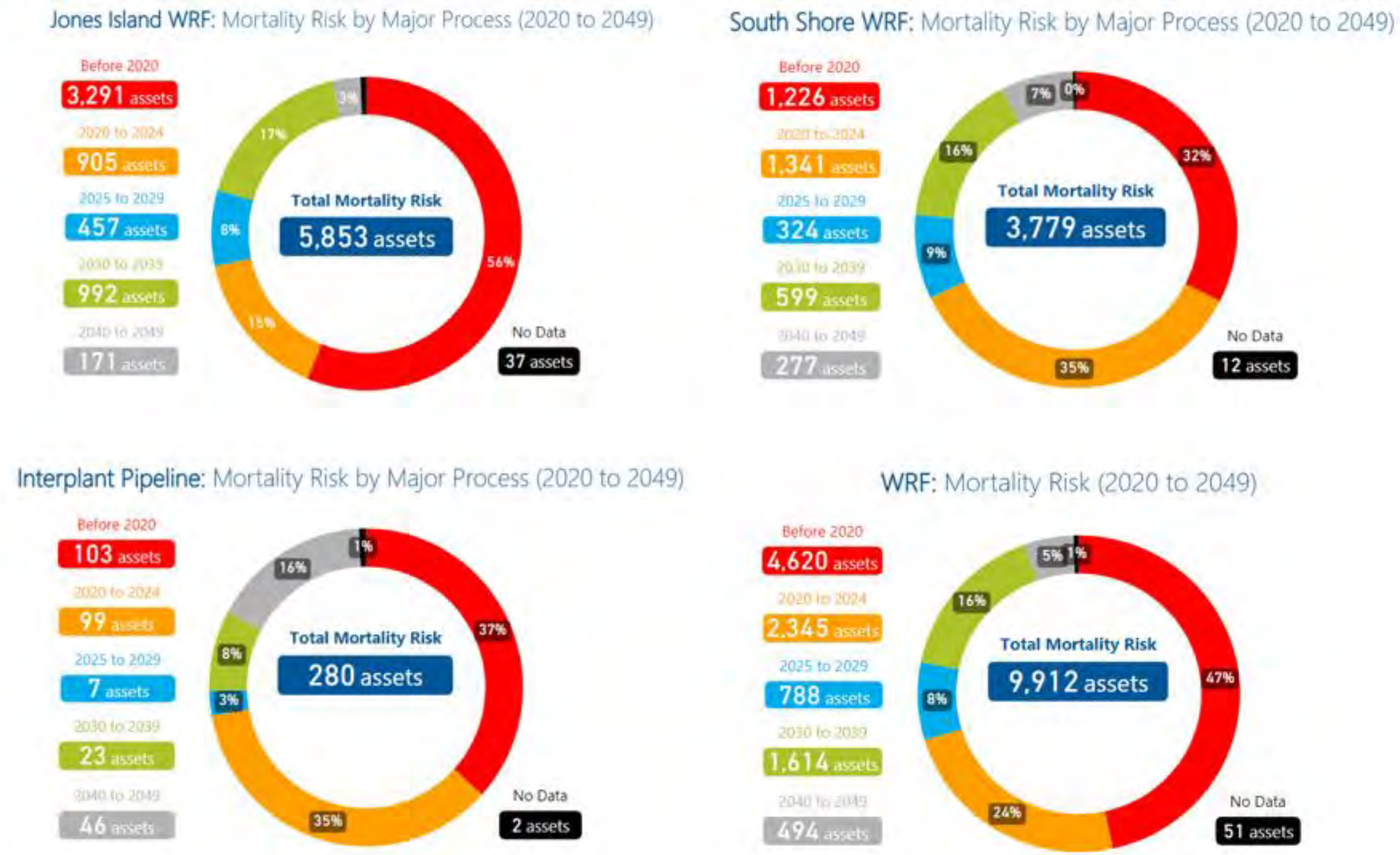

FIGURE 5-11: OVERVIEW OF WRFS AND BIOSOLIDS PHYSICAL MORTALITY ESTIMATES

Source: MMSD AssetView, assessed in PowerBI

In addition to the risks identified in the AssetView data, the WRF Risk Register was reviewed to identify medium and high physical mortality risks that are not already being addressed by MMSD strategies. In a review with MMSD and Veolia staff, the 2050 FP project team determined that MMSD does not already have a strategy to address 102 of these risks (100 at JIWRF, two at SSWRF), as summarized in Table 5-8. Details of the physical mortality risks from the WRF Risk Register are presented in Appendix 5B-6, WRF Risk Register – Physical Mortality Risks.

TABLE 5-8: MODERATE AND HIGH PHYSICAL MORTALITY RISKS IDENTIFIED IN WRF RISK REGISTER NOT ALREADY ADDRESSED BY MMSD STRATEGIES

Risk ID	Risk Level	Risk Title
JIWRF		
R057	High	Risk of excessive power consumption and potential air permit non-compliance due to the condition, performance and power use of D&D wet ESPs
R005	Moderate	Risk of loss of JIWRF electrical power due to the condition of substation equipment (Dewey and Harbor)
R125	Moderate	Risk of loss of power due to age and reliability of electric substations, MCCs, and other power distribution systems
R173	Moderate	Risk of wet weather capacity restrictions and permit violations due to D&D facility drying capacity/reliability issues
Multiple	High/ Moderate	Multiple Dewatering and Drying (D&D) system risks - 12 high and 84 moderate risks (See Appendix 5B-3 for individual risks)
SSWRF		
R111	Moderate	Risk of failure of the plate and frame dewatering system due to the aged PLC system and the fact that parts are no longer supported by the vendor
R112	Moderate	Risk of failure of the plate and frame dewatering system due to costs and long lead times for replacement parts associated with the feed pumps

Source: Appendix 5B-8, WRF Risk Register – Physical Mortality Risks

Level of Service Failure Mode

Level of service failures can be specific failures in the sense of failure to achieve targets for KPIs and PIs or contributing to potential failure through poor relative performance. The WRF Risk Register developed in 2016 was the primary basis for assessing potential level of service failures. MMSD focused on high and moderate risks that are not already being addressed by MMSD strategies, which are summarized in Table 5-9.

TABLE 5-9: MODERATE AND HIGH LEVEL OF SERVICE RISKS IDENTIFIED IN WRF RISK REGISTER NOT ALREADY ADDRESSED BY MMSD STRATEGIES

Risk ID	Risk Level	Risk Title
JIWRF		
R177	High	Risk of safety issues in dryer systems due to the utilization of waste heat and the high oxygen levels in the dryer systems
R120	Moderate	Risk of negative publicity, community impacts, and not meeting current NR 110 requirements[1] due to JIWRF treatment process odors
R172	Moderate	Risk that phosphorus content of Milorganite relative to nitrogen may exceed regulations in some states where Milorganite is currently sold
R228	Moderate	Risk of air permit non-compliance due to increasing trends in emissions (as noted by stack testing)
SSWRF		
R090	High	Risk of conveyance system overflows at BS0405 and DC0103 by not utilizing potential additional capacity at SSWRF
R197	Moderate	Risk of limited black start capability during a power outage because the existing battery has capacity for only one start and backup power capacity is not available in a power outage
R211	Moderate	Risk of incorrect reporting, treatment management, and future planning due to Incorrect results from the influent sampling system

1) NR 110 requirements are updated regularly; therefore, they may be more stringent than when the design was approved. In these instances, MMSD is not in violation of NR 110 requirements, but it is noted as a potential risk.

