2019 Water System Master Plan Update

Volume 1 – Final Report

Madison Water Utility
Madison, Wisconsin

MADWU 139057 | May 2020

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Madison Water Utility

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Executive Summary

1 History and Purpose

The Madison Water Utility (MWU) drinking water system serves the City of Madison, Wisconsin and portions of adjacent communities providing safe drinking water to approximately 255,000 residents, UW students, and regional employees. MWU has used a Water Master Plan since 1964 to guide development, operation, and expansion of the water distribution system. This plan is routinely updated every 5 to 8 years to accommodate current and projected water use trends, development pressures, fire protection requirements, and to sustain the Utility's level of service to area consumers.

MWU is currently developing an Asset Management Program that will incorporate asset condition assessment, core risk, business risk evaluation, and asset renewal into the Utility Capital Improvement Program (CIP). Asset Management will use data driven decisions to develop the right project, at the right time, for the right reasons, at the right price. Asset Management will maximize return on investment and help to ensure the water system will meet established levels of service now and in the future.

The City of Madison is home to the University of Wisconsin, a Big 10 institution, and Madison is the capital of the State of Wisconsin making the City a premier urban area and leader in the region. Proper planning is essential combined with optimal operations to meet the long term needs of the community.

This water master plan report (*2020 Master Plan Update*) represents a comprehensive water system planning effort to develop and identify priority water system improvements to support the growth and operational optimization of the Madison Water Utility (MWU) Water Supply System. A Capital Improvement Program prioritized to meet existing and projected needs will position MWU to support the needs of the City of Madison though the year 2040.

2 Water Needs

2.1 Study Area

The study area for this project includes all areas MWU currently serves and all areas MWU projected to serve by Year 2040. The study area was coordinated with the City of Madison Planning Department and is based on current intergovernmental agreements with neighboring community and governmental units. The study area boundaries are presented in the map in Appendix 2A.

2.2 Population and Growth

Projected population growth over the planning period to 2040 is based on several population estimation methodologies. Information about the population projection process is presented in Chapter 2. Population, employment, and student growth is dependent on the regional economy and employment growth. MWU will monitor and adjust population and growth projections as they develop throughout the 20 year planning period. A range of population growth projections is presented in Figure 2-1 which is presented below for convenience.

Population by Pressure Zone was also estimated and is presented in Figure 2-2. That information is presented below for the readers information and use.

Figure 2-1 - Historical and Projected Population Estimates

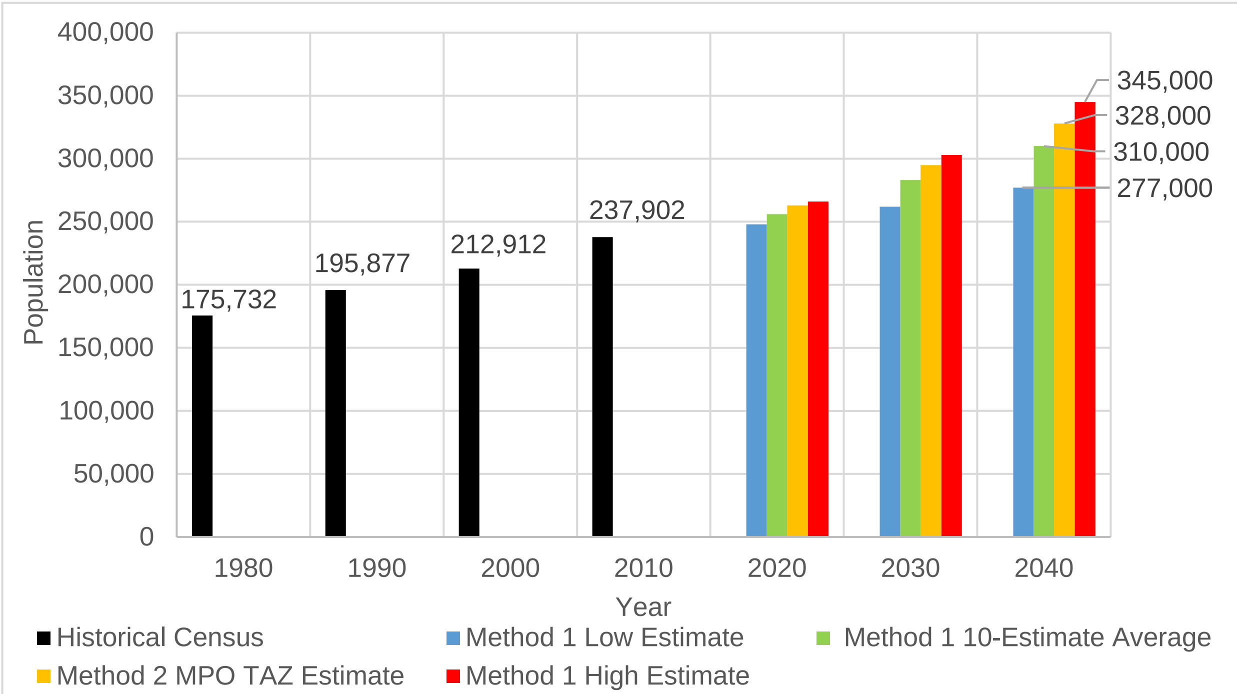
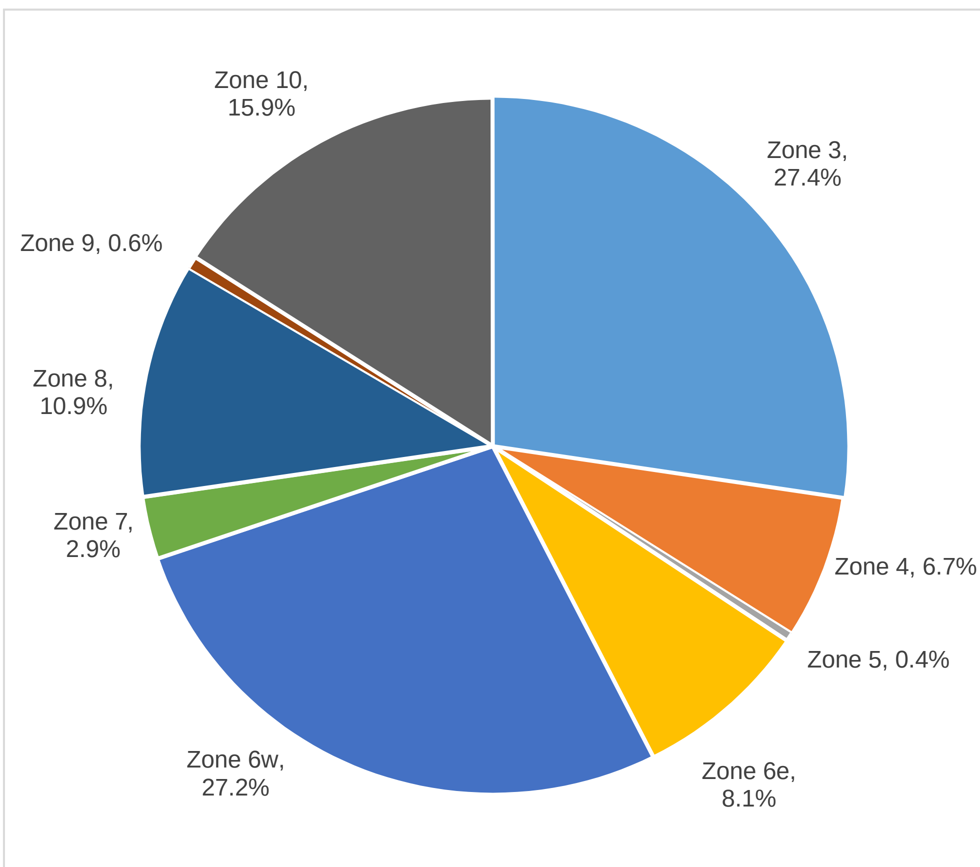
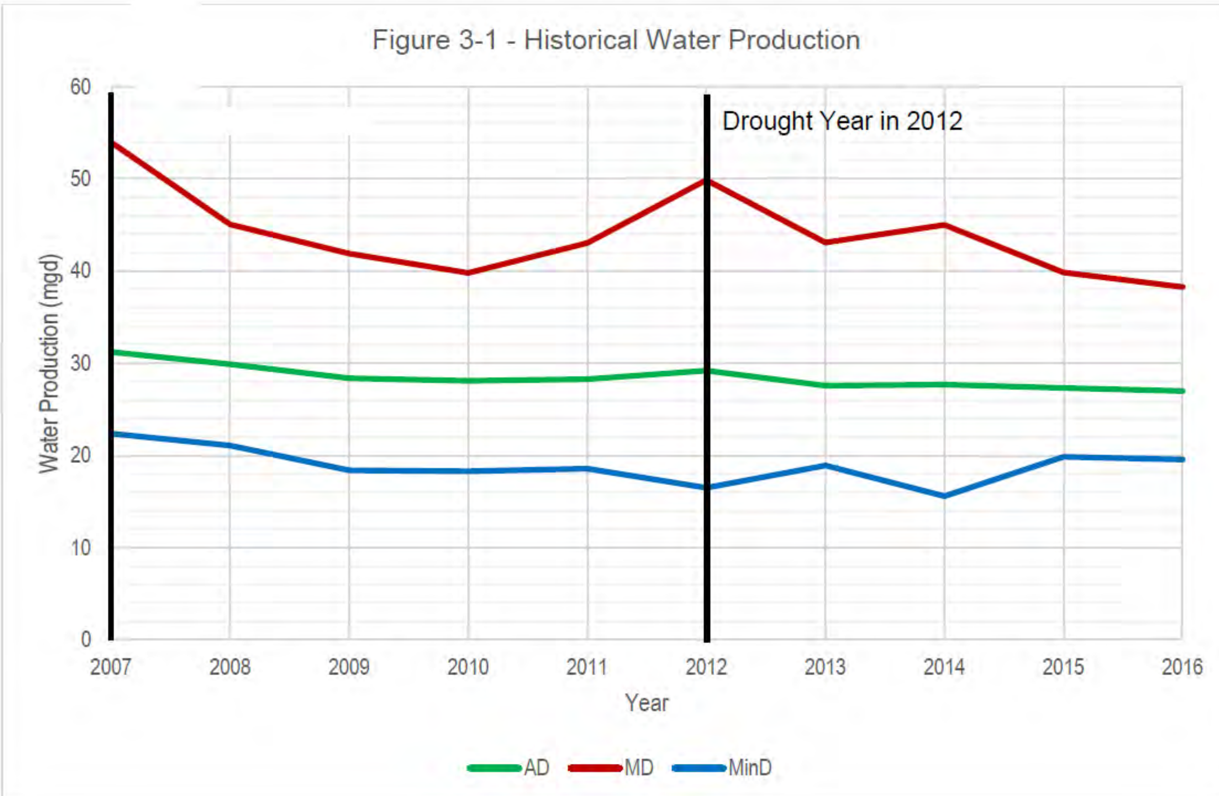


Figure 2-2 – Method 2 Population Growth Distribution by Pressure zone



2.3 Historical Water Demands

Water demands have been declining over the past two decades due to a national trend of conservation and a change in water use habits. Historic water production from 2007 to 2016 is presented in Chapter 3 in Figure 3-1 and is included below for the reader's information.



2.4 Conservation and Weather Impacts

Plumbing codes have improved the efficiency of water use on common household appliances and commercial and industrial customers have taken steps to improve conservation and reduce water demands. This has resulted in a general downward trend in total water demand. This situation makes projecting future water needs a significant challenge. Weather is also a factor in water use and annual precipitation will drive water use up during droughts and down during wet years. The last drought year experienced in Madison was 2012 which had a noted upswing in water demand. Generally speaking MWU experiences maximum water use during drought periods.

Conservation data is presented in Chapter 3. Conservation trends will continue to improve and drive individual customer water demands down. It is assumed that climate change will make drought years more common and potentially more severe. For the purposes of this water master plan, the design year was developed based on a drought year with continual improvement in conservation as the service area grows.

2.5 Future Demands

A range of future water demands based on population and employment projections, conservation trends, and weather are developed and presented in Chapter 3. The range provides a significant variation in projected water demands and the water needs projections shall be routinely reviewed and updated. For the purposes for this Master Plan, the middle projected range will be used for analysis. Figure 3-8 provides average day projections to 2040 and Figure 3-9 provides maximum day demands. Those figures are included below for the reader's convenience.

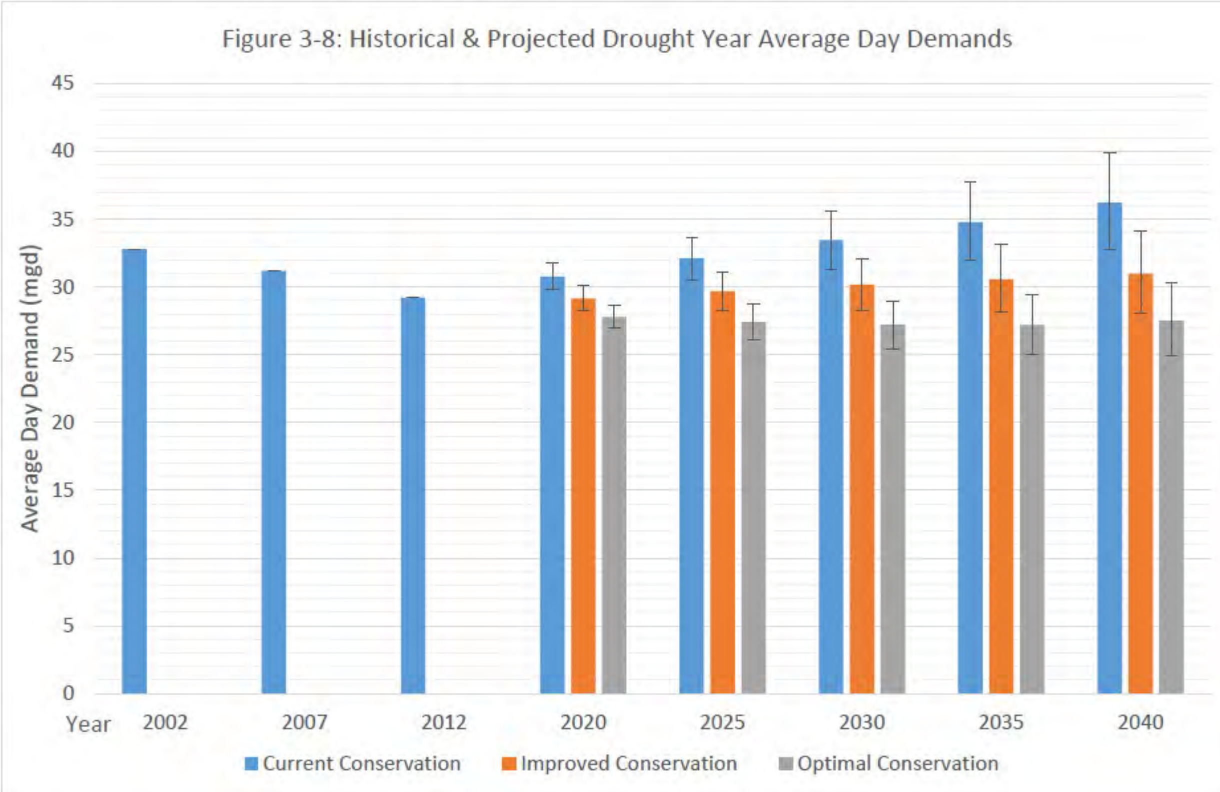


Figure 3-8: Historical & Projected Drought Year Average Day Demands
Average Day Demand (mgd)
45
40
35
30
25
20
15
10
5
0
Year
2002
2007
2012
2020
2025
2030
2035
2040
Current Conservation
Improved Conservation
Optimal Conservation