Source: Appendix 5B-9, WRF Risk Register – LOS Risks

After the development of the WRF Risk Register in 2016, one additional level of service risk was identified: the risk that the disinfection systems at JIWRF and SSWRF are not adequate to meet future WPDES permit requirements. As of October 23, 2019, WDNR has approved new regulations that require that Escherichia coli (*E. coli*) be used as the pathogen indicator in wastewater as opposed to the historical use of fecal coliform. [10] While this change was not imposed on MMSD in the 2019 permit, it will likely be in the next permit, which will be issued in approximately 5 years. Because this is a risk to meeting future permit requirements, this risk is included in the Level of Service Failure Mode Assessment rather than the Capacity Failure Mode Assessment, which identifies gaps in capacity that may risk exceeding the active 2019 WPDES permit.

Economic Efficiency Failure Mode

For the 2050 FP, broad economic efficiency risks were considered and identified in the WRF Risk Register developed in 2016 using the same methodology outlined above. No high economic efficiency risks were identified. The two moderate economic risks are:

- JIWRF: R261 – Risk of not being able to contract with a Milorganite packaging/bagging vendor due to the limited number of vendors (only one)
- SSWRF: R113 – Risk of unplanned costs and not meeting MMSD energy goals due to high maintenance costs and high downtime of the engine generators

Summary of WRFs and Biosolids Asset System

The assessments indicate that the majority of risks fall under the capacity and physical mortality failure modes. The following summarized the identified risks. These risks are evaluated in Chapter 6 to identify recommended projects to address these risks:[5]

- **Capacity Risks**: There are 17 UPs identified with capacity risks within the 2020 to 2050 planning period: 9 at JIWRF, 7 at SSWRF, and 1 at ISP. In addition, 3 capacity risks from the WRF Risk Register were identified.
    - There are 3 UPs at JIWRF projected to have deficient capacity by 2020 based on the mass balance analysis under MP02, Primary Clarification; MP04, Aeration; MP05, Secondary Clarification; MP06, Activated Sludge; and MP08, Sludge Thickening.
    - In addition, to maintain interim goal of maintaining the baseline CSO frequency (3.25 CSOs per year), which was established in Chapter 4, either 11 UPs (Scenario 1) or 3 UPs (Scenario 2) at JIWRF are projected to need additional peak flow capacity.
    - There are 5 UPs at SSWRF projected to have deficient capacity by 2020 based on the mass balance analysis under MP01, Preliminary Treatment; MP02, Primary Clarification; MP04, Aeration; and MP05, Secondary Clarification.
- **Physical Mortality Risks**: Over 9,900 assets are identified to have physical mortality risks within the 2020 to 2050 planning period.
    - Over 4,600 assets are identified before 2020.
    - In addition, the WRF Risk Register identifies 102 potential high and moderate risks (100 at JIWRF, two at SSWRF) for which MMSD does not already have a strategy to address.
- **Level of Service Risks**: There are seven moderate and high level of service risks (four at JIWRF and three at SSWRF) from the WRF Risk Register plus one additional risk related to disinfection at both WRFs for which MMSD does not already have a strategy to address.
    - At JIWRF, these risks are related to safety, product quality, and air emissions related to Milorganite production and also odors.
    - At SSWRF, these risks are related power and wet weather capacity.

[5] *There is overlap between the risks identified under each failure mode, which is addressed in Chapter 6.*

  - o At both WRFs, the risk that the disinfection systems are not adequate to meet future WPDES permit requirements to meet *E. coli* effluent limits.

- **Economic Efficiency Risks**: There are two moderate economic risks (one at JIWRF and one at SSWRF) for which MMSD does not already have a strategy to address.
  - o At JIWRF, the risk is related to Milorganite vendor availability.
  - o At SSWRF, the risk is related to power generation related to renewable energy goals.

These identified risks are evaluated, with total project costs for recommended projects, as part of the alternative analyses in Chapter 6.

5.7 WATERCOURSE AND FLOOD MANAGEMENT ASSET SYSTEM ASSESSMENTS

Capacity Failure Mode

The purpose of this assessment is to identify engineered watercourse assets that are predicted to fail to perform as intended, such as rehabilitated channels that are not maintained, nuisance vegetation and debris blockage of trash racks, culverts and bridges. Flooded structures are covered under the level of service failure mode. MMSD focused on high risks for the 2050 FP.

Capacity assessments of the WCFM Asset System were conducted by using the risk register developed in 2016 to identify risks due to potential failure in operation of or maintenance issues at an engineered asset. A summary of capacity risks identified in the risk register throughout the planning area is provided in Table 5-10. No high-level risks were identified.

TABLE 5-10: IDENTIFIED WATERCOURSE AND FLOOD MANAGEMENT CAPACITY RISKS BY WATERSHED

Watershed	High Risk	Moderate Risk	Low Risk	Minimal Risk	Total
Lake Michigan Drainage	0	0	0	0	0
Kinnickinnic River	0	6	0	0	6
Root River	0	1	0	0	1
Menomonee River	0	3	1	0	4
Oak Creek	0	3	0	0	3
Milwaukee River	0	2	1	0	3
Multiple watersheds	0	1	0	0	1
Totals	**0**	**16**	**2**	**0**	**18**

Source: Appendix 5C-7, WCFM Risk Register

Physical Mortality Failure Mode

Physical mortality assessments are performed to identify the risk of failure due to asset deterioration. The remaining life of an asset can be difficult to predict. The timing of the replacement or rehabilitation of an asset can be estimated based on either the asset age or a condition assessment.

Two methods were used to conduct physical mortality assessments of the WCFM Asset System:

1. The risk register was used to identify risks due to potential failure due to physical mortality as of 2016.
2. Because inspection data as of fall 2018 were available for concrete-lined channels and underground enclosures (culverts), the estimated physical mortality of these assets were calculated.

A summary of physical mortality risks identified in the risk register is presented for each watershed in Table 5-11. Of the 32 identified risks, four risks are high; these risks are presented in Table 5-12. Chapter 6 presents the identified projects to address these potential risks.

The analysis of concrete-lined channels and underground enclosures indicated that 0.2 mile of channel is in failing condition, which is located in the Menomonee River watershed and 0.1 mile is in very poor condition, located in the Kinnickinnic River watershed.

TABLE 5-11: WATERCOURSE AND FLOOD MANAGEMENT ASSET SYSTEM - PHYSICAL MORTALITY RISKS IDENTIFIED IN THE RISK REGISTER BY WATERSHED

Watershed	High Risk	Moderate Risk	Low Risk	Minimal Risk	Total
Lake Michigan Drainage	0	0	0	0	0
Kinnickinnic River	1	3	5	2	11
Root River	0	0	0	0	0
Menomonee River	1	4	6	2	13
Oak Creek	0	0	0	0	0
Milwaukee River	2	4	2	0	8
Totals	**4**	**11**	**13**	**4**	**32**

Source: Appendix 5C-7, WCFM Risk Register

TABLE 5-12: HIGH PHYSICAL MORTALITY RISKS IDENTIFIED IN WATERCOURSE AND FLOOD MANAGEMENT RISK REGISTER NOT ALREADY ADDRESSED BY MMSD STRATEGIES

Risk ID	Risk Level	Risk Description
W014	High	Increased safety risk from erosion and potential sinkhole formation due to failure of corrugated metal pipe culvert at State Fair (Honey Creek Reach 2)
W015	High	Increased safety risk from erosion and potential sinkhole formation due to failure of corrugated metal pipe culvert at 43rd and Lincoln (43rd St Ditch)
W109	High	Increased safety risk due to metal cage from gabion/revetment fraying, leading to sharp edges poking out (Lincoln Creek Reach 4)
W110	High	Increased safety risk due to metal cage from gabion/revetment fraying, leading to sharp edges poking out (Lincoln Creek Reach 5)

Source: Appendix 5C-7, WCFM Risk Register

Level of Service Failure Mode

The WCFM Risk Register developed in 2016 was used as the primary basis for assessing potential level of service risks. Note that for risks that applied to more than one watershed, the identifier “Multiple” was used.