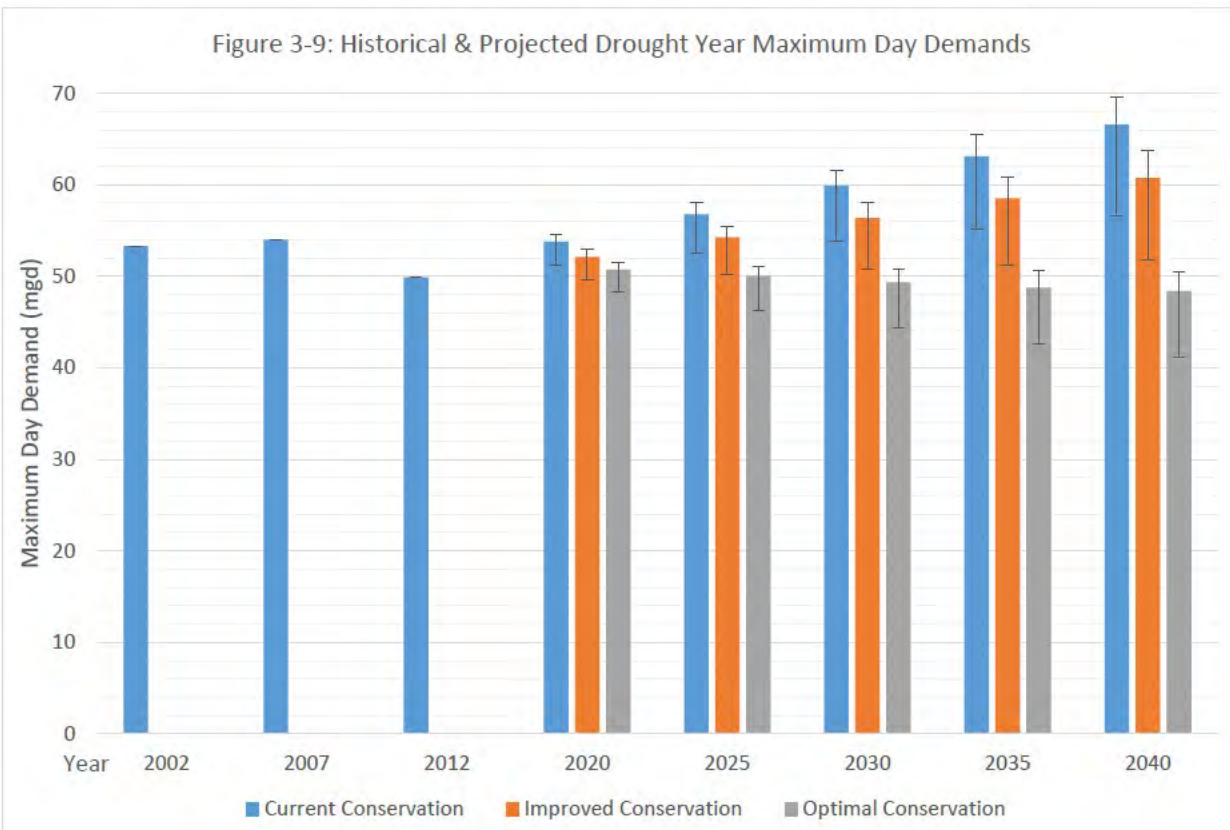


Figure 3-9: Historical & Projected Drought Year Maximum Day Demands
Maximum Day Demand (mgd)
70
60
50
40
30
20
10
0
Year
2002
2007
2012
2020
2025
2030
2035
2040
Current Conservation
Improved Conservation
Optimal Conservation

2.6 Hydraulic Regions

To facilitate the analysis of the system, the service area was divided into four (4) regions based on pressure zones. Region A included Zones 3, 5, and 6e; Region B included Zone 4; Region C included Zones 6w, 7 and 9; and Region D included Zones 8, 10, and 11. The regions were also consolidated into geographical areas comprising the East Side, Regions A & B; and the West Side, Regions C & D. Water supply capacity, pumping capacity, storage volume, and system redundancy and reliability were examined by Region and then by geographical area, east side and west side. Using regions as a basis of analysis is consistent with how the system is operated and controlled.

3 Water Computer Model

3.1 Calibration, AMI data and SCADA Data

The MWU water distribution system computer model was updated and calibrated using AMI and SCADA data. The AMI data from the smart metering system will provide hour by hour water usage data based on geographic location. This allows the model demands to be allocated to where and when the water is actually being used. This data also allows the development of accurate diurnal curves to allow accurate extended period simulations of system operation. Extended period simulation will provide vital information on system performance.

SCADA data is a second reliable source of operational data that provides information on pump operation, pressures, and reservoir levels. This data is critical to calibration of the computer model and provides a measure of the accuracy of that calibration.

3.2 Level of Service

In 2011 MWU developed Level of Service criteria for evaluating system operation and identifying deficiencies. The level of service criteria has been updated and expanded as a part of the Asset Management Program development. The Level of Service criteria provide the standard that operations are measured against. If an area cannot meet the established level of service criteria, it is considered to be a deficiency and mitigation will be considered in the development of improvement projects.

3.3 Water Utility Board Policy, Regulations, and Engineering Practice

Water Utility Board Policy, Public Service Commission Regulations, Department of Natural Resources Regulations, and sound engineering practice set criteria that are summarized within the established level of service. Several categories are considered and included in the rules and regulations of utility operations as follows: Water Quantity: sufficient quantity to meet domestic and firefighting needs at required pressures; Water Quality: Sampled, tested and certified safe drinking water; Reliability: built in redundancy, backup emergency power; and Zone interconnection; Affordability: efficiently produced and delivered water at a reasonable price; Sustainability: protect the water resource and the environment for current and future generations; Fiscal Responsibility: Set rates that support the long term needs of the utility and enable the infrastructure to be repaired and replaced in an efficient cost effective manner.

3.4 Operations

3.4.1 Pressure Zones

The MWU water system is comprised of 10 pressure zones designed to operate independently of each other. Each zone has supply coming from wells or connected booster pumping systems. Each zone is also provided with a storage reservoir that floats on the system providing stable pressures in the system and setting a hydraulic grade elevation.

3.4.2 Seasonal Variation

Water demand varies by season and the water system must respond to these variations to sustain supply and pressure and meet the required level of service. MWU maintains seasonal wells that are shut down during the winter due to the reduced water demand. Seasonal variation in water demand allows facilities to be shut down for maintenance and repair.

3.4.3 Emergency operations

Emergency operations include providing fire protection and water supply during power outages. Reservoirs are sized to provide 12 hours of emergency water storage based on the average day demand and provide firefighting capacity within their service area. During the analysis of system operation, reservoir capacity and firefighting capacity were key criteria for operational viability.

3.4.4 Water quality considerations

Well water quality impacts operations. Wells with lower water quality are not operated during low demand periods or winter months. Additionally wells in violation of water quality regulations or Water Utility Board (WUB) policy will be taken off line until treated or otherwise mitigated. The availability of a well and the potential to be impacted by water quality was considered in the system alternative analysis and ultimately the development of recommendations to ensure system reliability in meeting established levels of service.

4 Hydraulic Analysis

4.1 Methods

The hydraulic analysis investigated how the system operates under stressed conditions. Stress is imposed on the system by taking wells out of service and applying maximum water demands over a several day period. Being able to evaluate the operational characteristics during high stress events will identify deficiencies in the water supply network. Once identified, alternatives can be developed and tested for their ability to mitigate the identified deficiency.

To be efficient in analysis, several techniques are used to model system performance. Simple mass balance analysis will identify supply deficiencies, steady state network analysis can identify fire flow and pressure issues, and extended period simulations are used to evaluate overall performance of the system.

4.1.1 Mass balance

A mass balance evaluation was completed looking at the total volume of supply available versus water demand for each Region. This provides information on the capacity of the supply system to meet projected demands on the average day and the maximum day. Wells are taken off line in the analysis to simulate maintenance or mechanical failure of a well system. Within each geographical area, it is assumed that 3 wells were offline during in the analysis. The analysis to stress the system during evaluation of the east side required 3 wells to be off line in Regions A & B and all wells were operational on the west side. The west side was evaluated in a similar manor.

Moving water from an area of surplus to an area of need was a prime objective of the mass balance evaluation. To evaluate the benefits of interzone pumping, each region was analyzed for adequate supply capacity to determine if a region could be supplier or a recipient of water from an adjacent area. Following a regional analysis, each geographical area was evaluated separately.

Moving water significant distances may not be economically practical due to hydraulic capacity of the piping system. This condition would be investigated during modeling and it will be determined whether or not interzone transfer will benefit areas of supply deficiency.

4.1.2 Computer modeling

4.1.2.1 Development of Diurnal curves

Using AMI data, diurnal curves were developed for all pressure zones. AMI data provides hour by hour information based on the geographic location of the meter. AMI data significantly improves the accuracy of the computer model and provides an improved picture of system operations.

4.1.2.2 Max 10-day Extended Period Simulation

A water system is stressed during maximum demand periods and must recover from that condition to fill reservoirs. Evaluating the system over the maximum 10-day demand period provides vital information on how the system operates, responds, recovers, and will identify deficiencies that may not have been evident in a mass balance or a steady state evaluation.

The maximum 10-day demand extended period simulation was used to test the performance of proposed alternatives. Alternatives were proposed and considered based on system knowledge and understanding and water system engineering standards. Once developed the alternative was inserted into the model and performance was tested to determine if it would mitigate the problem.

4.1.2.3 Steady state fire flow evaluation

Fire flow is tested during the highest demand day to determine if the system has the capacity necessary to meet established capacity standards while maintaining minimum pressure. To evaluate the full fire flow capacity across the distribution system using an extended period simulation would be extremely time consuming. A steady state analysis of fire flow capacity on the maximum day will identify any areas of concern.

4.2 Identified deficiencies

The comprehensive analysis of the system itemized deficiencies is presented in Chapter 7. System deficiencies are summarized as follows:

Water Supply: All regions of the MWU system struggle to meet water supply standards during maximum demand periods with three wells off line for each geographical area. The far west side of the system has the greatest water supply deficiency due to current and projected development.

InterZone Pumping: BPS 213 and BPS 129 were itemized as being deficient. BPS 213 is undersized for fire flow requirements in Zone 5 and requires a standby generator to become fully reliable during an emergency. BPS 129 would provide needed redundancy, capacity, and reliability to the Zone 3 supply system.

Storage: The only storage deficiency identified was in Zone 5 and that deficiency is to be addressed with the upgrade of BPS 213.

Water Quality: Several water quality deficiencies were identified by MWU staff. Iron and manganese impacts 7 different wells, Radium impacts 2 wells, VOCs have been measured in 4 wells, sodium and chloride are a concern at Well 14, and PFAS has impacted Well 15. A minor concern was expressed with mixing within the large reservoirs resulting in stagnant water and chlorine decay issues. This would be mitigated with the addition of either static or mechanical mixers in the large reservoirs.

Facility Condition and Renewal: There is a general need for renewal of the older existing facilities. This was not within the scope of this Master Plan and will be covered by the MWU Asset Management Program.

Pipelines: Pipelines with high velocity and therefore with high friction loss were identified during the computer analysis of the water system. Generally speaking, the piping system performed well with a few exceptions. The pipeline deficiencies are identified in Section 6.7.3.1 and are illustrated on Figure 6-11. These pipelines can be upgraded during scheduled Public Works projects over the next 20 years or extended when development occurs.

MWU engineering and mapping staff developed a pipe rating system to identify existing pipe that need to be rehabilitated to sustain the system long term. This work is part of the Asset Management Program. The pipe identified in this Master Plan noted above will be considered as part of the main replacement program as the opportunity presents itself. An estimated 7.1 miles of pipe should be considered for replacement, relining, or upgrade annually. An annual budget of $9.7 million (2020 Dollars) is recommended to replace and upgrade the piping system and is included in the Capital Improvement program.

5 Alternative Analysis

5.1 Alternative development and evaluation

Twenty-six different alternatives were developed and evaluated looking at addressing identified deficiencies. All of the alternatives are detailed in Chapter 7 and in the appendix. New wells, pumping stations or upgrades to existing pumping stations to move water between zones, pipeline upgrade projects, water treatment projects, and water transmission projects were developed and detailed to consider their feasibility and priority. Other projects were considered but removed from further development due to cost, environmental issues, or feasibility.

5.2 Alternative prioritization and ranking

The 26 different alternatives were evaluated and scored using the triple bottom line to rank their priority for MWU. The weighted scores and the resulting priority is presented in Table 7.1. The top 10 prioritized projects are presented below for the readers use and information. Refer to companion documents from the most recent CIP exercise from 2022-2023 in Appendix 7-8.

Table 7-1 – Alternative Project Scoring

Project #	Alternative	Draft Budgetary Costs	Project Planning Horizon	Weighted Score	Notes
WQE-01 WQE-02 WQE-03	Well 19 Water Treatment Mitigation	Treatment Total: $5.8M Blending $2.0M to $3.0M Replacement $9.7M	2023	78	Critical supply source for the west side and the University of Wisconsin.
SE-01	Well 8 Water Quality Mitigation and Conversion to 3 Zone Facility	Total: $12.6M Several alternatives to consider	2025 to 2030	78	Rebuilds a critical east side supply source in the system. Will transfer water between three pressure zones. Cost will be high due to location. Neighborhood may oppose disruption of the park.
TW-04	UW 12 Upgrade and Conversion to a Two Zone Well	UW 12 Upgrade: $4.5M (Designed in 2018)	2024	76	Project designed and ready for bid in 2018 when funding was cut. Piping connection to Zone 8 is complete. Key transfer point between Z7 & Z8 on the west side.
WQE-04	UW 27 Fe, Mn & Radium Filter	Total: $7.4M	2030	74	Limited space @ Well 27 will require innovative facility design layout to accommodate a filtration system. Well 27 is a seasonal well that would provide year around benefit to the west side.
SE-05 SE-06 SE-07	Upgrade BPS 213	Total: $2.5M	2025	73	Critical project between Z6e and Z5 to provide required fire flow capacity to Zone 5. A generator will be added for reliability.
SW-01	New West Side Well	Total: $9.7M	2025 to 2030	70	The west side of Madison is rapidly growing and needs additional supply to support ongoing and protected growth. Three sites have been identified for a new well.
SW-05	Well 15 PFAS Mitigation	UW 15 Treatment: $4.6M	2025 to 2030	62	Treatment would allow Well 15 to be returned to service. No PFAS regulations. Implementation of regulation will impact scoring. A study of alternatives is recommended for long term viability.
SW-04	Isthmus Transmission Main to Well 24	Total: $4.4M	2032	59	Project is a pipeline that will use an pumps at UW 24 to convey water from east to west. Provides no increase in supply but optimizes existing pumping facilities and could reduce costs.
WQW-04	UW 30 Fe and Mn Filter	Total: $6.3M	2030	59	Iron and manganese filtration will reduce colored water complaints and flushing requirements in the area. The Well 30 property has sufficient area to accommodate an iron and manganese filter.

Table 7-1 – Alternative Project Scoring					
Project #	Alternative	Draft Budgetary Costs	Project Planning Horizon	Weighted Score	Notes
WQW-06	UW 24 Fe and Mn Filter	Total: $6.3M	2035	56	Iron and manganese filtration will reduce colored water complaints and flushing requirements in the area. UW 24 has limited space and will require innovative facility design layout to add filtration.