Table 5-13 provides a summary of the 65 potential level of service risks that were identified in the Risk Register by watershed and across multiple watersheds. The Menomonee River has the greatest number of risks, and the Kinnickinnic River has the greatest number of high and moderate risks among the watersheds. Some of these risks are already being addressed by MMSD through operations and maintenance plans and inspections or will be addressed in the future. The two high level risks that impact multiple watersheds relate directly to planned flood management projects or are anticipated to be addressed in Watercourse Management Plans under development as of 2019. Chapter 6 presents the identified projects to address these potential risks. The high risks are summarized in Table 5-14.

TABLE 5-13: WATERCOURSE AND FLOOD MANAGEMENT ASSET SYSTEM - LEVEL OF SERVICE RISKS BY WATERSHED

Watershed	High Risk	Moderate Risk	Low Risk	Minimal Risk	Total
Lake Michigan Drainage	0	3	0	0	3
Kinnickinnic River	0	12	9	0	21
Root River	0	0	2	0	2
Menomonee River	0	11	13	0	24
Oak Creek	0	3	1	0	4
Milwaukee River	0	3	3	1	7
Subtotal	*0*	*32*	*28*	*1*	*61*
Multiple watersheds	2	1	1	0	4
Totals	**2**	**33**	**29**	**1**	**65**

Source: Appendix 5C-9, WCFM Risk Register – LOS Risks

TABLE 5-14: HIGH LEVEL OF SERVICE RISKS IDENTIFIED IN WATERCOURSE AND FLOOD MANAGEMENT RISK REGISTER NOT ALREADY ADDRESSED BY MMSD STRATEGIES

Risk ID	Risk Level	Risk Description
W016	High	Risk of unforeseen emergency situations due to a lack of a Watercourse Asset Management Program.
W055	High	Risk of downstream MMSD assets (stream restoration projects, conveyance system, WRFs) being adversely impacted by non-MMSD entities not following Chapter 13 Stormwater Rule.

Source: Appendix 5C-9, WCFM Risk Register – LOS Risks

In addition to the WCFM Risk Register, MMSD's Watercourse Department has conducted numerous floodplain management studies that have identified flooded structures within the 1-percent-annual-probability event floodplain. Data for flooded structures are based on information developed by MMSD's Watercourse Department and included in an inventory used to track structures remaining in or no longer threatened by the 1-percent annual probability floodplain for all jurisdictional streams from 1999 to 2018.[6] The total number of flooded structures in each watershed during this event is presented in Table 5-15. Flood damages and the number of affected structures determined by SEWRPC for selected portions of the streams are also provided in Appendix 5C.

Note that the number of flooded structures as determined by MMSD and SEWRPC may differ in part because SEWRPC only evaluated selected reaches of the various watercourses, and the 1-percent annual probability event flows used in SEWRPC's analysis are based on updated hydrology and 2035 land use whereas MMSD's tabulation is based on historical studies and data for all jurisdictional streams.

TABLE 5-15: ESTIMATED NUMBER OF FLOODED STRUCTURES PER WATERSHED DURING 1-PERCENT ANNUAL PROBABILITY RAINFALL EVENT

Watershed	Number of Flooded Structures (1-percent annual probability event)
Lake Michigan Drainage and Estuaries (lake effect)	58
Kinnickinnic River	635
Root River	14
Menomonee River	147
Oak Creek	12
Milwaukee River	401
Total	**1,267**

Source: MMSD Watercourse Department

[6] *The structure counts are based on the best available data for each stream. In some cases, this was the existing Federal Emergency Management Agency (FEMA) regulatory floodplain (based on regulatory flows) as of 2018. In other cases, this was updated mapping with more recent data, but still represents conditions as of 2018.*

Economic Efficiency Failure Mode

For the 2050 FP, broad economic efficiency risks were considered and identified in the risk register developed in 2016. These risks are summarized in Table 5-16. Eight risks were identified, but none of them was classified as high risk. The other risks are summarized in Appendix 5C.

TABLE 5-16: WATERCOURSE AND FLOOD MANAGEMENT ASSET SYSTEM - ECONOMIC EFFICIENCY RISKS BY WATERSHED

Watershed	High Risk	Moderate Risk	Low Risk	Minimal Risk	Total
Lake Michigan Drainage	0	1	0	0	1
Kinnickinnic River	0	1	0	0	1
Root River	0	0	0	0	0
Menomonee River	0	2	0	0	2
Oak Creek	0	0	0	0	0
Milwaukee River	0	0	0	0	0
Multiple watersheds	0	1	2	1	4
Totals	**0**	**5**	**2**	**1**	**8**

Source: Appendix 5C-10, WCFM Risk Register – Economic Efficiency Risks

Summary of Watercourse and Flood Management Risks

The assessments indicate that capacity issues of various watercourses account for most of the necessary improvements. Additionally, many of the concrete-lined channels will need to be removed due to the advanced age of these assets. The following summarizes the identified risks:

- Capacity Risks. There are no high-level risks identified.
- Physical Mortality Risks. There are four high-level risks identified in the WCFM risk register. In addition, inspection data for concrete-lined channels and underground enclosures identified physical mortality risks.
- Level of Service Risks. There are two high risks identified, both of which apply to the entire WCFM Asset System. In addition, there is a total of 1,267 flooded structures remaining within the 1-percent annual probability event in MMSD's planning area as of 2018. The Kinnickinnic River watershed contains almost half of these flooded structures, yet it has the second smallest drainage area of the jurisdictional watercourses.
- Economic Risks. There are no high-level risks identified.

Projects to address these risks, with total project costs, are discussed in Chapter 6.

5.8 GREEN INFRASTRUCTURE ASSET SYSTEM ASSESSMENTS

MMSD's GI Asset System is relatively new and was not fully integrated into MMSD's AssetView system as of the writing of the 2050 FP. MMSD started supporting the implementation of GI assets in 2002 as part of the predecessor to the GI Asset System, the Best Management Practice (BMP) Partnership Program. [11] However, the first full year of tracking of the existing GI Asset System was in 2012 after the adoption of the 2035 Vision in 2011.

As noted previously, the GI Asset System is different from other components of MMSD's system because, in most cases, these assets are not directly owned or operated by MMSD, but rather MMSD assists in paying for these assets and retains a conservation easement. Therefore, the failure mode assessments are approached differently as noted below and costs are included because most of the desired assets do not yet exist and the funding necessary to create them is a foundational part of the discussion.

Capacity Failure Mode

Prior to 2012, partner reporting requirements were not as detailed as they were as of 2018 during 2050 FP development; therefore, capacity assessments for each GI asset were not completed. Capacity risk for GI is expected to be very low because the flow and load demands placed upon GI assets are not expected to change significantly. As explained in Chapter 4, climate change might result in increasing precipitation intensity in a few larger events, which might result in additional stress on existing GI assets. However, the consequences of this happening are not expected to be significant because most of the larger GI assets are already designed with underdrains so that excess water is simply diverted to the storm system when this occurs. It is important to note that MMSD understands GI is a beneficial supplement to the existing grey infrastructure system. Although the capacity risk for GI is considered low, MMSD has committed to using GI to supplement the grey system and recognizes the other triple bottom line benefits that GI brings to the region.