6 Water System Improvements

6.1 Summary of recommended improvements

Recommended capital projects are itemized in Chapter 8 of this report. The projects have been developed and tested for their applicability to effectively address identified deficiencies. As MWU develops its Asset Management Program, a Business Risk Evaluation (BRE) will be developed and will be used to fully prioritize projects for inclusion in the capital budget. It is recommended that the projects be routinely and regularly reviewed an updated to ensure the best return on investment.

Projects were grouped as near term and long term in Chapter 8. Actual schedules will depend on MWU financial capacity, system wide priorities, the regional economy, and level of service.

6.1.1 Near Term (2020)

Recommended Near Term Improvement Projects:

- Well 19 Water Treatment Mitigation – Fe, Mn, and Radium
- UW8 Reconstruction to a 3 zone well + Filtration + Watermain. (S.E02 + S.E08)
- UW 12 - Conversion to a Two Zone Well (T.W04)
- Lakeview Booster Station 213 Upgrades (T.E01)
- New West Side Well (UW 32 - Mineral Point Road)
- BPS 128 Upgrade (T.W05)

6.1.2 Long Term (2040)

Recommended Long Term Improvement Projects

- UW 27 Water Treatment Mitigation – Fe, Mn, and Radium
- UW 15 PFAS Mitigation
- UW 30 Fe and Mn Filtration
- UW 24 Fe and Mn Filtration
- New East Side Well (UW 33A Felland Road)
- BPS 129 Relocation (T.E02)
- BPS 109 at UW9 (T.E03)

6.2 CIP

A draft CIP was included as Table 8-2 to provide guidance to MWU for the next decade. An updated version was created in 2023, available in Appendix 7-8. The current City of Madison Water Utility approved capital budget was considered when developing this draft CIP. Each spring it is expected that the project list will be evaluated against current conditions, a Business Risk Evaluation will be completed, and projects will be added or deleted as necessary.

Pipeline projects will continue to be coordinated with City Engineering as a part of Public Works projects. Individual pipeline projects are not itemized here due to the wide variation of project scope and schedule. MWU will utilize a water main rating system developed with the Asset Management Program to schedule and implement pipe upgrades and replacement.

Table 8-2 is provided here for information and use.

Table 8-2 Recommended Capital Improvement Program											
Priority	Project	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
1	UW 19		$ 891,000	$6,691,000	$ 81,000						
2	UW 8	$120,000			$ 100,000	$2,000,000	$2,000,000	$7,000,000	$1,500,000		
3	UW 12			$ 300,000	$3,800,000	$ 400,000					
4	UW 27								$ 900,000	$6,500,000	
5	BPS 213				$ 200,000	$1,250,000			$1,000,000		
6	New West Side Well							$ 100,000	$1,100,000	$1,000,000	$7,500,000
7	UW 15	$122,000									
	Pipe Rehab*	$4,166,000	$2,961,000	$2,990,000	$3,033,000	$2,608,000	$4,714,000	$7,000,000	$7,350,000	$7,718,000	$8,104,000
	Totals	$4,408,000	$3,852,000	$9,981,000	$7,214,000	$6,258,000	$6,714,000	$14,100,000	$11,850,000	$15,218,000	$15,604,000
	*2021-2026 based on actual budget. 2027 to 2030 Projected and adjusted for Annual Inflation Current Budget through 2026 not displayed										

6.3 Budgeting

Madison Water Utility's most recent 10-year Financial Plan (provided as a companion document to this report as of 2023) was filed with the Wisconsin Public Service Commission in February of 2023. Identified in the plan, is budgeting for capital improvements through its CIP; in addition to facility improvement projects, one of MWU's priorities in its capital improvement/ investment strategy is its water main replacement programs.

The 2021 and 2022 adopted capital budgets reduced all capital improvement spending to help minimize the need for long-term financing. In the 2022 water rate case, MWU obtained approval for $5.0 million of annual expense depreciation to fund water main replacements. This represents an approximate annual replacement rate of 0.4% of the water mains in MWU's system. Generally, an annual replacement rate of 1% of the water mains in MWU's system will provide for the full replacement cost of a given main within its lifespan and is the preferred benchmark by both MWU and the Wisconsin Public Service Commission to avoid intergenerational inequities. MWU expects to increase the amount of funding for the main replacement program to the level of 1% in the coming years as it progresses through this financial plan and, more specifically, reduces its debt load.

Chapter 1

Introduction & Overview

1 Introduction

Madison Water Utility (MWU) water system serves the City of Madison, Wisconsin and the approximately 255,000 residents. MWU provides water service to residences and businesses within the City limits of Madison and some nearby communities.

MWU provides water to its customers via twenty-two (22) deep aquifer sandstone water supply wells (nineteen Unit wells and three independent wells), located throughout the water system and additionally includes: Five (5) elevated tanks, four (4) ground level reservoirs and one (1) standpipe which provide distribution storage, and Eight interzone Booster Stations transfer water from one pressure zone to another. MWU maintains over 900 miles of transmission and distribution water mains ranging in size up to 24 inches in diameter.

City of Madison's status as a premier urban area with principal transportation corridors, and available lands offers potential for future growth and development. Therefore, proper planning is essential to coordinate the expansion of municipal water system facilities with short term as well as long term needs of the community.

This water master plan report (*2020 Master Plan Update*) represents a comprehensive water system planning effort to develop and identify priority water system improvements to support the growth and optimization of the Madison Water Utility (MWU) Water System. This has been an ongoing collaborative planning effort including team members from Madison Water Utility and SEH (Short Elliott Hendrickson). Previous master planning efforts had developed a comprehensive list of recommended water system improvements to serve the City of Madison well into the future. This planning effort works to revisit existing recommendations and develop new alternatives to optimize the operation of the water system. The driving factor behind the optimized water system recommendations is the emergence of new citywide water use trends. Additionally, more advanced water system analytics were harnessed to more precisely define future water system demands. This water system master plan serves to provide a roadmap for future water system infrastructure development that is right sized to serve the Madison Water Utility well into the future.

1.1 Purpose

This report summarizes the results of a comprehensive water system evaluation. The primary purposes of the study were to evaluate the water needs and system expansion required to serve current and future utility customers. Present and future water needs of the MWU water system have been evaluated, and recommendations made concerning improvements necessary to maintain an adequate level of water service. Current and future water needs were evaluated over a planning period extending to the year 2040. The Water Master Plan will serve as a plan to guide future expansion and redevelopment of the water system. The report has been prepared to evaluate all of the MWU water system assets and to develop short-term (through year 2030) and a long-term (through year 2040) plan of improvements needed to improve the current water system deficiencies and to serve anticipated water system growth over the next 20 years. This plan builds upon previous planning efforts and accounts for recent changes in water use trends. The goals and objectives of this water master plan assessment include:

- Review current and anticipated water system service area.
- Analyze and understand current water use trends.
- Develop Updated Water Use Projections.
- Assess the reliability and capacity of the existing water system to meet future water use projections.
- Re-evaluate current near term water system improvement plans.
- Recommended updated long term water system improvement plans.
- Develop supporting documentation for the design, construction, and financing of facilities to improve current service capabilities, and to serve future increases in water demand as a result of projected population and employment growth anticipated from planned residential, commercial and industrial development.
- Account for current water conservation trends and the effect on water system demand projections and impact on the need for future water system improvements.
- Hydraulic modeling of the existing and future water distribution system.
- Developing and evaluating alternatives to address identified system deficiencies.
- Prioritize selected alternatives and develop a feasible Capital Improvement Program (CIP)
- Develop planning level cost estimates to facilitate budgeting and financial planning.

1.2 Background and Previous Studies

This report builds on several other projects and activities completed by MWU in recent decades. In 2008 MWU completed a full update of the Water Master Plan. The 2008 Water Master Plan Update was prepared to evaluate MWU's water system and to develop a short-term (through year 2010) and a long-term (through year 2025) plan of improvements needed to correct identified deficiencies and to serve anticipated growth over the 20-year planning cycle. The net result of the effort was a 20-year capital improvement program (CIP). Since the completion of the 2008 Master Plan update, several of the proposed short term improvements have been constructed and commissioned for use.

In 2005, MWU developed an Infrastructure Management Plan that was a precursor to an Asset Management Program. The Plan evaluated the condition of all of the system assets and recommended a CIP to systematically renew MWU system assets. In 2007, MWU started work on a comprehensive water main replacement program. As the opportunity presented itself, water main capacity was increased based on the 2008 Water Master Plan.

Public input to MWU in the late 2000's indicated a strong desire to improve water quality throughout the system. MWU shifted its focus to water treatment and constructed and commissioned the first system iron and manganese filter at Unit Well 29 in 2009.

Building on a desire for improved water quality, MWU commissioned the East Side Water Supply Plan in 2010. This plan identified the need for several filtration plants and a VOC air stripper. The MWU capital spending focus shifted away from adding supply and system expansion.

Below is a brief summary of the water system planning efforts that this Master Plan Update builds on.

- December 1999 Water System Master Planning update prepared by Earth Tech, Inc. This update included the development of an in house water system computer model for MWU.
- 2005 Infrastructure Management Plan prepared by Black & Veatch Corporation. This plan was a precursor to
- December 2008 Madison Water Utility Water Master Plan update prepared by Black & Veatch Corporation.
- 2012 East Side Water Supply Project prepared by Black & Veatch Corporation.

1.3 Scope

The study began with an analysis of community development and growth including population, and existing and expected future land uses in Chapter 2. Chapter 3 covers water consumption projections, which serve as the foundation for evaluating and identifying recommended improvements to the system. The assumptions and conclusions presented in Chapter 2 were used to develop projections of water requirements presented in Chapter 3. Chapter 4 summarizes the current water system and identifies current capacities and capabilities. Chapter 5 summarizes the modifications, updates and verification of the water system model. Chapter 6 summarizes the evaluation of the water system and develops a list of deficiencies based on current demand projections. Chapter 7 identifies potential alternatives to address the water system deficiencies . Chapter 8 lays out proposed water system improvements. The proposed improvement alternatives were tested for performance within the water modeling environment to assure they mitigate identified deficiencies and work to meet minimum level of service standards.

Because needs change with time, municipal water system planning is a continuous function. Long term projections and improvements discussed in this report should be reviewed, re-evaluated and modified at least annually during budgeting. Annual review will assure the adequacy of future planning efforts and accommodate current trends and needs. Future planning will help assure that system expansion is coordinated and constructed in the most cost effective manner.

1.3.1 Current operation analysis, assessment and documentation

1. Collect and review MWU level of service standards, State and Federal regulations, policies, and operational objectives.
2. Conduct in-person interviews of available MWU Operation staff to obtain information regarding Utility operational concerns, challenges, and alternative operating improvements.
3. Review and analyze current MWU SCADA system configuration, communications and operations to understanding the MWU water system from an operational standpoint, and begin to integrate/setting up hydraulic model controls based on this review.
4. Review the existing MWU water conservation programs, and current program goals and objectives to integrate and understand the scenarios to update the hydraulic water model.
5. Review and update the System Level of Service Memorandum (LSM) and the draft Asset Management Program documentation. Work with MWU staff to evaluate LSM performance measures and Asset Management standards with regard to items listed below. Recommend revisions, additions, and updates as appropriate to MWU's LSM.
    a. Water Quality
    b. Regulatory issues
    c. Pressure management
    d. Energy management
    e. Emergency response management
    f. Utility financial strength, borrowing capacity, water rate position, and annual CIP capability
    g. Customer service
    h. Internal business capabilities and limitations
    i. Anticipated system growth
    j. Critical system components and impacts
    k. Redundancy and reliability
    l. Pipeline rehabilitation or replacement evaluation
    m. Technology upgrades

6. Identify potential operational issues and objectives that may impact MWU's future CIP.
7. Recommend revisions, additions, and updates as appropriate to MWU system operation and/or operational historical documentation protocols and reporting. .

1.3.2 Task 2 – Hydraulic Model Update & Calibration

1. **Water Needs Analysis.** Review MWU current and future service area population forecasts and update MWU water demand projections over the planning period.
   a. Collect available current demographic data and planning forecasts for the identified service area based on the City of Madison's Comprehensive Plan.
   b. Collect and review water demand data information including billing (AMI), SCADA pumping records, MWU PSC annual reports, other historical data sources, and other available planning and engineering reports.
      i. Using existing MWU GIS-based mapping and Automatic Metering Infrastructure (AMI), associate demands to junction nodes spatially throughout the water system, assigning each demand to the correct pressure zone. GIS geocoding can be used to locate meters based on address. AMI data will provide hour by hour water demand information resulting in accurate diurnal curve development throughout the MWU service area. A demand allocator tool will automatically assign demands based on the GIS fields.
   c. Develop unit demands (gallons/day/unit) to be used for projecting future MWU water requirements.
   d. Forecast future average day demand for each MWU pressure zone in 5-year increments starting with year 2020 and going through year 2040.
   e. Develop pressure zone peaking factors for maximum day (MD), maximum hour (MH), average day (AD), average summer day (ASD), and average winter day (AWD). Develop 10 max day (MD10) use patterns for modeling purposes.
      i. Using a combination of SCADA data, AMI data, land use considerations, and field calibration measurements, produce diurnal demand curves for estimating peaking factors.
      ii. Some field measurements or observations from MWU for the above information will be used to accurately develop these factors and may consist of tank levels, pump flow measurements, pumping time, totalized flow data, pressure data at various locations.
   f. Identify water requirements on a system-wide, pressure zone, and user class basis for AD, MD, ASD, AWD, and MH demands in 5-year increments starting with year 2020 and going through year 2040.
      i. Using the same information as above (e), the diurnal and seasonal demand curve will be generated for each pressure zone.
      ii. Using automated allocated processes within water modeling programs, each water meter can be designated a particular "customer type." Each customer type can be designated a unique diurnal demand curve. Customer-type diurnal demand curves can be estimated from customer surveys or can be directly measured from AMI meter data that have the capability to measure real time water demand.
2. Water Conservation
   a. Incorporate current MWU water conservation program goals into future water demand projections.
   b. Evaluate potential water demand reduction that could result from system-wide conservation programs.
   c. Water conservation shall be considered to be a priority in all long term planning.
   d. Analyze reduction in water losses in future MWU water demand projections.

e. Develop current, medium, and high conservation ranges for water demand projections for each planning period considered in operating scenarios to be modeled.

3. Peak Demand Reduction
   a. Evaluate programs and methods to reduce peak demands.
   b. Consider peak demand reduction measures on a daily and seasonal basis.
   c. Recommend capital improvements, customer incentives, and operational modifications that could reduce peak demands.
4. Allocate Updated Water Demands throughout full MWU existing system.
5. Develop diurnal curves by pressure zone, by weekday, by weekend, and by season for the full system.
6. Update the full MWU system Distribution System Hydraulic Model.
7. Update the full system hydraulic profile drawings.
8. Hydraulic Model Update and Calibration on-site workshop.
   a. Prepare for and conduct a one day (8 hour) workshop with MWU project team at MWU Office to review system operation and model update. This will be a model operation and control verification meeting.
   b. Review results of system operational review performed in Task 1.
   c. Review and validate system operational parameters.
   d. Review and validate model demand allocation updates.
   e. Review and validate model pump operation and controls.
   f. Review calibration procedures and results.
   g. Review scenario development and extended period simulation results.
9. Calibration and Testing of the MWU Hydraulic Model
   a. Develop a distribution system hydraulic model calibration and testing plan with steps, processes, and schedule for review by MWU.
      i. SEH will provide a calibration packet to MWU and will include procedures, maps, and fill-in data sheets, with an overall location map of each test proposed to be conducted.
      ii. This organized testing plan approach allows for MWU field staff to “leap-frog” to test locations to reduce time spent at each test site.
      iii. Testing procedures will be done in accordance with AWWA M32 and with certified calibrated pressure gages accurate to 0.5 percent.
   b. Following review and agreement on the model calibration and testing plan, calibrate MWU hydraulic model to meet project objectives and standards.
10. Updated Water Demand and Model Calibration Technical Memorandum. (RFP Task 2.11)
   a. Prepare a 90 percent draft Water Demand Forecast and Model Update/Calibration Technical Memorandum.
   b. Provide draft memorandum to MWU project team for review and comment.
   c. Incorporate MWU project team comments and finalize memorandum. (RFP Task 2.11)
   d. Incorporate Technical Memorandum as a chapter into Master Plan Update report.

1.3.3 System Hydraulic Analysis

1. Using the updated and calibrated MWU hydraulic model created from Task 2, perform an evaluation of the full MWU distribution system.
   a. Ten day extended period simulations will be used for scenario evaluations. Time periods to be considered will include current system (2015), 5-year (2020), 15-year (2030) and 25-year

(2040).

2. Develop a hydraulic analysis plan. Plan will include the following: (RFP Tasks 3.2 & 3.3)
   a. Pressure zone configuration and pressure management with regard to MWU LSM developed in Task 1.
   b. Water supply capacity analysis.
   c. Storage volume capacity analysis.
   d. Pumping capacity analysis.
   e. Interzone water transfer analysis.
   f. Fire flow capacity analysis
   g. Emergency operations analysis.
   h. Scenarios needed to analyze system, identify deficiencies and needed improvements
   i. Analysis evaluation criteria and methodology
   j. Draft plan provided to MWU project team for review and comment.
   k. Following approval of plan, perform hydraulic analysis of MWU system.
3. Perform a deficiency analysis.
   a. Identified system deficiencies will be classified under the categories listed in RFP Task 3.4.1.
4. Hydraulic Analysis Report
   a. Prepare a 90 percent draft Hydraulic Analysis Report.
   b. Provide draft report to MWU project team for review and comment.
   c. Incorporate MWU project team comments and finalize report.
   d. Incorporate Hydraulic Analysis Report as a chapter into Master Plan Update report.

1.3.4 Alternative Development

1. Work with MWU project team to develop improvement alternatives to mitigate identified deficiencies.
2. Use improvements recommendations in 2008 MWU Master Plan and 2012 MWU East Side Water Supply project considering improvements implemented by MWU over past 10 years.
3. The following will be considered in evaluating alternative improvements to address system deficiencies in developing a Capital Improvement Program (CIP):
   a. Energy Conservation
      i. Evaluate potential energy conservation programs with regard to operational requirements.
      ii. Identify benefits and challenges of off-peak pumping with regard to energy costs
      iii. Identify benefits of variable speed pumping.
   b. Water Quality
      i. Work with MWU project team to itemize and define identified water quality projects.
      ii. Prioritize and include water quality projects in CIP.
   c. Administration
      i. Work with MWU project team to itemize identified administration and support projects.
      ii. Include any administration and support improvement projects in the CIP.
4. Classify system projects as addressing one of the following primary improvement categories: (RFP Task 7.5)
   a. Hydraulic capacity

    b. Fire flow
    c. Storage
    d. Growth
    e. Water Quality
    f. Energy conservation
    g. System optimization
    h. Pipeline repair, upgrade or replacement
    i. Administration and Support
    j. Other
5. Verify benefits of recommended improvement projects with MWU's hydraulic model (as appropriate).
    a. Projects shall be described and justified with reference to an identified deficiency and benefit to MWU.
6. Recommended improvement project alternatives will be illustrated and identified on Master Plan report figures and/or maps.
7. Improvement Project Prioritization and Scheduling.
    a. Work with MWU project team to prioritize proposed projects based on criticality and category.
    b. Prepare a preliminary schedule for projects taking into account MWU financial, siting, permitting, and staffing capacity and goals.
8. Financial Analysis and Capacity
    a. Prepare an opinion of probable cost for each recommended improvement project.
    b. Prepare a project cost/benefit analysis.
    c. Include life cycle costs in project cost analysis.
    d. Work with MWU financial staff to prioritize recommended projects taking into account water rate and annual funding capacity.
9. Work closely with MWU project team to refine and finalize recommended improvement project list.
10. Prepare a 90 percent draft project improvement list and map.
11. Provide draft project list/map to MWU project team for review and comment.
12. Incorporate MWU project team comments and finalize recommended project list and map.

1.3.5 Capital Improvement Planning

1. Develop a capital improvement project lists using two major categories:
    a. Facilities
        i. Supply
        ii. Water Quality
        iii. Pumping
        iv. Storage
        v. Other
    b. Pipelines
        i. Hydraulic capacity
        ii. Replacement
        iii. Rehabilitation
2. Refine project cost estimates for identified recommended projects.

3. Prioritize identified projects based on need and system benefit.
4. Implementation Plan (RFP Task 9.4)
   a. Create a project implementation plan based on identified project prioritization and MWU project capacity.
   b. Permitting, siting, and approval process will be considered in CIP project scheduling.
   c. Work with MWU project team to develop an annual project list based on anticipated MWU financing capacity.
   d. Prepare a map that includes recommended improvement projects by scheduled year, including MWU identifying tag names and planned project year.
5. Work with MWU project team to coordinate CIP with concurrent MWU Asset Management Planning Program.
6. CIP Financial planning
   a. Consider total MWU financial capacity for all improvement project categories; including infrastructure renewal, deficiency mitigation, and growth.
   b. Work with MWU financial staff and the current MWU economic model to align recommended MWU CIP with MWU annual financial capacity.
7. CIP Workshop
   a. Prepare a 90 percent draft CIP Technical Memorandum and provide to MWU project team in advance of CIP Workshop.
   b. Coordinate and facilitate a one day (8 hour) workshop with MWU project team to review proposed CIP.
   c. Review proposed CIP improvement projects.
   d. Review project priorities and criticality.
   e. Review opinions of probable project costs.
   f. Evaluate CIP project financial planning and scheduling.
8. Incorporate MWU project team comments and finalize CIP Technical Memorandum.

1.3.6 Report Documentation

1. Incorporate all technical memorandums and reports (as appropriate) into final master plan report.
2. Prepare a master plan executive summary.
3. Provide presentation of the final report to the MWU Water Utility Board and Utility Staff.
4. Provide report documentation as outlined in original master plan RFP.
5. Prepare a 90 percent draft Water Main Replacement Evaluation Technical Memorandum
   a. Include water main priority list and map locations.
   b. Provide draft technical memorandum to MWU project team for review and comment.

Chapter 2
Study Area

2 Background

The purpose of this chapter is to evaluate and understand the factors that will influence future water system demands.

2.1 Objectives

As part of the *2020 Master Plan Update* (Master Plan), the objectives of Chapter 2 include:

- Collect most current information on existing and anticipated population.
- Review and develop land use for the identified service area based on the City of Madison Plan Commission 2017 updates to the 2006 Comprehensive Plan (Comprehensive Plan).
- Develop a basis for future water use projections.

Municipal water system planning is a continuous function as needs change with time. Therefore, the longer-term projections and improvements discussed in this report should be reviewed, re-evaluated and modified as necessary to assure the adequacy of future planning efforts. Proper future planning will help assure that system expansion is coordinated and constructed in the most efficient manner. The water system master plan will be reviewed and re-evaluated every five to ten years.

2.2 Study Area

Madison Water Utility is one of several water utilities in the Madison Metropolitan Planning Area (MMPA). The study area for this project includes all areas MWU currently serves and all areas MWU intends to serve by Year 2040. The study areas referenced in this document are shown in Appendix. 2A.

- The City of Madison
- The Village of Maple Bluff (Maple Bluff)
- The Village of Shorewood Hills (Shorewood Hills)
- The Town of Madison
- Town of Bloomington Grove
- Town of Burke
- Town of Middleton

2.3 Population & Community Growth

Population and employment are important factors in evaluating existing water usage and projecting future water usage. Water system master planning is a function of where to serve water and how much water to serve. Population and land use distributions are key elements in water master planning.

2.3.1 Governmental Agencies

The City of Madison has key planning commissions in place already driving discussions and developing plans for community development. This section quickly reviews the various agencies and commissions within the City of Madison responsible for planning and development.

2.3.1.1 City of Madison Department of Planning, Community & Economic Development (DPCED

The DPCED is responsible for community planning, particularly for the Comprehensive Plan regarding the City of Madison and surrounding planning area. The DPCED is underway assessing progress, reevaluating issues, revisiting goals and clarifying the City's path forward for the eventual update to the Comprehensive Plan, adopted in 2006.

The Comprehensive Plan provides general goals, objectives, policies and implementation recommendations to guide the future growth and development of the City and includes the Generalized Future Land Use Plan Map with land use recommendations for areas within City limits and future growth areas. The land use categories mapped in the Comprehensive Plan are broad and are applied to relatively large geographic areas

2.3.1.2 Madison Area Transportation Planning Board (MATPB)

The Madison Area Transportation Planning Board is the federally designated Metropolitan Planning Organization (MPO) for the Madison Urban Area. As the MPO, it is the policy body responsible for cooperative, comprehensive regional transportation planning and decision making for the Madison Metropolitan Planning Area.

The MATPB has produced research, studies and mapping data on the spatial distribution and intensity of traffic, employment, housing and population.

2.3.2 Land Use & Development

As the City of Madison and surrounding communities develop, the Madison water system will experience new and changing demands in various areas of the distribution system. Thus, proper planning of existing and future land use and development is imperative for proper water system planning.

2.3.2.1 Existing and Future Land Use

Existing land and generalized future land use are shown in Appendix 2A. Revitalization and improvement of the Downtown region on the isthmus are planned and underway. Efficient multi-family housing units, high density commercial and industrial units are being constructed in the more dense urban areas and in the vicinity of the University of Wisconsin Madison (UW-Madison). Less dense residential, commercial and industrial units are being redeveloped and/or constructed in regions away from the Downtown, particularly along major highways and where land is available to the east and to the west.

The City of Madison has key US highways and many main aerial roads. US Highway 90 and 94 tie into the community to the east. US Highway 18 and 12/14 make up the "Beltline" highway passes across the southern area of the City connecting east and west with tie in points to the south. US Highway 151 connects the Downtown isthmus region to these other highways. High density residential as well as commercial and industrial development gravitate around the key highways and main roads within the City.

Existing and future land use were determined based on the on-going efforts to the Comprehensive Plan update. The DPCED provided SEH with the most current existing and future land use data in computer Geographic Information Systems (GIS) format. MWU provided other planning and utility data in GIS. MWU also provided SEH with aerial imagery dated March 2016.

General growth is summarized in Table 2-1. Approximately 45,100 acres were served in 2017 and approximately 35,300 additional acres are anticipated to be served by 2040. The total service area by 2040 is

80,400 acres. Land uses in Table 2-1 were determined from existing land use and generalized future land use. Specific neighborhood planning land use detail was not included.

Table 2-1 – Existing and Future Land Use Quantities (Acres)

Land Use	2017	2040 [1]	Increase
Residential	14,800	24,500	9,700
Commercial	4,800	5,110	310
Industrial	4,300	4,300	0
Institutional	2,300	2,590	290
Open Space	9,400	28,700	19,300
Transportation	9,500	15,200	5,700
Total	45,100	80,400	35,300

[1] 30 percent of future residential, commercial and institutional areas were assumed to be transportation areas.

2.3.2.2 Neighborhood Development Plans (NDPs)

The DPCED has implemented 19 Neighborhood Development Plans (NDPs) on the outer fringe of the City of Madison. The fringe NDPs are shown in Appendix 2A and are listed below:

- Blackhawk
- Cherokee
- Cottage Grove
- Cross Country
- East Towne-Burke Heights
- Elderberry
- Felland
- Hanson Road
- High Point – Raymond
- Junction
- Marsh Road
- Midtown
- Nelson
- Northeast Neighborhoods
- Pioneer
- Pumpkin Hollow
- Rattman
- Sprecher
- Yahara Hills

The individual NDPs were briefly reviewed to determine the buildout population of each NDP area. The population projections are also shown in Appendix 2A. These population projections are for total buildout and not necessarily population that is expected to occur by year 2040.

2.3.3 Water Service Area

The existing water system service area is shown in Appendix 2A. The existing water service area was based on development shown in the March 2016 aerial images, parcel boundaries and the locations of water mains in 2016. Planned developable areas not yet reached by existing water mains were not considered part of the existing service area. Large vacant regions planned but not yet developed and served with water main were also not considered part of the existing service area.

The future water service area is also shown in Appendix 2A. The future water service area is assumed to be identical to the comprehensive planning area boundary. County subdivisions and municipal boundary agreements in Appendix 2A show the Madison water system continuing to serve Shorewood Hills, Maple Bluff, a portion of Fitchburg, portions of Bloomington Grove (Waunona Sanitary District #2) and all of the Town of Madison.

As a result of an agreement made in 2002, the Town of Madison will be completely annexed to the City of Madison by year 2022.Some areas of the Town of Madison are currently served by MWU. Extension of water service to the remaining areas of the Town of Madison are included in the future service area projections. MWU is annexing the Waunona Sanitary District in mid 2017 and adding the District’s approximate 430 customers. The Town of Blooming Grove is planned to be annexed by year 2027 and to be served by MWU

2.3.3.1 Pressure Zone Boundaries

MWU owns and operates ten pressure zones within the Madison water system. Each pressure zone was designed with its own hydraulic grade line (HGL) in order to serve adequate pressures to its customers at varying elevations. Appendix 2A shows the existing layout of the pressure zones, as well as the water mains and facilities in the MWU water distribution system.

Wisconsin Statute NR 811.70(4) mandates a minimum 35 psi and a maximum of 100 psi. Appendix 6-A *Design Guideline Criteria* established that MWU would provide a minimum pressure of 40 psi during peak demands with a preferred pressure range of 50 to 90 psi and an absolute maximum pressure of 125 psi. Table 2-2 shows the HGL of each pressure zone and the corresponding lowest and highest elevations they may serve according to elevation (static pressure) according to the pressures in Appendix 2B.

Table 2-2 – Design Operating Elevations for Pressure zones

Pressure Zone	Hydraulic Grade Line (feet)	Absolute Highest Service Elevation for 40 psi (feet)	Service Elevation for 50 psi (feet)	Service Elevation for 90 psi (feet)	Absolute Lowest Service Elevation for 125 psi (feet)
3	1137.6	1045	1022	930	849
4	1046.5	954	931	839	758
5	1140.0	1048	1025	932	852
6e	1080.0	988	965	872	792
6w	1054.8	963	939	847	766
7	1170.6	1078	1055	963	882
8	1200.0	1108	1085	992	912
9	1244.6	1152	1129	1037	956
10	1320.6	1228	1205	1113	1032
11	1300.0	1208	1185	1092	1012

Future pressure zone boundaries were taken from the Water Master Plan, dated December 2008 (2008 Water Master Plan). Pressure zones were updated according to existing and near future pressure zone boundaries as established by MWU. Appendix 2A shows the planned future pressure zones with Zones 10 and 11 merged into one pressure zone: Pressure zone 10. Pressure zone 11 will be retired from service.

In the 2008 Water Master Plan, Black & Veatch and MWU established planned future pressure zone boundaries. Since the 2008 study, existing pressure zone boundaries have changed and the extents of the future service area have changed slightly. Revised future pressure zone boundaries were generated for this *2020 Master Plan Update*. The future pressure zone boundaries from 2006 were the basis of design, except modified to include new service areas, include existing pressure zone boundaries, and reduce complexity to increase constructability of the pressure zone. In addition to these revisions, MWU will soon be retiring Pressure zone 11 from service and combining Pressure zones 10 and 11. Using GIS analysis processes, the modified future pressure zones were reviewed according to elevation against the overflow elevation of each pressure zone's elevated reservoir. Elevations were color coded according to the difference between ground elevation and overflow elevation divided by 2.307 feet/psi. Using this approach, the boundaries of each pressure zone were validated, and the results are shown in Appendix 2A.