Physical Mortality Failure Mode

MMSD has been completing visual assessments of the GI assets and recording that information in a separate database. GI assets paid for through MMSD-funded programs are typically young in age and have not yet reached the end of their useful life; therefore, comprehensive condition assessments were not available for all existing GI assets. As such, the physical mortality risk was based on asset age and a typical useful life for the asset. Mortality risk was evaluated both for the existing GI assets as of 2017 (with initial assets funded in 2003) as well as the ones that are expected to be built to reach the Regional GI Plan and 2035 Vision goals.

The weighted average life expectancy for the suite of GI assets planned to be constructed to meet the KPI target of 740 MG of GI storage is assumed to be 20 years based on information from the Regional Green Infrastructure Plan [11] and the MMSD GI Standard Specs and Plan Templates Report. [12] A life expectancy of 20 years means that, on average, 4.9 percent of all GI assets will need to be replaced each year, meaning that assets installed in 2003 will need to be replaced starting in 2023. The 2050 FP assumes that replacement costs will primarily be the responsibility of the owners of the GI assets, with MMSD paying for 5 to 10 percent of replacement costs to cover situations where critical assets cannot be replaced by the owners. The rationale for the 5 to 10 percent assumption is that MMSD is expected to only have a very limited role in GI replacement as GI becomes more of a standard practice across the region. The upper end of the assumption (i.e., 10 percent) is to cover situations where MMSD might take a more active role in replacement for GI assets located on private property that are treating runoff from public areas. The upper end of the assumption was used to project potential MMSD replacement costs starting to be incurred in 2023 when the GI installed in 2003 begins to reach the end of their useful life. The anticipated replacement costs also include those needed to replace future GI assets built after 2017.

The total (non-discounted) replacement funding needed for the different time periods is as follows:

- 2020 to 2024: $3.1 million
- 2025 to 2029: $8.0 million
- 2030 to 2039: $45.8 million
- 2040 to 2049: $62 million

The breakdown of these projected costs over time is presented in Figure 5-12. The projected capital and maintenance costs for these assets are presented in the next section, Level of Service Failure Mode.

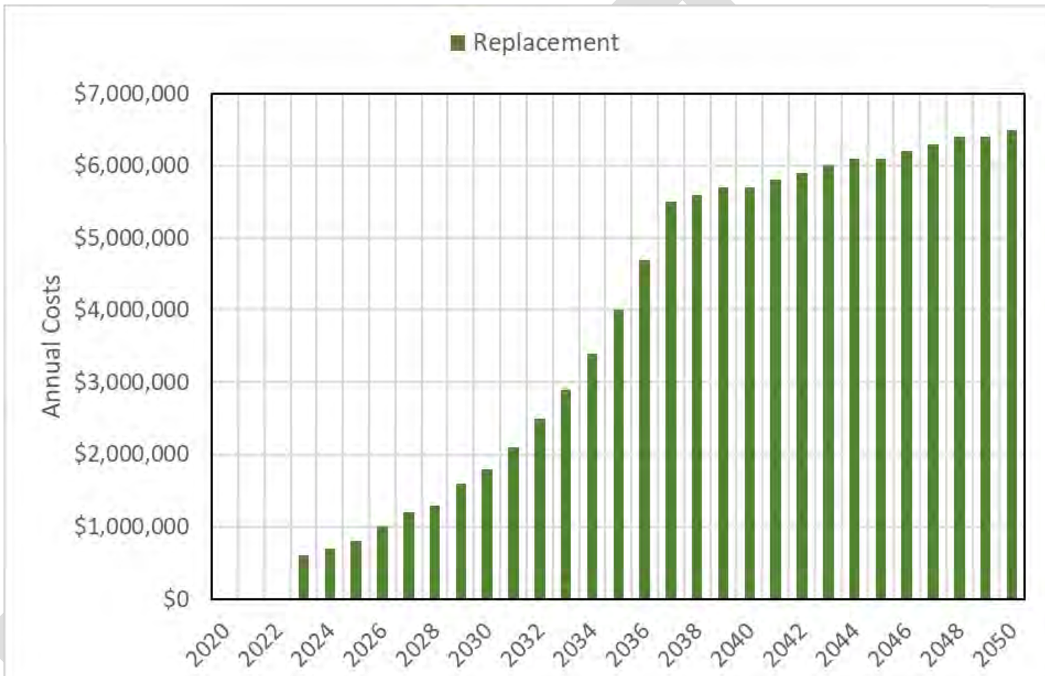

FIGURE 5-12: PROJECTED GREEN INFRASTRUCTURE REPLACEMENT COSTS OVER TIME

Source: MMSD

Level of Service Failure Mode

Limited asset level data were available to relate asset performance to the KPIs and PIs identified in Chapter 3. Therefore, the primary basis for risk analysis was the GI Risk Register developed by the 2050 FP project team in 2016. The level of service specific risks are summarized in Appendix 5D-3, GI Risk Register – LOS Risks of Appendix 5D.

Most of the risks identified for the GI program are associated with having an insufficient number of GI assets to meet the KPI target of 740 MG of GI storage, the projected permit goal of 200 MG of GI storage, and the 2035 Vision goal of zero overflows. The concern is based on several factors, including the following:

- As of 2017 only 35.3 MG of KPI target of 740 MG of GI storage had been achieved. The 2050 FP has assumed approximately 40 MG of GI had been installed as of the end of 2019. The Regional GI Plan [11] recommended that 40 MG of GI be added per year starting in 2019. That may be unrealistic given the pace of the last several years (i.e., 9 MG in 2014, 1 MG in 2015, 10 MG in 2016, and 4 MG in 2017).
- Funding programs to-date have focused on an opportunistic approach where willing partners contact MMSD to assist with funding their projects. While this approach was critical to build knowledge and acceptance of GI, this path alone will not achieve the projected permit goal of 200 MG of GI storage nor the KPI target of 740 MG of GI storage. A scale up in programming that focuses on targeted efforts is necessary.
- Given current average costs and the traditional proportion of GI paid for by MMSD, MMSD would have needed to spend about $26M/yr to add 40 MG of GI in 2019 and 2020. That amount exceeds what has been budgeted for GI in the 2019 and 2020 budgets.
- In addition to increased funding for GI, MMSD needs to address a variety of other related issues. For example, there is currently a mismatch between the expected life of GI assets (typically 20 years) and the easement length of GI projects (nationally this can range from 11 years to perpetuity; MMSD attempts to get 20 years for each easement, but has to be flexible). There are also issues with the financial reporting and accounting treatment of GI.
- Reaching the goals set forth in the Regional GI Plan and 2035 Vision is very dependent on a wide variety of stakeholders implementing GI at their homes, businesses, and on government property. However, some key stakeholders within the region are still skeptical of GI and are therefore unlikely to make the investments needed to reach the 740 MG GI KPI target. Reasons for skepticism include:
    - Perception in the region that certain types of GI can have a negative impact on I/I
    - Lack of confidence by some individuals that GI can help to reduce the frequency and volume of CSOs and SSOs
    - Concerns that GI will not be adequately maintained
    - Greater cost to install GI than other stormwater control technologies (e.g., detention ponds)
    - Perception that GI capacity is not needed outside of the combined sewer service area (CSSA)
- The regulatory environment is not as conducive to GI installation as it needs to be. For example:
    - GI is not yet as integrated into transportation and development/redevelopment design standards as it needs to be to meet the 740 MG GI KPI target.
    - Some municipal codes and ordinances still pose a barrier to GI. Even though MMSD has invested significant resources to address this issue over the past several years, more work needs to be done.
- Insufficient MMSD staffing could hold back program growth and implementation rates.
    - Current programs are operating at maximum capacity for what can be managed.
    - GI Maintenance Assessments are being completed by interns rather than by fully-trained maintenance personnel.

The total (non-discounted) MMSD funding needed for capital investment and maintenance is shown in Figure 5-13, with the totals by time period listed below. The replacement costs for these assets were presented previously in Figure 5-12.