2.3.4 Population

There is generally a close relationship between a community's population and total water consumption volumes. Future water sales can be expected to generally reflect future changes in service area population. Similarly, commercial and public water consumption also tend to vary proportionately with the growth of the community. Industrial water consumption depends on many variables, one of which is population. The identification and utilization of a meaningful population projection will heavily influence future water use projections. For purposes of this master plan, two specific population projections are defined, analyzed and ultimately utilized to project future water use estimates. The two methods are discussed further below and explain how each method is used within the context of this water master plan.

2.3.4.1 Method 1: City of Madison Plan Commission (DPCED)

Estimates of existing and future service population were provided by the City of Madison Department of Planning & Community & Economic Development (DPCED) based on the 2017 Draft Imagine Madison Comprehensive Update Population Projections (IMCUPP). The Madison Planning Department reviewed ten population projection estimates which are listed below:

1. *Department of Administration Demographic Services Center 2015-2040 populations and household projections and municipality and MCD (vintage 2013).*
2. *Department of Administration Demographic Services Center 2015-2040 projections modified for known town annexations and attachments (vintage 2013).*
3. *Madison Area Transportation and Planning Board (MATPB) 2035 Regional Transportation Plan Projections (extrapolated out from 2035).*
4. *MATPB 2050 Regional Transportation Plan Projections (interpolated from 2050).*
5. *25-Year (1990-2015) annual growth rate projected out from 2015 DOA population estimate (242,216).*
6. *15-Year (2000-2015) annual growth rate projected out from 2015 DOA population estimate (242,216).*
7. *5-Year (2010-2015) annual growth rate projected out from 2015 DOA population estimate (242,216).*
8. *25-Year (1990-2015) annual growth rate projected out from 2015 Census population estimate (248,951).*
9. *15-Year (2000-2015) annual growth rate projected out from 2015 Census population estimate (248,951).*
10. *5-Year (2010-2015) annual growth rate projected out from 2015 Census population estimate (248,951).*

These population projections are shown in Table 2-3 and Figure 2-1. When comparing all 10 projections, the average 2015 population estimate was 244,704 and the average 2040 projection is 309,768, an increase of 65,064. The high 2015 estimate was 248,956 and the high 2040 projection is 345,109, an increase of 96,153. The low 2015 estimate was 241,177 and the low 2040 projection is 276,828, an increase of 35,651. The population estimates and projections listed in Table 2-3 will ultimately be the high, average and low population projections used in this chapter.

Table 2-3 – Draft Population Estimates Provided by DPCED (Method 1)

	10-Estimate Average		High Estimate		Low Estimate	
Year	Population	Households	Population	Households	Population	Households
2015	245,000	110,000	249,000	114,000	241,000	108,000
2020	256,000	116,000	266,000	121,000	248,000	113,000
2025	270,000	123,000	284,000	130,000	255,000	117,000
2030	283,000	129,000	303,000	140,000	262,000	121,000
2035	296,000	136,000	323,000	150,000	269,000	125,000
2040	310,000	143,000	345,000	161,000	277,000	129,000
Annual Growth Rate	**0.95%**	**1.06%**	**1.31%**	**1.41%**	**0.55%**	**0.72%**

2.3.4.2 Method 2 – Madison Area transportation Planning Board (MATPB)

The Madison Area Transportation and Planning Board (MATBP) provided population and employment data by TAZ for years 2010 and 2050. The advantage of the TAZ data is that it provides not only a total service area population, but also provides information on the spatial distribution of the population and employment. The TAZ distribution population and employment will assist in determining where the future water needs will occur, adding confidence to future demands of each pressure zone. TAZ data was combined with current city limit and anticipated service area boundaries to develop the population and employment projections for the service area. Linear interpolation was used between 2010 and 2050 to determine intermediate year values. This data is summarized on Table 2-4 and graphically depicted in Figure 2-1.

Table 2-4 shows the household measurements from 2010 and the household projections for year 2050 for each TAZ within the planning area as researched by the MATPB. In 2010, approximately 101,600 households (including all single family and multi-family dwellings) existed in the MWU water service area. By 2040, approximately 143,000 households are expected within the MWU service planning area. With the assumptions stated in Table 2-4, approximately 327,789 people will be served by MWU according to the household and population projections from the 2040 MATPB. The average annual increase according to Method 2 would be 3,230 persons per year.

Table 2-4 also shows the employment measurements from 2010 and the employment projections for Year 2050 for each TAZ within the planning area as researched by the MATPB. In 2010, approximately 203,900 employment positions existed within the MWU water service area. By 2040, approximately 257,000 employment positions are expected within the MWU service planning area.

The MATBP provided GIS data for the TAZ areas. The TAZ polygons were clipped to the comprehensive planning area. The polygons were scaled in population growth proportional to the area of the polygon within the planning area. 2040 populations were interpolated between 2010 and 2050 population estimates.

Total population increase per TAZ polygon is shown in Appendix 2A. Population increase per acre is shown in Appendix 2A. Total employment increase is shown in Appendix 2-D.3. Employment increase per acre is shown in Appendix 2A. The per-acre population and employment maps show growth to be occurring primarily in the downtown core, in the east and in the west. The total population and employment maps in Appendix 2A and Appendix 2A show totals, but do not account for TAZ polygon size as in Appendix 2A and Appendix 2A.

Population growth is expected in the eastern, western, and central isthmus regions of the City. The neighborhood development planning areas, as well as the planned full-buildout populations, are shown in Appendix 2A The neighborhood development plans, however, are not expected to all occur by year 2040 nor experience full-buildout by year 2040. The studies by the City of Madison DPCED Plan Commission (DPCED Plan Commission) and the MATPB expect growth throughout the City, with higher growth in the vacant areas to the east and west (total population growth is shown in Appendix 2A and total employment growth is shown in Appendix 2A. However, on a per-acre basis, the densest development is anticipated to the east, west, and in the downtown core around Capitol Square (per-acre population growth is shown in Appendix 2A and per-acre employment growth is shown in Appendix 2A). The population and employment growth maps generally align with the neighborhood development plans with the bulk of future development to occur to the east and west where land is available.

For water planning purposes, the distribution of future residential water needs will be associated with the distribution of future population growth, and the distribution of future commercial and public water needs will be associated with the distribution of future employment growth.

Table 2-4 – Projected Population and Employment According to Madison Area Transportation Planning Board (MATPB) Data (Method 2

Year	Total Households[1,2,3]	Estimated Population[1,2,3]	Average Persons Per Household	Equivalent Exponential Growth Rate[4]	Total Employment[1,2]
2010	101,600	230,900	2.27	---	203,900
2015	107,000	247,000	2.31	1.35%	212,800
2016	108,100	250,300	2.31	1.30%	214,500
2020	112,000	263,000	2.34	1.26%	222,000
2025	118,000	279,000	2.37	1.19%	230,000
2030	123,000	295,000	2.40	1.12%	239,000
2035	129,000	312,000	2.42	1.06%	248,000
2040	**134,000**	**328,000**	**2.44**	**1.01%**	**257,000**
2045	140,000	344,000	2.46	0.96%	266,000
2050	145,000	360,000	2.48	0.92%	275,000

1 Value Year 2050 based on data provided by MATBP. Data was clipped to existing and future service areas with valued scaled according to area.

2 Years between 2010 and 2050 assume linear increase with time with linear growth in water service area.

3 2010 values based on 2010 census per TAZ region.

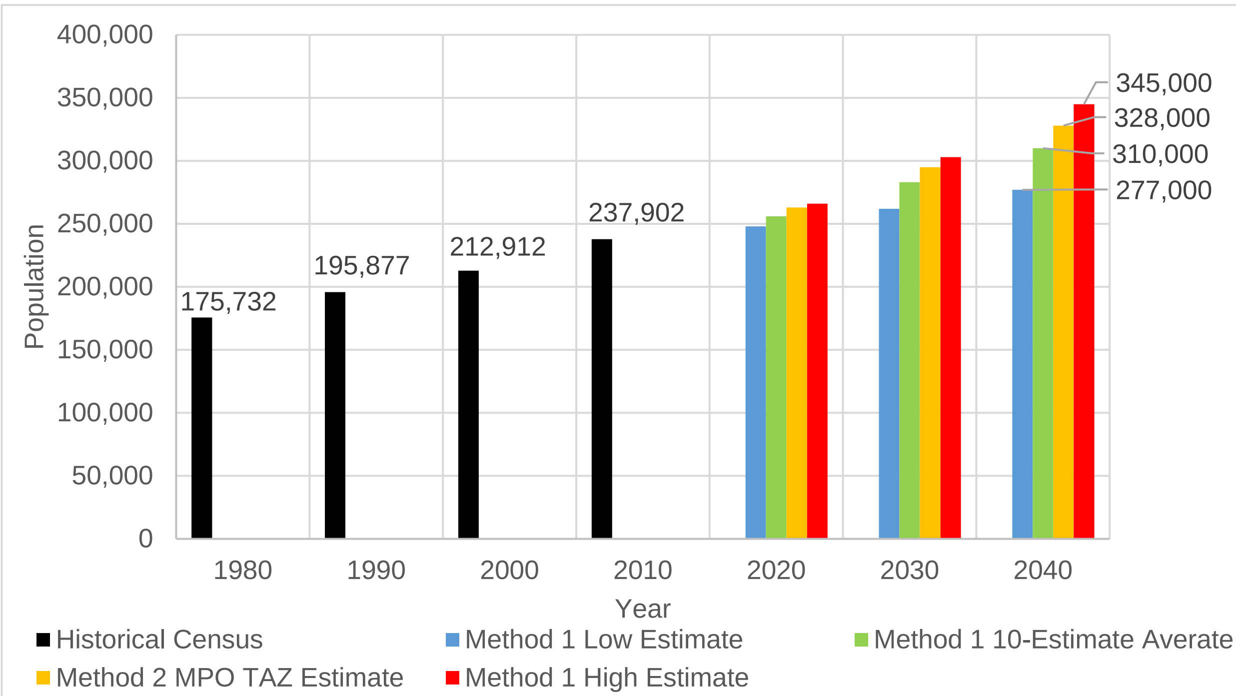
4 Exponential growth rate = [Ln(Final Population/Initial Population)]/#years.

2.3.4.3 Design Population

The population projections are shown graphically on Figure 2-1. Method 2 falls within the range of population projections provided in Method 1, as shown in Figure 2-1. Method 1 was provided by the DPCED Plan Commission based on a more macroscopic approach, comparing, 3and averaging the projections from the WDOA, the US Census Bureau, and the MATPB (Method 2). The projections in Method 2 were based on extensive research of land use and potential development for the purposes of planning traffic needs and budgeting for street and highway improvements. Method 1 provided a range of population projections, which is prudent for planning as the future is truly unknown. Method 2 was included as part of Method 1 and Method 2 agrees with the range of projections in Method 1.

Chapter 2 will use the range of projections in Method 1 with the population and employment growth distribution in Method 2. This approach will utilize the work of the DPCED Plan Commission and the MATPB in the process of determining future water needs.

Figure 2-1 – Historical and Projected Population Estimates



2.3.4.4 Population and Employment Growth by Pressure zone

As previously stated, the range of Method 1 population projections will be the basis of design with the Method 2 population and employment growth distributions as the basis of spatial distribution of future growth. Population and employment data from Table 2-4 was provided spatially by the MATPB and could be used to project population and employment distribution between the future pressure zones. Using GIS, the Method 2 data was clipped to the pressure zones in Appendix 2A. Because this study will utilize multiple population projections, the distribution will be assumed constant based on the TAZ study (Method 2) regardless of which population scenario occurs. The population and employment growth distributions are shown in Figure 2-2 and Figure 2-3.

Figure 2-2 – Method 2 Population Growth Distribution by Pressure Zone

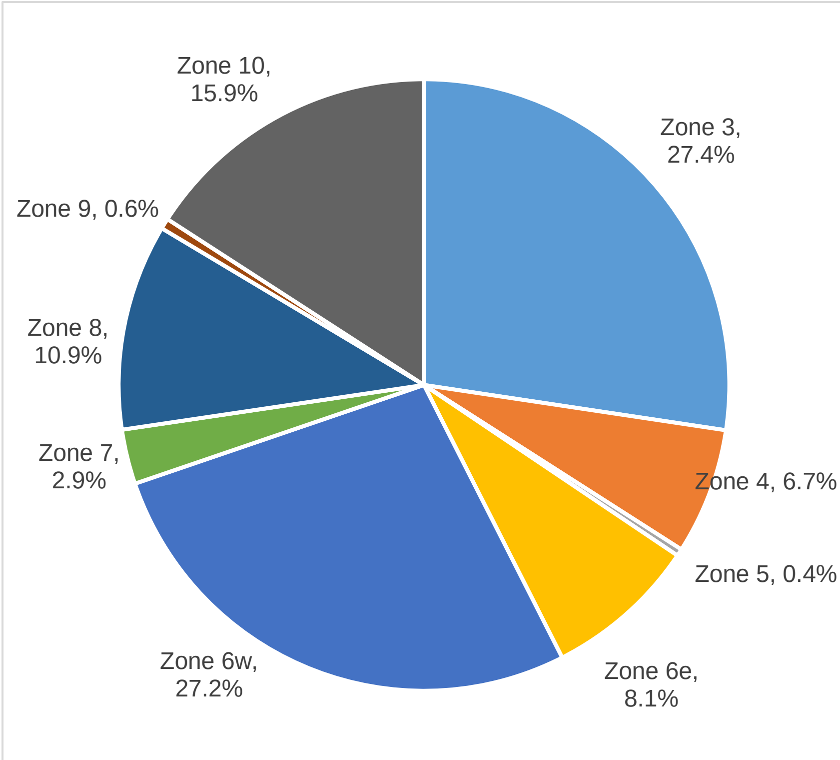
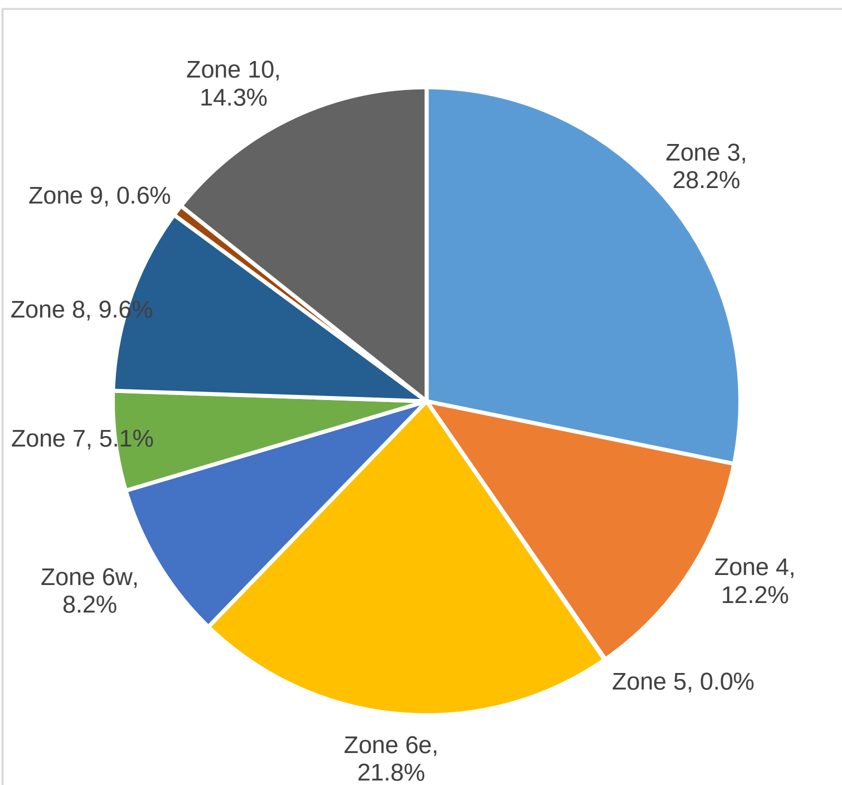


Figure 2-3 – Method 2 Employment Growth Distribution by Pressure Zone



Chapter 3

Water Needs Analysis

3 Background

The purpose of this chapter is to evaluate the water needs and system expansion required to serve current and future Madison Water Utility (MWU) customers. This Chapter summarizes the planning assumptions made regarding future service area characteristics for Madison Water Utility. Past, present and future MWU water needs have been evaluated and projections of future water needs have been made per service zone. Chapter 3 will serve as a plan to guide future growth and operation of the water system.