- 2020 to 2024: $77.3 million
- 2025 to 2029: $148.3 million
- 2030 to 2039: $567.8 million
- 2040 to 2049: $119.4 million

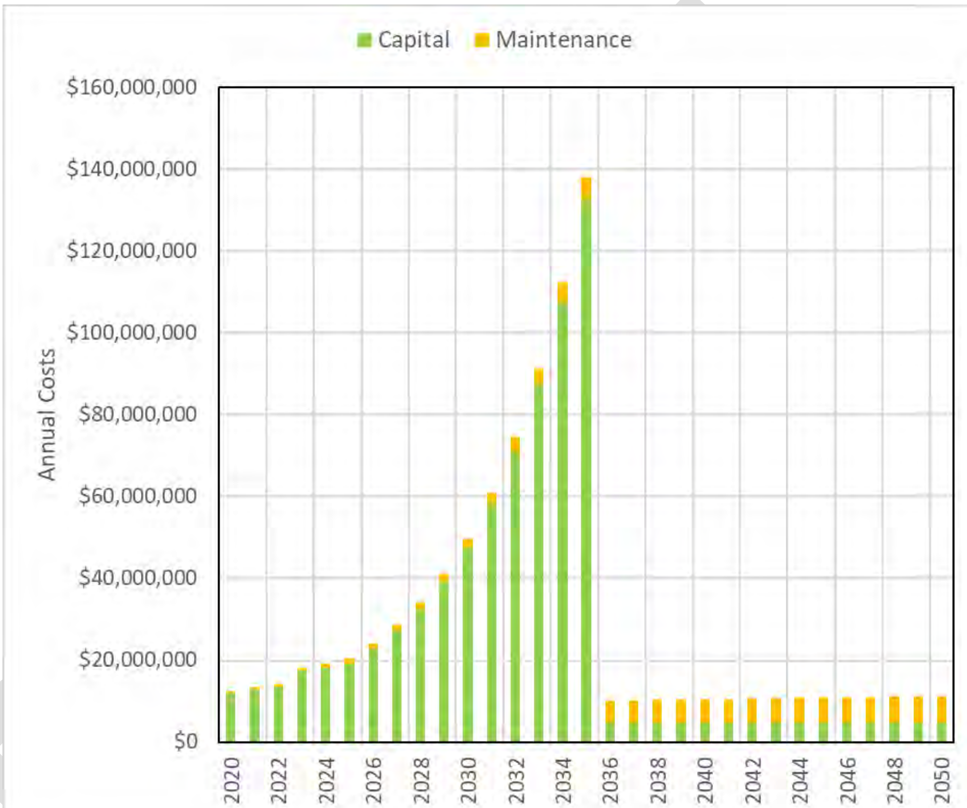

FIGURE 5-13: PROJECTED FUTURE MMSD GI CAPITAL AND MAINTENANCE COSTS

Source: MMSD

The GI Risk Register developed in 2016 identified the following level of service risks:

TABLE 5-17: GI ASSET SYSTEM – LEVEL OF SERVICE RISKS

Failure Mode	High Risk	Moderate Risk	Low Risk	Minimal Risk	Total
Level of Service	1	17	4	2	24

Source: Appendix 5D-3, GI Risk Register – LOS Risks

The one high risk (G012) is defined as follows:

> *TMDL requirements will offer a significant opportunity for municipalities to install GI to treat stormwater to meet future load reductions. MMSD risks missing out on that opportunity by not working with municipalities to put policies in place to allow credit for both quality and quantity benefits, or by somehow having non-GI practices primarily used to reduce loads.*

Potential strategies to mitigate this risk and all of the other risks except for one are addressed in Chapter 6; the one risk that is not addressed is a minimal risk that is unrelated to all of the high and moderate risks. The other minimal risk and all of the low risks are related to the high and moderate risks so they are addressed at the same time.

Economic Efficiency Failure Mode

The only economic efficiency risk identified for GI was identified in the risk register developed in 2016. The risk is that traditional stormwater projects can store runoff more cheaply than many types of GI. For example, average costs for a detention pond are reported at $1.06/gallon (capital cost) compared to the average cost of GI in the MMSD SharePoint database of $2.09/gallon (capital cost). This risk was determined to be a moderate risk.

Summary of Green Infrastructure Risks

The following summarizes the GI system risks that are evaluated in Chapter 6 to identify the recommended projects to address these risks:

- **Capacity Risks.** Capacity risk for GI is expected to be very low because the flow and load demands placed upon GI assets are not expected to change significantly. Therefore, a capacity risk assessment was not conducted for this asset system.
- **Physical Mortality Risks.** There are no physical mortality risks for the pre-2020 planning period, $3.1M for the 2020 to 2024 planning period, $8.0M for the 2025 to 2029 planning period, $45.8M for the 2030 to 2039 planning period, and $62M for the 2040 to 2049 planning period.
- **Level of Service Risks.** Most of the risks identified for the GI program are associated with not providing the desired level of service due to an insufficient number of GI assets being built by 2035 (i.e., not meeting the 200 MG permit goal or the 740 MG GI KPI target, with only approximately 40 MG of GI installed as of the end of 2019). The funding needed for capital investment and maintenance to achieve these goals is $77.3M for the 2020 to 2024 time period, $148.3M for the 2025 to 2029 time period, $567.8M for the 2030 to 2039 time period, and $119.4M for the 2040 to 2049 time period. Twenty-four of the 25 risks in the risk register are level of service risks. The one high risk is associated with not taking advantage of the opportunity to use municipal TMDL requirements to encourage municipalities to install GI as a step towards achieving the goal of 740 MG of GI storage.
- **Economic Efficiency Risks.** There is one economic efficiency risk, which is a moderate risk.

These potential risks are evaluated, with total project costs for recommended projects, in Chapter 6.

5.9 Systemwide Assessments

Systemwide assessments were conducted to identify risks that could be considered from an overall systemwide level versus by individual asset system. Two of the four failure modes—physical mortality, and economic efficiency—were only assessed at the asset system level. However, capacity risks also can be considered from a systemwide basis. In addition, the fourth failure mode—level of service—contains many KPI and PI metrics[7] established in Chapter 3 that can be assessed at the systemwide level as well as the asset system level. As an example, the KPI for '% of annual overall capture of flow into the MMSD system' is applicable to the Conveyance, WRFs and Biosolids, and GI Asset Systems; therefore, it is evaluated under each of these asset systems. However, this KPI also needs to be evaluated at a systemwide level to see how the overall system performs.

The purpose of the systemwide assessments is to:

1. Assess asset-level risks from a systemwide perspective
2. Assess level of service performance metrics as follows:
    a. Assess performance against defined KPIs and PIs
    b. Identify priority KPIs/PIs
3. Assess renewable energy performance
4. Review Energy Plan to identify potential renewable energy alternatives

MMSD is still gathering performance data on performance metrics so chose to focus on just the high priority KPIs/PIs for the 2050 FP.

Methodology

Systemwide Asset-level Risk Assessment

The risks identified under the four asset systems were reviewed from a systemwide standpoint to determine if any of them also could be addressed by implementing systemwide solutions.

Level of Service Performance

MMSD analyzed available data for the years 2015 to 2017 to track level of service performance metrics against permit requirements and internal KPI/PI targets. These years were chosen because they were the most recent three years of data available when the analysis was conducted in 2018. After reviewing these performance metrics, MMSD identified several priority KPIs and PIs relating to its 2035 Vision to be analyzed as part of the 2050 FP.

Renewable Energy Performance

Two of the priority KPIs—both relating to renewable energy sources—did not have any performance data. Therefore, the 2050 FP project team completed a renewable energy assessment to develop the performance metrics necessary to analyze the energy alternatives in Chapter 6.

Energy Plan Alternatives

The 2050 FP project team also reviewed potential energy alternatives listed in the 2015 Energy Plan [13] to identify those that should be evaluated as potential strategies to mitigate the risk of not achieving the renewable energy KPIs.

[7] *KPI – Key Performance Indicator, a metric that demonstrate how effectively MMSD is achieving a key business objective; PI – Performance Indicator, additional metrics MMSD identified to track; see Chapter 3 for more details*

Findings

Systemwide Asset-level Risk Assessment

The 2050 FP team reviewed the individual asset system risks and determined that the following potential risks could also be evaluated by a more holistic, systemwide perspective:

- Risk of increased rates to rate payers if capacity risks are not mitigated in the most cost-effective manner. In order to optimize treatment plant capacity in the most cost-effective manner, it is important to identify the most effective ways to reutilize various treatment and transportation options at JIWRF, SSWRF, and the Conveyance System.
- Risk of negatively impacting community relationships if changes in customer expectations related to JIWRF odors, noise and nuisance, and recreational opportunities around JIWRF are not addressed.
- Structural risks identified at JIWRF that are due to the construction on wood piles.

Potential alternatives to address these risks through the most cost-effective reutilization of the WRFs and Conveyance System are analyzed in Chapter 6.

Level of Service Performance

Tables 5-18 and 5-19 present actual performance results during 2015 to 2017 for level of service KPIs (Table 5-18) and PIs (Table 5-19). One PI is not tracked on an annual basis but is regularly updated; therefore, it is reported as “Rolling” with specific details presented below the table:

- PI: Percent by count of assets with estimated cost of rehabilitation/replacement and estimated year of rehabilitation/replacement in Asset Information Management System

In addition, two PIs did not have performance data because they were identified as new performance metrics through development of the 2050 FP and therefore data was not being calculated or tracked yet:

- PI: % of annual N recovered
- PI: % of annual P recovered

Reviewing the performance data, three out of the 10 KPI and three out of 11 of the PIs with performance data met the level of service targets. The targets of all KPIs and PIs were not expected to be in compliance as these targets were first developed as part of the 2050 FP. MMSD intends to incorporate monitoring of KPI and PI targets in the asset management planning process, which focuses on continuous improvement. The KPIs and PIs that met level of service targets are as follows:

KPIs:

- Effluent permit violations/year (ammonia, TSS, BOD, fecal)
- Annual tax levy increase (%)
- Annual user charge billing increase (%)

PIs:

- Air operating and construction permit violations/year
- Biosolids permit violations/year
- Basement backups due to MIS capacity/year

After reviewing the available performance data, MMSD identified the following KPIs and PIs as the top priorities for meeting key level of service targets related to the 2035 Vision.[8]

Priority Key Performance Indicators

- % of annual overall capture of flow into MMSD system
- % of annual energy from renewable sources
- % of annual energy from MMSD-generated renewable sources

Priority Performance Indicators

- SSO events/year
- CSO events/year

[8] *By default, the KPI for "percent of annual overall capture of flow into the MMSD system" would be met if the two PIs for SSO and CSO events per year met; therefore, Chapter 6 focuses on analyzing alternatives to meet the two PIs.*

TABLE 5-18: KEY PERFORMANCE INDICATORS 2015–2017 RESULTS

Key Performance Indicator (KPI)	Triple Bottom Line Measure	Level of Service (LOS) Category	Level of Service		KPI/LOS Target Source	Actual Performance Results		
			Permit Requirement	MMSD Target		2015	2016	2017
% of annual overall capture of flow into MMSD system	Environmental	Permit Requirements	85	100	WPDES Permit Section 4.3.4	98.9	99.8	99.9
		Environmental Improvements	--		2035 Vision			
Effluent permit violations/year (ammonia, TSS, BOD, fecal)	Environmental	Permit Requirements	0	0	WPDES Permit Section 6.3	0	0	0
MG of permit qualifying green infrastructure retention capacity installed in planning area	Environmental	Permit Requirements	50 MG (20 MG in CSSA) by March 31, 2024	740 MG by 2035	WPDES Permit Section 4.3.4.3.1	20.6 MG total	31.1 MG total	35.3 MG total
		Environmental Improvements	--		2035 Vision			
% of annual energy from renewable sources	Environmental	Energy	--	100	2035 Vision	31	29	31
% of annual energy from MMSD-generated renewable sources	Environmental	Energy	--	80	2035 Vision	30	29	30
% of annual total biosolids that are beneficially reused	Environmental	Environmental Improvements	--	95	Internal Goal	88	91	88
Annual tax levy increase (%)	Economic	Fiscal Responsibility	--	0 - 4	Annual Budget	2.65	2.50	2.50
Annual user charge billing increase (%)	Economic	Fiscal Responsibility	--	0-2.5	Annual Budget	3.25	2.50	2.50
Total number of buildings in 1% annual probability floodplain	Social	Safety	--	0	2050 FP Commission Direction/2035 Vision	1,173	1,297*	1,267
Count of odor issues/year (total count of complaints and notices of violation)	Social	Customer Service, Comm, Employee Development	--	0	CCO Reports/WPDES Permit	7	14	64

* MMSD is constantly improving accuracy of information. Based on improved information, the total number of structures tracked by MMSD, including structures no longer in the floodplain and structures remaining in the floodplain, went up from 2015 to 2016.

Source: MMSD, various sources

TABLE 5-19: PERFORMANCE INDICATORS, 2015–2017 RESULTS

Performance Indicator (PI)	Triple Bottom Line Measure	Level of Service (LOS) Category	Level of Service		PI/LOS Target Source	Actual Performance Results		
			Permit Requirement	MMSD Target		2015	2016	2017
SSO events/year (wet weather)	Environmental	Permit Requirements	0	0	WPDES Permit Section 9.3.1.1	1	0	1
CSO events/year	Environmental	Permit Requirements	6	0	WPDES Permit Section 4.3.4	1	2	0
		Environmental Improvements	--		2035 Vision			
Air operating and construction permit violations/year	Environmental	Permit Requirements	0	0	Construction Permit 10-POY-005; Operating Permits 241029250-P11 and 241228350-P11	0	0	0
Biosolids permit violations/year	Environmental	Permit Requirements	0	0	WPDES Permit Section 8.2	0	0	0
Effluent operating contract limits exceeded/year (multiple parameters)	Environmental	Environmental Improvements	--		VWM 2008-2018 Operating Contract	0	0	1
Reduction in annual MMSD GHG emissions from 2010 baseline (%)	Environmental	Energy	--	90	2035 Vision	16.9	20.4	Unk*
Total acres of Greenseams/river buffers (annual/cumulative)	Environmental	Environmental Improvements	--	Acquire 10,000 acres by 2035	2035 Vision	3,182	3,433	3,647
% of annual N recovered	Environmental	Environmental Improvements	--	TBD	Stakeholder Expectations	Unk*	Unk*	Unk*
% of annual P recovered	Environmental	Environmental Improvements	--	TBD	Stakeholder Expectations	Unk*	Unk*	Unk*
Percent by count of assets with estimated cost of rehabilitation/replacement and estimated year of rehabilitation/replacement in Asset Information Management System	Economic	Management Effectiveness	--	100	Asset documentation gap identified in AM Strategy	Rolling**	Rolling**	Rolling**
Basement backups due to MIS capacity/year	Social	Safety	--	0	2035 Vision	0	0	0
Annual MMSD employee safety severity rate (No. of injuries X 200,000 / Total Man Hours Worked)***	Social	Safety	--	0	Internal Goal	3.30 (0.00)	3.20 (0.00)	1.14 (0.09)
Annual VWM employee safety severity rate (No. of injuries X 200,000 / Total Man Hours Worked)***	Social	Safety	--	0	VWM 2008-2018 Operating Contract	0.39 (0.79)	0.79 (1.99)	1.51 (0.78)

* Unk = unknown, data not available or currently calculated
** Rolling = Data has not historically been reported as an end of year value; however, data is regularly being updated by MMSD staff. Count of assets with estimates cost and year from AssetView information as of June 6, 2019 used for the 2050 FP plan:
Conveyance: 36.5%, WRFs and Biosolids: 45%, WCFM: 0%, GI: 0%
*** Values presented first represent Total Recordable Injury Rate, while values presented in parenthesis represent Lost Time Injury Rate.