3.1 Objectives

As part of the *2020 Master Plan Update* (Master Plan), the objectives of Chapter 3 are to:

1. Collect and review water demand data information including billing (AMI), SCADA pumping records, MWU PSC annual reports, other historical data sources and other available planning and engineering reports.
2. Develop unit demands to be used for projecting future MWU water requirements.
3. Forecast future average day demand for each MWU service zone in 5-year increments starting with year 2020 and going through year 2040.
4. Develop service zone peaking factors for maximum day (MD), maximum hour (MH), average day (AD), average summer day (ASD) and average winter day (AWD). Develop max 10 day (M10D) use patterns for modeling purposes.
5. Identify water requirements on a system-wide, service zone, regional area and user class basis for AD, MD, ASD, AWD and MH demands in 5-year increments starting with year 2020 and going through year 2040.
6. Incorporate current MWU water conservation program goals into future water demand projections.
7. Evaluate potential water demand reduction that could result from system-wide conservation programs. Water conservation shall be considered to be a priority in all long term planning.
8. Analyze reduction in water losses in future MWU water demand projections.
9. Develop current, improved and optimal conservation ranges for water demand projections for each planning period considered in operating scenarios to be modeled.
10. Evaluate programs and methods to reduce peak demands.
11. Consider peak demand reduction measures on a daily and seasonal basis.
12. Recommend capital improvements, customer incentives and operational modifications that could reduce peak demands.
13. Develop water use projections related to average day and maximum day demands for each service region.
14. Develop diurnal curves by service zone, by weekday, by weekend and by season for the full system.

Municipal water system planning is a continuous function as needs change with time. Therefore, the longer term projections and improvements discussed in this report should be reviewed, re-evaluated and modified as necessary to assure the adequacy of future planning efforts. Proper future planning will help assure that system expansion is coordinated and constructed in the most efficient manner. The water system master plan will be reviewed and re-evaluated every five to ten years.

3.2 Water Needs

Future water needs are defined by projected water demands. These demands are projected by applying defined per-capita water use trends to selected population projections. Anticipated impacts of growth concentration and conservation will also be accounted for in future water needs projections. MWU recently implemented a new water metering system called Advanced Metering Infrastructure (AMI) which is able to increase MWU's understanding of where and how demands occur in the system. This is especially valuable for the purpose of defining projected demand locations and intensities.

Advanced Metering Infrastructure (AMI) data can be used to develop an understanding of the spatial component (geography) of demands. Since 2013, MWU has been coordinating and implementing the new system on its approximately 66,000 water meters. By the end of year 2013, approximately 98 percent of meters were connected to the new system. 100% of the MWU system was incorporated into the AMI system by the end of 2014. This provides a comprehensive record of water demand starting in January 2015. MWU now records water sales on an hour-by-hour basis for all meters in the system. This hour-by-hour information can be used to accurately allocate where demands occur in the system and how the demands fluctuate throughout the day.

3.3 Definitions and Usage

A water utility must be able to supply water at rates that fluctuate over a wide range. Yearly, seasonally, monthly, weekly, daily and hourly variations in water demand occur in all water systems, with higher water use typically occurring during hot, dry weather due to increased outdoor use. Water use rates follow a daily (diurnal) pattern that will vary by season and day of the week. Water demand is typically lowest at night and greatest in the early morning and late afternoon. The importance of the key demand rates to the hydraulic design and operation of a water supply and distribution system are as follows (for analysis purposes, January 1 of the year is assumed be immediately after December 31 of the same year to assess all design periods in a single year in a closed loop):

- Average Day (AD) Demand: the AD demand rate is used primarily as the basis from which to estimate the maximum day (MD) and maximum hour (MH) demands. The AD rate is also used to estimate future revenues and operating costs. The AD demand rate is calculated as the total volume of water used during the year, divided by the number of days in the year.
- Average Summer Demand (ASD): This gives insight into the additional pumping required in the summer and the amount of water used in outdoor applications. It is calculated as the water volume used during the highest 90 days of the year divided by 90.
- Average Winter Demand (AWD): This gives insight into the additional pumping required in the winter and the amount of water used summer outdoor applications are not in service. It is calculated as the water volume used during the lowest 90 days of the year divided by 90.
- Maximum 7 Day (M7D) Demand: The M7D is the average rate of use during the maximum 7 day period. It is calculated as the water volume used during the highest 7 days of the year divided by 7.
- Maximum 10 Day (M10D) Demand: The M10D is the average rate of use during the maximum 10 day period. It is calculated as the maximum value of water used in a 10 day period divided by 10. This demand level is typically indicative of what happens when the system is highly stressed and serves to demonstrate the water systems ability to meet MWU's level of service. It is calculated as the water volume used during the highest 10 days of the year divided by 10.

- Maximum 30 Day (M30D) Demand: The M30D, also called the maximum month, the average rate of use during the M30D is a good indicator of the period in which the MD use rate will be found. It also indicates the season of elevated use over a prolonged period, which is used to evaluate the ability of the source of supply to yield adequate quantities of water over extended periods. It is calculated as the water volume used during the highest 30 days of the year divided by 30.
- Maximum Day (MD) Demand: The MD rate is used to size water supply and treatment facilities and booster pumping stations when equalization storage is properly sized. The MD demand distribution is combined with fire flow demand at selected locations to assess the maximum hydraulic capacity of the distribution system to satisfactorily serve required fire demand. It is calculated as the maximum volume of water used during a single day of the year.
- Maximum Hour (MH) Demand: Since minimum distribution system pressures are usually experienced during MH, the sizes and locations of distribution facilities are generally determined on the basis of this condition. MH water requirements are partially met through the use of strategically located system storage. The use of system storage minimizes the required capacity of transmission mains and permits a more uniform and economical operation of the water supply, treatment and pumping facilities. It is calculated as the maximum volume of water used during a single hour, multiplied by 24 hours.
- Minimum Day (MinD) Demand: MinD usage is becoming increasingly significant relative to issues of water quality in the distribution system. It is the basis for evaluating the maximum water age in the distribution system, which coincides with greatest degradation of water quality. It is calculated as the minimum volume of water used during a single day.

3.4 Historical Water Demands

Historical water production and water billing data was used in combination with population and employment to develop an understanding of historical water use in each service zone of the comprehensive planning area.

Past water consumption characteristics were analyzed by reviewing annual pumpage and water sales records from 2007 to 2016. Average and maximum day water consumption during this period, together with the amount of water sold in each customer category, was analyzed. Projections of future water requirements are based on the results of the consumption analysis coupled with estimates of population and community growth discussed in Chapter 2.

3.4.1 Average Day, Maximum Day & Minimum Day Production

Water demand fluctuates throughout the year for various reasons, one major factor being climate. Maximum daily water demands usually occur during the summer months on hot days when additional water is used for watering lawns, gardening, bathing and industrial cooling. The maximum day demand is defined as the amount of water pumped during a single day of the year with the highest water usage and is often expressed as a ratio of the annual average day pumpage. The maximum day pumpage is of particular importance to water system planning, because water supply facilities are sized to meet this demand. The minimum day, however, represents the opposite of the maximum day, when the least demand is required on the system, usually occurring in the winter months when irrigation is not occurring.

Table 3-1 summarizes historical water production by MWU with the characteristics provided for AD, MD and MinD, which are shown graphically on Figure 3-1. Population has increased by approximately 7.2 percent since 2007, while the AD demand decreased by 13.6 percent. MWU has been proactive in reducing water demand in recent years. See the “Conservation” section in a later section of this report. Additional historical data is shown in Appendix 3B.

The maximum day to average day (MD:AD) ratio in Table 3-1 provides an indication of how much the maximum day exceeds the average day. Year 2012 is a representative drought planning year and the climate data is discussed in Table 3-3 . For future planning purposes, the maximum day needs in year 2012 will be used for a future drought year. Each service zone will be individually analyzed for peaking factors in later sections.

3.4.2 Water Sales

A summary of historical water sales is provided in Table 3-2. In 2016, approximately 31.7 percent of the total water sales was attributed to single family and duplex residential customers, 22.8 percent to multi-family customers, 23.7 percent to commercial customers, 4.8 percent to industrial customers, 4.3 percent to public authority customers, 11.0 percent to UW-Madison and 1.7 percent to resale customers. Over the past 10 year period of data summarized in the table, water sales have varied between a high of 27.9 mgd to a low of 23.3 mgd.

The decreasing trend in AD demands in the past decade, despite the growth in population, is partially attributed to conservation efforts, but not fully, as summer climate characteristics are also a factor in water usage. Table 3-3 and Appendix 3A summarize the ASD water production, average temperature and precipitation data for years 2007 through 2016. As can be seen from this information, water demand can vary as a function of temperature or rainfall; year 2012 represents a relatively hot and dry year with higher water demand rates and year 2012 provides a representative drought planning year.

3.4.2.1 Residential, Commercial & Public Sales

Residential, commercial and public water usage can be correlated to a community's population. An analysis of per capita water consumption for MWU for each of these customer classifications was made from the available sales records and is summarized in Table 3-4. Since 2007, residential and public authority per capita sales have declined noticeably, while commercial per capita sales have declined marginally. Part of this decline, as discussed previously, was due to climate and drought. 2012 was a drought year and in that year per capita sales occurred at an increased rate compared to surrounding years.

The *Water Demand Projections* report (2012 Demand Report) within the *2012 East Side Water Treatment Supply Planning and Project Development* Project made various assumptions regarding per capita water use. The 2012 Demand Report made the following assumptions:

- Service population included all persons within the City, Town of Madison, Shorewood Hills, Maple Bluff and an additional 8,000 persons in the "expansion area."
- Sales to multi-family residential comprised 75 percent of the total commercial sales.

Table 3-1 – Historical Water Production

Year	AD (mgd)	MD (mgd)	MD:AD Ratio	MinD (mgd)	MinD:AD Ratio
2007	31.2	54.0	1.73	22.4	0.72
2008	29.9	45.1	1.51	21.1	0.70
2009	28.4	41.9	1.48	18.4	0.65
2010	28.1	39.8	1.42	18.3	0.65
2011	28.3	43.0	1.52	18.6	0.66
2012	29.2	49.9	1.71	16.5	0.56
2013	27.6	43.1	1.56	18.9	0.69
2014	27.7	45.0	1.63	15.6	0.56
2015	27.3	39.8	1.46	19.8	0.73
2016	27.0	38.3	1.42	19.5	0.72
Maximum	31.2	54.0	1.73	22.4	0.73
90th Percentile	30.0	50.3	1.71	21.2	0.72
5-year Average	27.7	43.2	1.56	18.1	0.65
Minimum	27.0	38.3	1.42	15.6	0.56

Figure 3-1 - Historical Water Production

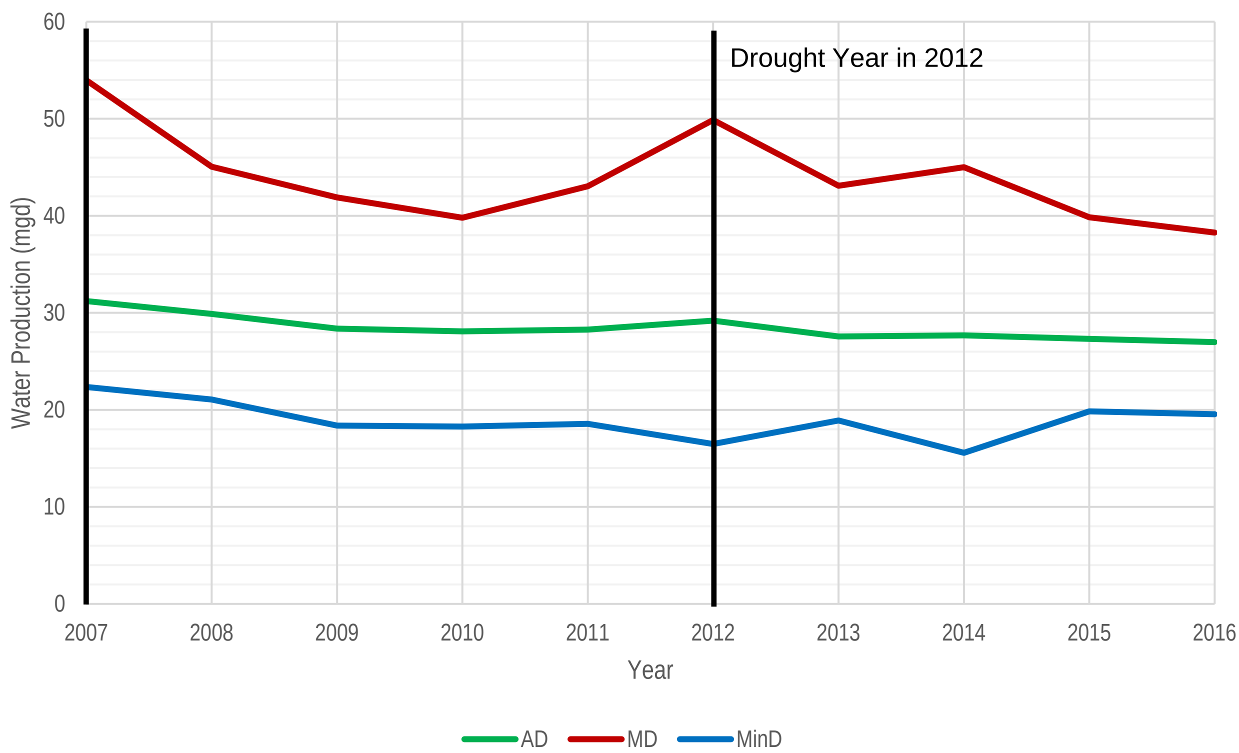


Table 3-2 – Historical Sales by Water Type (mgd)

Year	Single Family & Duplex Residential	Multi-Family Residentia[1,2]	Commercial[1,2]	Industrial	Public Authority	UW Madison[3]	Resale	Total Sales
2007	9.38	5.64	5.64	2.21	1.71	2.78	0.51	27.9
2008	8.95	5.44	5.44	2.06	1.10	2.96	0.63	26.6
2009	8.76	5.30	5.30	2.29	0.22	2.78	0.51	25.2
2010	8.43	5.34	5.34	2.10	0.97	2.58	0.51	25.3
2011	8.48	5.27	5.27	2.00	1.30	2.24	0.49	25.1
2012	9.14	5.41	5.41	1.66	1.30	2.72	0.55	26.2
2013	8.00	5.34	4.99	1.58	1.26	2.67	0.44	24.3
2014	8.19	5.63	5.54	1.44	0.74	2.48	0.48	23.7
2015	8.06	5.15	5.41	1.52	0.56	2.10	0.49	23.3
2016	7.36	5.30	5.51	1.13	1.00	2.56	0.40	23.3
Average	8.48	5.38	5.39	1.80	1.02	2.59	0.50	25.1
Maximum	9.38	5.64	5.64	2.29	1.71	2.96	0.63	27.9
Minimum	7.36	5.15	4.99	1.13	0.22	2.10	0.40	23.3

1. In 2013, MWU began to report multi-family residential sales separately; in previous years, multi-family residential units with 3 or more family units were included in commercial sales.
2. Previous to 2013, commercial sales are assumed to be 50 percent of reported commercial sales, with the other 50 percent as multi-family residential sales. As in Note #1, multifamily sales were not separated from commercial sales until 2013. Commercial sales prior to 2013 were separated out by SEH with the assumption that 50 percent of commercial sales were multi-Family sales to help the reader see how this assumption fits with multifamily and commercial sales after 2012.
3. Sales to UW Madison assumed to be part of PCS public authority sales.

Table 3-3 – Summer Production vs. Climate Data

Year	Average Summer Demand (mgd)	Maximum Day Demand (mgd)	Average Summer High Temperature (°F)	Total Summer Rainfall (inches)	Average Annual Demand (mgd)	Total Annual Precipitation (inches)
2007	37.46	53.97	77.7	17.7	31.2	41.1
2008	35.09	45.06	77.3	11.6	29.9	46.3
2009	32.20	41.89	77.9	6.1	28.4	39.6
2010	31.54	39.80	80.3	22.4	28.1	45.9
2011	32.79	43.05	81.0	8.2	28.3	35.0
2012	36.82	49.87	84.6	8.3	29.2	31.8
2013	31.93	43.10	80.1	15.2	27.6	47.0
2014	30.58	45.00	75.6	11.7	27.7	36.5
2015	29.91	39.85	78.8	13.9	27.3	41.9
2016	29.85	38.27	77.7	20.2	27.0	43.4
Average	32.82	43.99	79.1	13.5	28.5	40.9
Maximum	37.46	53.97	84.6	22.4	31.2	47.0
Minimum	29.85	38.27	75.6	6.1	27.0	31.8

1. Summer defined as period of highest 90 day pumpage.
2. Year 2012 is emphasized as the design drought condition. A drought year is defined as rainfall less than one standard deviation below the average between 1988 to 2018 = 35.9".

Chapter 2- revised the above assumptions to the following assumptions:

- Service population includes all persons within the water service area.
- No "Expansion Area" population is added to the service population as in the 2012 Demand Report.
- Sales to multi-family residential customers is assumed to have comprised 50 percent of historical commercial sales through year 2012. In 2013, MWU began to report multi-family sales separately and Table 3-2 validates the 50 percent assumption for year prior to 2013 when examining multi-family and commercial sales since 2013.

Chapter 2 also makes the following additional assumption:

- Residential per capita sales are all single and duplex residential sales as reported to the Public Service Commission (PSC) divided by number of single family and duplex customers multiplied by 2.3 persons/unit.
- Resale per capita sales are all resale sales as reported to the Public Service Commission (PSC) divided by the resale area population.
- Multi-Family sales are all multi-family sales as reported to the Public Service Commission (PSC) divided by multi-family population. Multi-family population was assumed to be the remainder from total service area population minus assumed single family, duplex, and resale populations.

Table 3-4 – Historic Sales on Per Capita Basis

Year	Total Water Service Population[1,2]	Residential Sales (gpcd)[3,7]	Multi-Family Sales (gpcd)[4]	Commercial Sales (gpdc)[5]	Public Authority (gpcd)[6]
2007	230,405	67.6	64.9	24.5	7.4
2008	232,904	69.8	54.7	23.4	4.7
2009	235,403	67.8	52.3	22.5	0.9
2010	237,902	65.0	51.5	22.4	4.1
2011	239,262	65.2	50.4	22.0	5.4
2012	240,623	70.3	51.3	22.5	5.4
2013	241,983	61.0	50.3	20.6	5.2
2014	243,344	62.2	52.7	22.7	3.0
2015	244,704	60.9	48.0	22.1	2.3
2016	247,029	55.4	48.8	22.3	4.1
Average	---	64.5	52.5	22.5	4.3
Maximum	---	70.3	64.9	24.5	7.4
Minimum	---	55.4	48.0	20.6	0.9
Design (2012)	---	70.3	51.3	22.5	5.4

1. Interpolates 2015 IMCUPP 10-Estimate Average populations extrapolated to 2016.
2. Includes all served areas, includes Shorewood Hills, Maple Bluff and Bloomington Grove populations.
3. Include Single-Family and Duplex residential sales per PSC annual report divided by the respective population for this PSC category.
4. Multi-Family residential sales per PSC annual report divided by the respective population for this PSC category.
5. See assumptions in Table 3-2. Total commercial sales divided by total water service population.
6. Total public authority sales divided by total water service population.
7. In 2008, MWU changed from 2.5 to 2.3 persons per household for PSC designated residential customers.

Water demand projections used in Chapter 3 will include projected conservation efforts and will use the drought year of 2012 as a baseline. Establishing a drought year as the base case will ensure that water demand projections used for this water needs analysis include the impacts of weather on overall water demands. These assumptions inherently include all conservation practices incorporated up to year 2012, with a factor of safety for outdoor water use that is expected to occur during a prolonged drought. Using 2012 as the base year assumes all conservation efforts up to 2012 will continue through the planning period. For future planning purposes, baseline supply needs for combined residential sales will be projected at the rate of **61.7 gpcd,** the combined average including all single family, duplex and multi-family sales**.** Baseline supply needs for commercial sales will be projected at the rate of **22.5 gpcd** and baseline supply needs for public sales at the rate of **5.4 gpcd**. Baseline supply needs for Resale sales will be projected at the rate of **2.3 gpcd.**

3.4.2.2 Industrial Sales

Industrial water consumption has played a somewhat major role in MWU water sales over the last 10 years. In Table 3-2, sales to Industrial customers has been declining. The decline is due to industries becoming more efficient with water or due to industries leaving Madison.

It is important to note that fluctuations in water consumption for industrial customers can be attributed to several factors, including:

1. Changes in production schedules or operational capacity
2. Changes in manufacturing processes
3. Changes in the number of persons employed
4. Addition or removal of product lines
5. Seasonal variation in cooling requirements
6. Seasonal changes in business activity
7. Implementation of conservation measures

In 2016, the average day industrial sales was 1.13 mgd, which comprised 4.8 percent of the mgd in average day total sales. For the purpose of future planning, industrial sales are expected to remain constant for existing customers: Oscar Meyer will be excluded in future projections, approximately 780,000 gpd in 2016. From Table 2-1, no future additional industrial land use is expected.

Industrial sales will be projected at a constant 350,000 gpd through the planning period, based on 2016 sales minus 2016 Oscar Meyers sales.

3.4.2.3 Largest Customers

MWU served multiple large customers. The 20 largest water customers are listed in Table 3-5. In 2016, the 20 customers shown comprised 6.21 mgd of the 23.3 mgd total sales, or 26.7 percent. These include the University of Wisconsin, hospitals, government entities and resale customers (Shorewood Hills and Maple Bluff). The University of Wisconsin (UW-Madison) alone comprised 2.56 mgd in 2016, or 11.0 percent. UW-Madison will be discussed later in Chapter 3. At the time of the analysis, it was understood that Oscar Meyer would soon not operate in Madison.

Resale customers - Shorewood Hills and Maple Bluff – see a more drastic change from year to year, as these two resale customers served dominantly residential areas with seasonally varying demands. Sales for resale customers are assumed to be included with population growth in this study. Resale customers, however, are given no conservation reductions.

Table 3-5 – Average Day Sales of Largest Customers, in Thousand Gallons per Day (kgal/day)

Water Customer	2010	2011	2012	2013	2014	2015	2016
University of Wisconsin	2,573	2,232	2,716	2,667	2,476	2,092	2,560
*Oscar Mayer Foods	1,640	1,430	1,204	1,036	1,103	951	780
Government (Federal, State, County)	539	519	488	445	435	568	673
City of Madison	452	459	477	570	300	482	331
Covance	118	227	180	252	270	358	288
Meriter/Madison General Hospital	143	113	107	125	147	122	129
St. Mary's Hospital	123	112	88	179	129	122	131
Webcrafters, Inc.	102	14	15	14	16	14	12
Airgas Merchant Gases	112	114	122	122	167	124	122
V.A. Hospital	100	97	100	79	89	62	40
Aramark	83	93	97	90	116	132	141
Forest Products Lab	91	50	69	37	34	30	27
Superior Health Linens	77	75	46	41	48	52	50
Danisco, USA	53	48	62	80	109	109	121
American Family Insurance	90	81	93	66	66	80	80
Shorewood Hills	100	160	179	171	190	633	509
Maple Bluff	192	189	153	133	125	117	113
Waunona Sanitary District No. 2	81	95	91	111	198	102	100

3.4.3 Non-Revenue Water

There is generally a close relationship between the total gallons of water pumped and the gallons of water metered and sold to water utility customers. Total metered water sales are always less than the amount of pumpage due to several factors, including:

- Unmetered water usage for maintenance purposes such as hydrant flushing and water main repairs
- Water used in water treatment
- Unmetered water usage for fire fighting
- Inaccuracies in water metering devices
- Unaccounted-for public water consumption
- Leakage within the distribution system

After the authorized unmetered uses are accounted for, the remaining portion of non-revenue water is termed "water losses." The amount of water loss is an indication of the condition of the water system and is usually expressed as a percentage. When a distribution system is very old or poorly maintained, the percentage of water loss often increases dramatically. As the Wisconsin Public Service Commission (PSC) emphasizes, the percentage of water loss should be less than 15 percent for a Class AB water utility such as the MWU.

The difference between total pumpage and total water sales is termed "non-revenue" water. As listed in Table 3-6, from 2007 to 2016 the average amount of water sold was 88.1 percent; thus, the average amount of non-revenue water over this period was 11.9 percent of the total water pumped from the supply wells. A portion of non-revenue water is due to authorized activity like hydrant flushing and system maintenance. MWU makes good approximations for its authorized unmetered water uses.

The percent of non-revenue water varies from year to year. The percentage is calculated as 1 - (total sales/total pumpage). Drought years have lower percentages to around 10 percent. Non-drought years have higher percentages. This difference can be partially attributed to the mathematical fact that as the denominator increases, the percentage decreases. The data does not make it clear that more or less total non-revenue water is used in a drought year than in a non-drought year.

Table 3-6 – Non-Revenue Water

Year	AD Demand (mgd)	AD Sales (mgd)	Percent Water Sales	AD Non-Revenue Water (mgd)	AD Real and Apparent Water Loss (mgd)	Percent Non-Revenue Water	Percent Real and Apparent Water Losses
2007	31.2	27.9	89.3%	3.3	3.0	10.7%	9.6%
2008	29.9	26.7	89.2%	3.2	2.8	10.8%	9.4%
2009	28.4	25.2	88.7%	3.2	2.7	11.3%	9.7%
2010	28.1	25.3	89.9%	2.8	2.5	10.1%	8.8%
2011	28.3	25.1	88.6%	3.2	2.8	11.4%	9.9%
2012	29.2	26.3	89.9%	2.9	2.6	10.1%	9.0%
2013	27.6	24.3	88.1%	3.3	2.8	11.9%	10.0%
2014	27.7	23.7	85.7%	4.0	3.4	14.3%	12.4%
2015	27.3	23.3	85.3%	4.0	3.3	14.7%	12.1%
2016	27.0	23.3	86.5%	3.7	3.5	13.5%	12.9%
Average	28.5	25.1	88.1%	3.4	2.9	11.9%	10.4%
Maximum	31.2	27.9	89.9%	4.0	3.5	14.7%	12.9%
Minimum	27.0	23.3	85.3%	2.8	2.5	10.1%	8.8%

3.5 Water Conservation

Water conservation occurs in two different forms, active conservation and passive conservation. Active conservation efforts include mechanisms such as educational programs, customer incentives and conservation ordinances while passive conservation results are a product of the installation of water efficient fixtures (toilets, showerheads and washers) implemented by manufacturing standards and plumbing codes which may or may not be a result of intended conservation efforts.

MWU developed and implemented a Water Conservation and Sustainability Plan (Conservation Plan) in 2007. MWU has established a goal of maintaining the current annual rate of groundwater pumping despite community growth and population increase. The purpose of water conservation is to prevent further long term groundwater table drawdown by high capacity municipal wells. To achieve this objective the stated conservation goal is to reduce residential per capita water use by 20 percent by year 2020, corresponding to a residential average water demand goal of 58 gpcd by the year 2020. Table 3-4 indicates that with the moderate weather patterns of recent years that this goal has been achieved. When the region experiences a drought similar to 2012 in coming years, continued conservation efforts will be necessary to meet the 58 gpcd goal.

The Conservation Plan implemented various equipment rebate, water audit and water rate incentive programs for its various customer types. MWU has different conservation practices in place for each customer type and these practices are described in the Conservation Plan. MWU is considering the use of ordinances to mandate reduced water consumption, but has not yet exercised this authority.

Research has indicated that individual conservation efforts including educational programs, public information, school programs, retrofit programs, conservation ordinances and or regulations can reduce water use about 1%-4% per program. In reviewing recent MWU per-capita water use, it is apparent that there has been a reduction in per-capita water use since the Conservation Plan was first implemented. It should be also noted that nationwide, over this same time period, indoor residential water use has decreased about 15.4 percent from 69.3 GPCD in 1999 to 58.6 GPCD in recent years. Furthermore, homes built according to EPA's water sense specification use 37 percent less water than the average home and 47 percent less water than an average home in 1999. In summary, when estimating projected water use, both active and passive water conservation should be accounted for.

3.5.1 Conservation Potential

As previously noted, nationwide, per capita indoor water use has been trending downward. The Water Research Foundation previously published an executive report profiling the Residential End Use of Water in 1999 and followed up with a second version of the report in 2016. In Table 3-7, the report profiled water use trends across the country and found that per capita average water use has decreased from 69.3 gpcd in 1999 (REU 1999) to 58.6 gpcd in 2016 (REU 2016). The improved efficiency of clothes washers and toilets account for most of the water savings.

Even without an intentional conservation program and or effort to switch to more efficient fixtures, reductions in total water use will be expected as old toilets and washers wear out. Per capita water use has the potential to be reduced to 36.7 gpcd in the future (REU 2016). For purposes of this report, the figure will be considered the maximum water use reduction potential used in the optimal conservation projection.

3.5.2 Water Conservation Projections

Recent reductions in MWU's per-capita water is consistent with regional water consumption trends. The extent of reduction attributed to passive conservation and active conservation efforts separately is unknown and difficult to determine. What is known is that a combination of these is indicating an ongoing reduction in per capita water use. Moving forward, as future water use projections are made, a combination of passive and active conservation effects should be accounted for.

The effects of both active and passive conservation can be seen on a usage category basis when looking at Table 3-4. As expected, over the past 10 years, residential per capital water use has experienced the greatest measure of decline. When making estimates for future conservation potential, the greatest focus will be put on residential water use

Future water conservation potential is broken out by various usage categories. Residential water use (including multi-family) has the greatest potential for conservation since it makes up a majority of the water use in the MWU System. Additionally, residential water use has the most potential for reduction since there are more tools and mechanisms available to encourage conservation within a residential home.