Source: MMSD, various sources

Renewable Energy Performance

Because MMSD has identified a KPI of 100 percent of annual energy from renewable sources, the 2050 FP assessed existing data to define Baseline and Future Conditions for renewable energy usage.[9] For the assessment, Energy Baseline Conditions established 2017 as the most recent year of energy usage because it had the most detail, with one exception: because fleet vehicle fuel was not recorded for 2017, the 2018 vehicle fuel usage data were used for the analysis (note that vehicle fuel is a small energy need compared to heat and electricity). The 2017 Energy Baseline is summarized in Table 5-20.

TABLE 5-20: BASELINE ENERGY DEMANDS

2035 Energy Balance Annual Totals	Units[1]	Total Baseline	Renewable	Difference
JIWRF Heat Demand	Dth/yr	1,065,559	297,542	768,017
JIWRF Electricity Demand	Dth/yr	342,789	141,776	201,013
SSWRF Heat Demand	Dth/yr	127,733	98,282	29,451
SSWRF Electricity Demand	Dth/yr	138,727	63,828	74,899
Non-process (NP) Heat Demand	Dth/yr	136,627	0	136,627
Non-process (NP) Electricity Demand	Dth/yr	18,119	639	17,480
Fleet Vehicles	Dth/yr	1,921	0	1,921
Totals	Dth/yr	1,831,475	602,067	1,229,408
% renewables	NA	33%	NA	NA
Landfill Gas Purchased	Dth/yr	380,423	NA	NA
Digester Gas Produced	Dth/yr	284,706	NA	NA
Solar Panels JI	Dth/yr	73	NA	NA
Solar Panels HQ	Dth/yr	41	NA	NA

1) Dth/yr – dekatherms per year

Future energy projections were calculated using biosolids output from mass balances developed using WRF Future Conditions projections and set to the year 2035 to align with the 2035 Vision goals. Non-process energy needs include purchased natural gas and electricity for conveyance facilities and the MMSD headquarters and laboratory. No increase in non-process energy loads are projected for 2035. Future WRF process needs were modeled in terms of solids and non-solids needs. Non-solids electricity will increase in proportion to plant flow and non-solids heat needs will essentially be building heat and therefore not increase in 2035. Solids energy needs and digester gas production increase according to 2035 solids inputs. The 2035 solids inputs were derived from the annual average mass balance presented in Appendix 5B, WRFs and Biosolids. The future energy demand projections are summarized in Table 5-21.

[9] *Energy performance was not projected for Buildout Conditions because the LFG supplier has only predicted LFG supply to the year 2032.*

TABLE 5-21: FUTURE ENERGY DEMANDS UNDER WRF FUTURE CONDITION PROJECTIONS

2035 Energy Balance Annual Totals	Units[1]	Total Baseline	Renewable	Difference
JIWRF Heat Demand	Dth/yr	1,081,768	409,047	672,721
JIWRF Electricity Demand	Dth/yr	400,397	0	400,397
SSWRF Heat Demand	Dth/yr	145,990	145,990	0
SSWRF Electricity Demand	Dth/yr	174,920	31,390	143,530
Non-process (NP) Heat Demand	Dth/yr	136,627	136,627	0
Non-process (NP) Electricity Demand	Dth/yr	18,119	41	18,078
Fleet Vehicles	Dth/yr	1,921	1,921	0
Totals	Dth/yr	1,959,742	725,015	1,234,726
% renewables	NA	37%	NA	NA
Landfill Gas Purchased	Dth/yr	417,623	NA	NA
Digester Gas Produced	Dth/yr	282,802	NA	NA
Solar Panels JI	Dth/yr	73	NA	NA
Solar Panels HQ	Dth/yr	41	NA	NA

1) Dth/yr – dekatherms per year

Figure 5-14 compares renewable to non-renewable energy demand under both Baseline and WRF Future Conditions. The 2017 Baseline indicates that currently MMSD is meeting 33 percent of its annual average energy needs from renewable sources. All renewable sources are prioritizing the generation of electricity over the production of heat. In other words, digester gas is used in the engine generators as a first priority, then boilers. At JIWRF, all landfill gas (LFG) is used in the combustion turbines. The LFG that is used in the turbines converts about 37 percent of its energy value to electricity and an additional 30 percent as recovered heat, for a total energy recovery of approximately 67 percent. The dryers can use turbine waste heat year-round, so there is not a seasonal fluctuation of usable heat recovery. At SSWRF, the engine generator useable combined heat and power production is about 55 percent of its incoming energy content, based upon MMSD energy models; there are seasonal fluctuations in digester and building heat needs. The percent of energy provided by renewable sources under WRF Future Conditions increases to 37 percent. This is due to an increased use of LFG in the dryers to dry more biosolids. This projection is much lower than the 2035 Vision goal of 100 percent. Chapter 6 evaluates opportunities to increase renewable energy to meet MMSD 2035 Vision goals over and above the Energy Plan alternatives already being implemented.

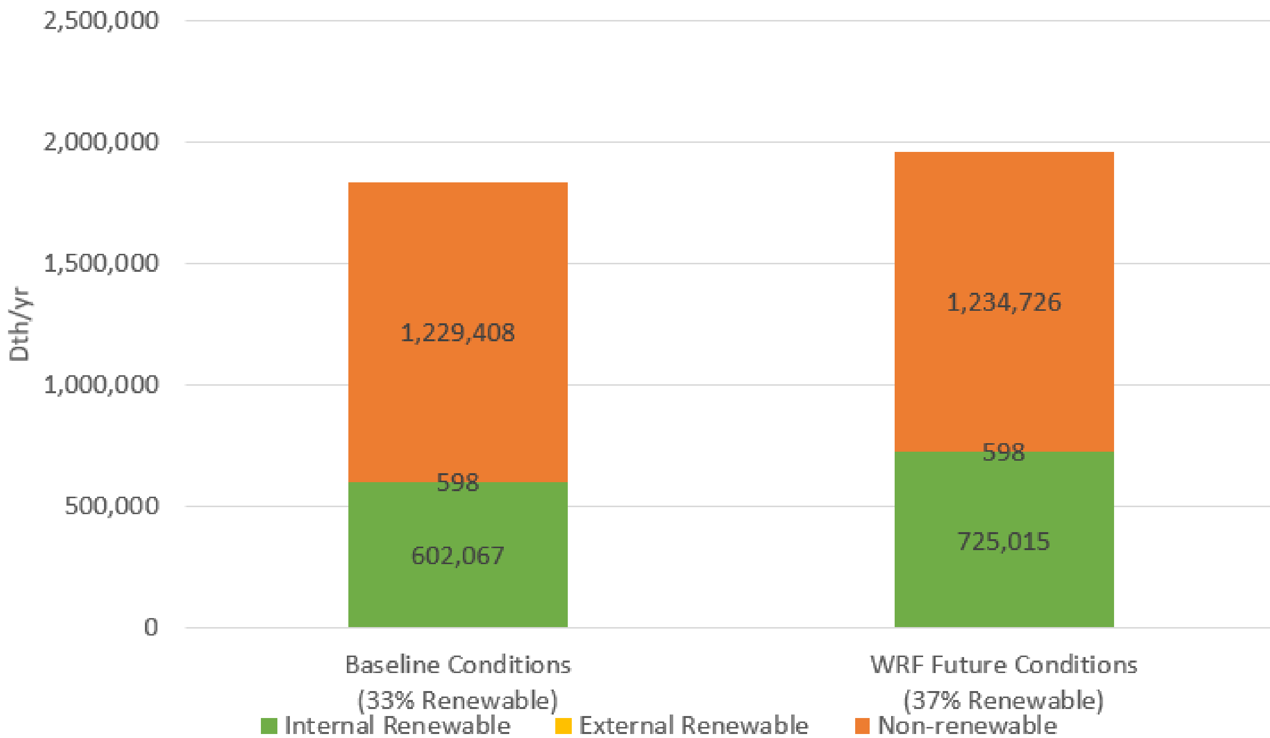

FIGURE 5-14: BASELINE AND PROJECTED PERCENT RENEWABLE ENERGY

Notes:

1) Dth/yr – dekatherms per year
2) The value "598" in the figure represents external renewable energy in Dth/yr, which is very small compared to Internal Renewable and Non-renewable energy values.

Review of Energy Plan Alternatives

The 2050 FP project team reviewed the Energy Plan to determine if there were any recommended energy alternatives that, if not implemented, could be risks to meeting the 2035 Vision goals of 100 percent renewable energy. A meeting in March 2015 was held to review the Energy Plan alternatives; in that meeting, 24 alternatives were selected to be evaluated in the 2050 FP, which are presented in Table 5-22. The full list of Energy Plan alternatives and the decisions made at the March 2015 meeting are documented in Appendix 5E, Energy Reduction Alternatives for 2050 FP Review.

TABLE 5-22: ENERGY PLAN ALTERNATIVES IDENTIFIED FOR FURTHER REVIEW IN THE 2050 FP

Energy Plan Alternative Number	Energy Plan Alternative Name
2	Optimized influent flow split between WRFs
4	Bypass JIWRF High-Level Screw Pumps
6	Optimize pumping energy using PLC for RAS/WAS
9a/9b	Optimized waste heat pressure control by modifying damper on the waste heat boiler or dryer waste heat dampers
12	Increase belt press feed solids to increase cake solids
17	Use waste heat to heat biological process at JIWRF
22	Recover heat from dryer exhaust
23	Capture more heat from existing IC engines
24	Jones Island Aeration Control Using DO and Ammonia/Nitrate Probes
29	South Shore based flow UV disinfection with renewable energy
31	Heat recovery from effluent
34	Large bubble mixing for JIWRF channels
44b	Send excess heat to nearby industries, commercial buildings, and residences
54/55	Supplement biosolids processing
75	Identify alternative drying technologies that offer higher efficiencies
78	Hydropower at South Shore using either preliminary treatment influent or primary clarifier influent
82	Install jockey pump within ISS PS for dewatering tunnel
NEW	Consider alternative dryer air filtration process or modify operation of existing electrostatic precipitators
NEW	Evaluate modifying existing induced draft fans in D&D with VFDs
NEW	Discharge scum to digesters
NEW	SSWRF use of effluent pumping to create mixing for chlorination
NEW	SSWRF energy system audit

Source: Appendix 5E, Energy Alternatives Selection

Summary of Systemwide Risks

Only the level of service failure mode was assessed at the systemwide level. Specifically, the KPIs and PIs that were identified in Chapter 3 were assessed. The findings were as followings:

- As shown in Tables 5-18 and 5-19, all KPIs and PIs had 2015–2017 performance data available, except for two PIs: % of annual N recovered and % of annual P recovered. These new metrics are proposed to be tracked moving forward and future updates of the facilities plan will incorporate actual performance metrics as they become available.
- Out of those KPIs/PIs with performance data, only three out of 10 KPI and three out of 11 PIs met the level of service targets. These KPIs/PIs relate to permit violations, budget, and basement backup targets.
- MMSD identified three KPIs and two PIs as priorities for meeting key level of service targets related to the 2035 Vision. Chapter 6 identifies potential mitigation strategies and identifies recommended projects to mitigate these risks:
    - Key Performance Indicators:
        - % of annual overall capture of flow into MMSD system
        - % of annual energy from renewable sources
        - % of annual energy from MMSD-generated renewable sources
    - Performance Indicators:
        - SSO events/year
        - CSO events/year
- A review of Energy Baseline indicates that the percentage of total energy demand that comes from renewable energy sources is 33 percent and is projected to increase to 37 percent under WRF Future Conditions, which is much lower than the 100 percent goal set in the 2035 Vision.
- Twenty-four Energy Plan alternatives are identified as potential strategies to mitigate the risk of not achieving the renewable energy goals.

These identified risks are evaluated, with total project costs for recommended projects, as part of the alternative analyses in Chapter 6.

5.10 APPENDICES

- Appendix 5A: Conveyance Assessment of Existing Facilities and Risks
- Appendix 5B: WRFs and Biosolids Assessment of Existing Facilities and Risks
- Appendix 5C: Watercourse and Flood Management Assessment of Existing Facilities and Risks
- Appendix 5D: Green Infrastructure Assessment of Existing Facilities and Risks
- Appendix 5E: Energy Reduction Alternatives for 2050 FP Review

5.11 References

[1] 2020 Facilities Plan Team, "2020 Facilities Plan Report," MMSD, Milwaukee, WI, March 2007.

[2] Milwaukee Metropolitan Sewerage District, "MMSD Rules, Chapter 3 Amended, Management Operations & Maintenance of Tributary Sewers," MMSD, Milwaukee, WI, 2014.

[3] Milwaukee Metropolitan Sewerage District, "SOP: Performing Assessment of Compliance for a Metershed," MMSD, Milwaukee, WI, 2015.

[4] Brown and Caldwell, "Ad Hoc Modeling Request 211: Evaluation of I/I Influences," Brown and Caldwell, Milwaukee, WI, 2018.

[5] Brown and Caldwell, "Ad Hoc Modeling Request 206, Part 4 Response 1, Evaluation of Free Flows to the ISS," MMSD, Milwaukee, WI, 2018.

[6] Milwaukee Metropolitan Sewerage District, *Jones Island Operations and Maintenance Manual: Plant Summary and Administration,* Milwaukee, WI: MMSD, 1993.

[7] Milwaukee Metropolitan Sewerage District, South Shore Operations and Maintenance Manual: Plant Summary and Administration, Milwaukee, WI: MMSD, 1986.

[8] Legislative Reference Bureau, *Wisconsin Administrative Code, Chapter NR 110,* Madison, WI: Legislative Reference Bureau, 2017.

[9] Health Research Inc., Health Services Division, Recommended Standards for Wastewater Facilities ("10 States Standards"), Albany, NY, 2014.

[10] Wisconsin Dept. of Natural Resources, "Wisconsin Natural Resources Board Amended Agenda (rev. 10/15/19) Tuesday, October 22, 2019 and Wednesday, October 23, 2019," Wisconsin DNR, Madison, WI, 2019.

[11] CH2M Hill, "Regional Green Infrastructure Plan," MMSD, Milwaukee, WI, 2013.

[12] Milwaukee Metropolitan Sewerage District, "MMSD Green Infrastructure Standard Specifications and Plan Templates," MMSD, Milwaukee, WI, 2016.

[13] CH2M Hill, "Final Energy Plan," MMSD, Milwaukee, WI, 2015.