Table 3-7 – Indoor Conservation Potential Per Capita Water Use

Water Use	REU 1999[1]	REU 2016[2]	2007 MWCP[3]	High Eff.[4]
Showers	11.6	11.1	8.8	8.4
Clothes Washers	15	9.6	10	4.7
Dishwashers	1	0.7	0.7	0.4
Toilets	18.5	14.2	8.2	6.1
Baths	1.2	1.5	1.2	5.8
Leaks	9.5	7.9	4	3.2
Faucets	10.9	11.1	10.8	6.5
Other Domestic Uses	1.6	2.5	1.6	1.6
TOTAL	**69.3**	**58.6**	**45.3**	**36.7**

1. 1999 report, Residential end use of water (REU 1999)
2. 2016 report, Residential end use of water, Version 2 (REU 2016)
3. 2007 Madison Water Conservation Plan (Vickers, Amy. 2002. Handbook of Water Use and Conservation: Homes, Landscapes, Industries, Businesses, Farms.
4. High Eff from 2016 report, Residential end use of water, Version 2 (REU 2016)

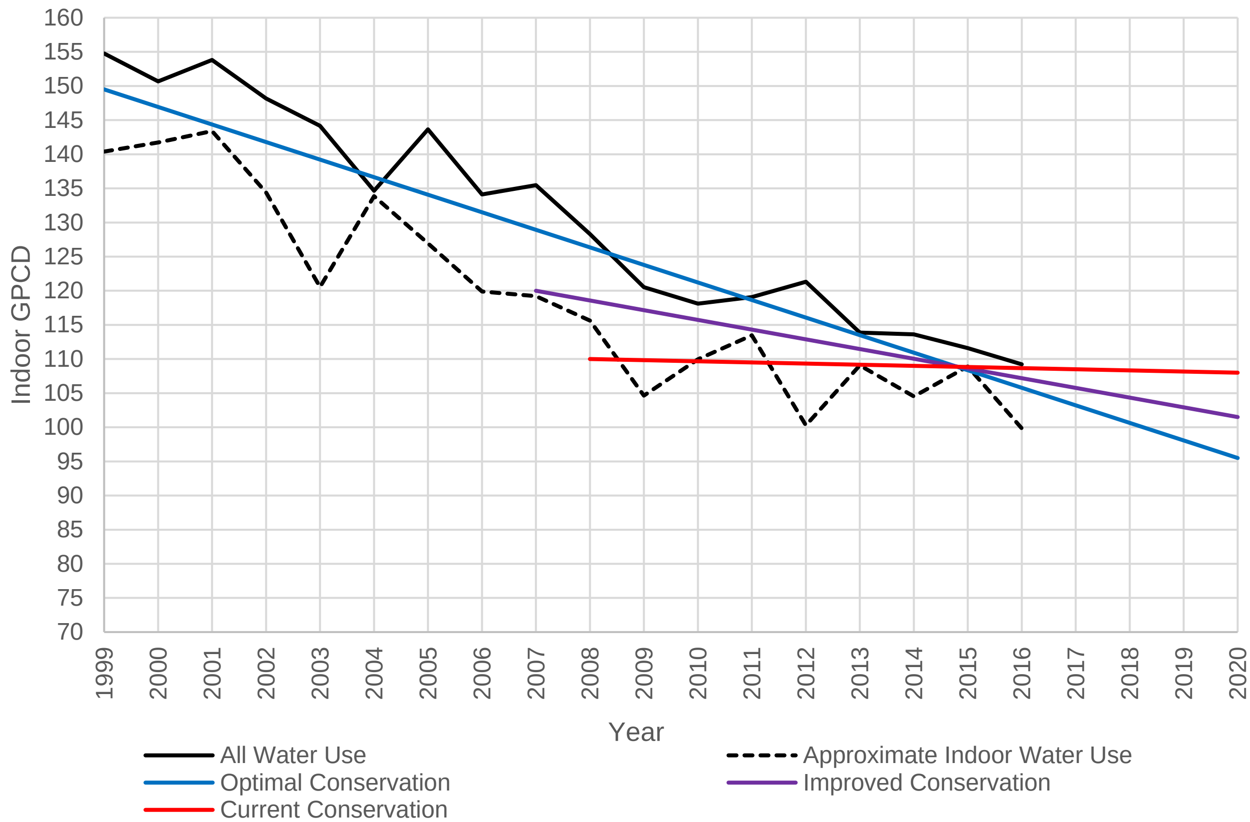
For the purposes of estimating the potential effects of both active and passive water conservation moving forward, an indoor water use conservation index was developed based on indoor water use records for MWU between the years of 1999 and 2016. Figure 3-2 shows the minimum monthly water production per capita between the years of 1999 and 2016. This provides for an approximation for total system wide indoor water use on a per capita basis. Water use over this time period had decreased about 25% system wide. A similar rate of decrease can be observed both before and after the conservation program was implemented. This indicates that passive conservation, following national trends, have likely been the biggest contributor to continued drop in per capita water use, with total system water use becoming more efficient over time.

3.5.2.1 Residential Water Conservation

MWU is working to maintain residential sales, by reducing residential per capita water consumption. In the years since the implementation of the Conservation Plan, MWU observed a reduction in residential per capita water use and shown previously in Table 3-4. However, some reduction was due to climate, as shown previously in Table 3-3. The Conservation Plan made multiple short term and long term recommendations for residential water conservation. Most short term recommendations have been implemented, such as the AMI infrastructure, monthly billing and residential rate structure. Other long term goals require customer involvement which varies with interest of the customer.

The optimal conservation projection utilizes a water conservation trend line paralleling water conservation reductions from 1999 to 2016, which is then projected forward through the 2040 projection year. The optimal conservation reflects the continued annual decrease of 1.7 percent until it reached the limits of realistic conservation. This figure was back checked by comparing historical indoor per capita water use multiplied yearly residential sales percentage and comparing that to published water conservation potential figures. Carrying the 1.7 percent reduction through 2040 would result in indoor per capita water use that is less than published potential figures Table 3-9, therefore the reduction potential was limited to a minimum per capita water use of 36.7. The result of the selected conservation index produces a 32 percent reduction per capita water use in 2040.

Figure 3-2: Estimated Total Indoor Water Use - Based on Minimum Month Production (All Water Use)



The improved conservation projection assumes a diminished, but continued reduction in water use. Carrying more recent reduction trends forward (after 2007) per capita water use is reduced by 0.83 percent on an annual basis, resulting in a 21 percent total reduction in per capita water use.

The current conservation projection assumes a minimal reduction in water use. Per capita water use is reduced by 0.11 percent on a yearly basis, resulting in a 3 percent total reduction in per capita water use.

For conservation planning, the conservation index factors can be applied to a selected residential per capita water use figure. Recent water use figures indicate a declining per capita water use figure, however, the most recent data occurs during “wet” years. In addition to normal domestic residential water use, lawn watering especially in drought seasons must be accounted for. MWU has the authority to restrict lawn watering, but has not yet used that authority. For future conservation planning, MWU is assumed to not restrict lawn watering on a continuous basis, except perhaps to reduce maximum day demands in special circumstances, thus some reasonable amount of lawn watering will be expected during a dry year. As a result, the per capita water use figures that will be utilized for future water use projections will be based on the most recent dry/drought year (2012) and varying/continued water conservation trends will be accounted for by multiplying the recently developed water conservation index by the selected per capita water use figure.

MWU is working to maintain total residential sales, by reducing residential per capita water consumption. Based on the findings of this report, the effect of future residential conservation efforts is shown in Table 3-8. Three values – current conservation trend, improved conservation trend and optimal conservation trend – are shown in Table 3-8 for years 2020 through 2040 on five year increments. The residential indices are compared to the total indoor water use trends in Figure 3-3. An apparently similar trend was observed between total and residential. Total projected residential sales based on Table 3-8 are shown in Table 3-9 and graphically in Figure 3-4.

Table 3-8 – Residential Per Capita Water Conservation Index

Year	Current Conservation	Improved Conservation	Optimal Conservation
2015	1.00	1.00	1.00
2020	0.99	0.96	0.91
2025	0.99	0.92	0.83
2030	0.98	0.88	0.76
2035	0.98	0.83	0.71
2040	0.97	0.79	0.68

Table 3-9 – Future Composite Residential Sales (gpcd)

Year	Current Conservation	Improved Conservation	Optimal Conservation
2020	61.4	59.1	56.4
2025	61.0	56.6	51.1
2030	60.7	54.0	46.9
2035	60.4	51.5	43.8
2040	60.0	48.9	41.8

1. Based on drought year 2012.
2. Combines single family, duplex and multi-family sales in Table 3-4, then multiplies by residential conservation index in Table 3-8.
3. Assumes all potential and practical conservation practices are in place, particularly system-wide minimization of outdoor water use. By year 2040, all goals for reductions in outdoor water use are assumed to be achieved.

Figure 3-3: Residential Per Capita Water Use Trends

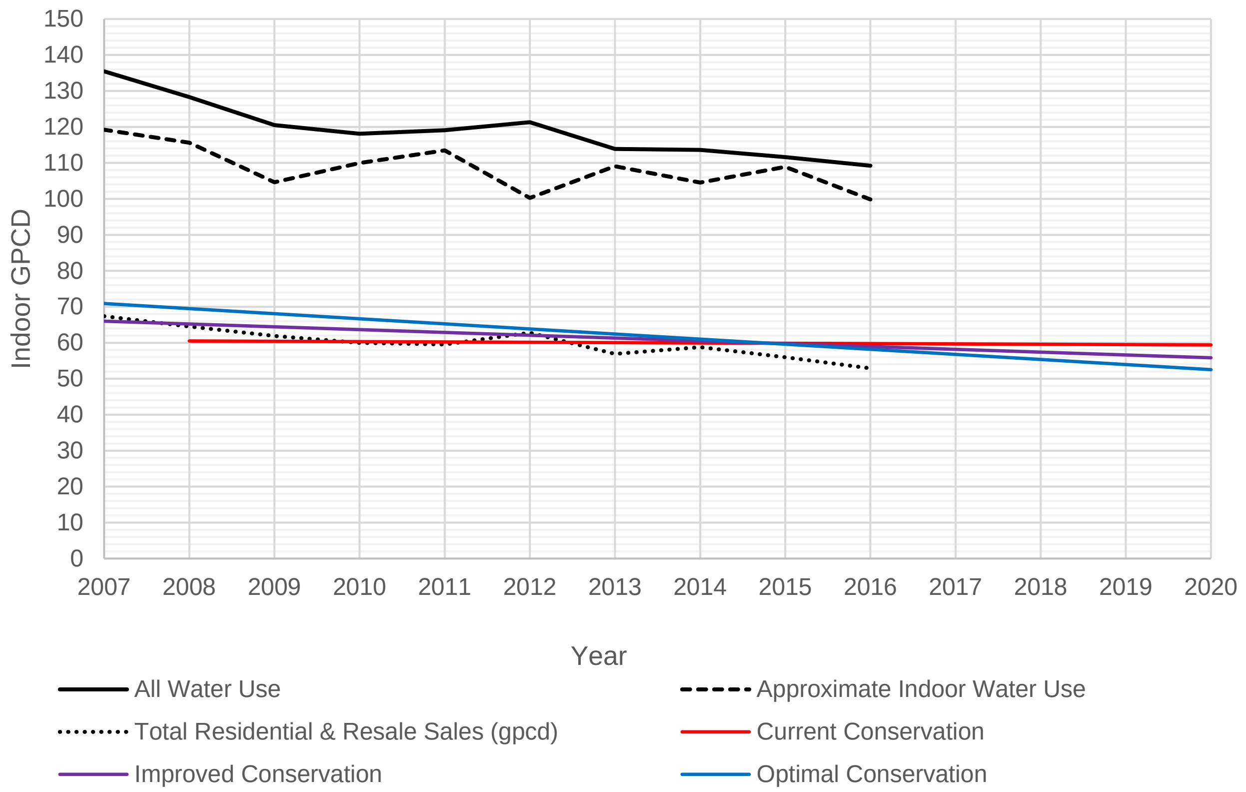
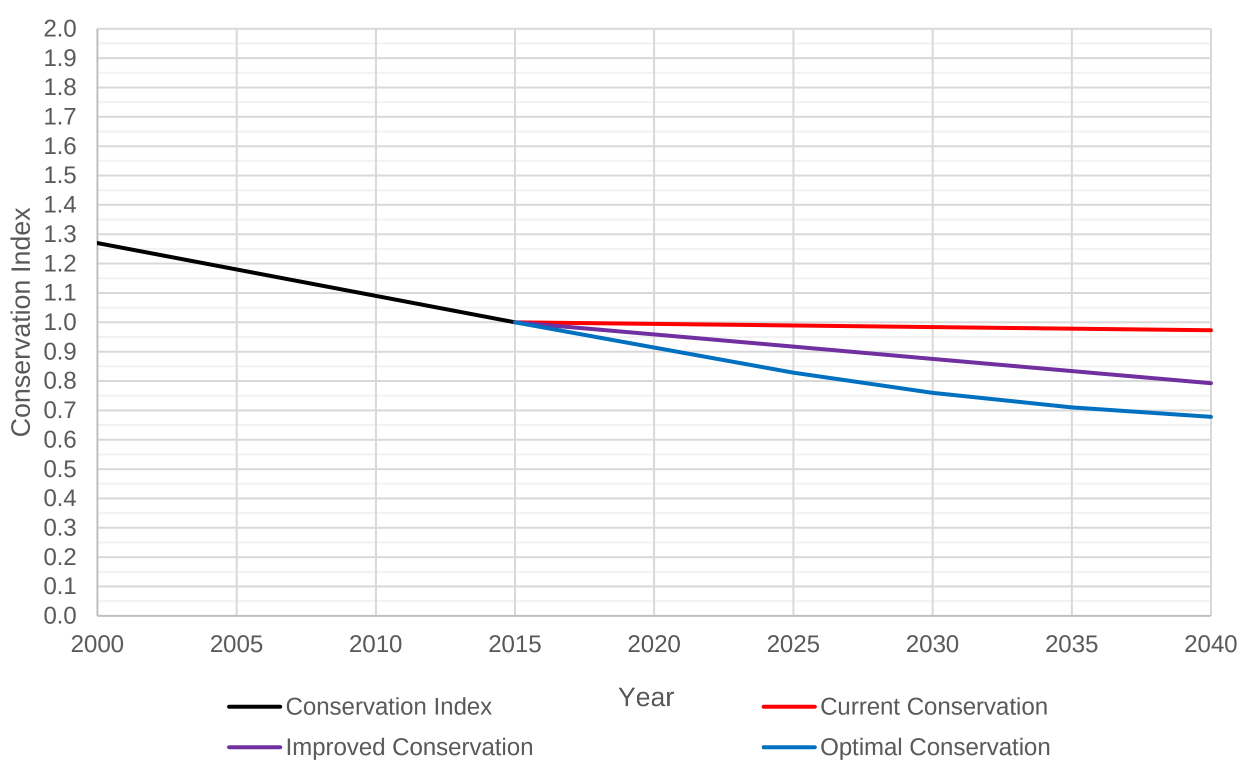


Figure 3-4: Projected Residential Water Use Conservation Index



3.5.2.2 Commercial Water Conservation

MWU is working to maintain commercial water consumption. Commercial water consumption includes sinks, toilets, laundry and sanitation. Services such as food, medical and lodging services must maintain a high degree of sanitation and cleanliness, and immediate reduction of water may not be practical in every situation. MWU has implemented incentives for high efficiency toilets, laundry equipment and dishwashers to encourage water conservation.

While “High efficiency” appliances have technical definitions associated to them, Energy Star and the National Geographic Green Guide estimate high efficiency appliances can reduce water use by 40 to 60 percent. Laundry and dishwashing, however, are large components of only some commercial service industries, but can reduce water consumption nonetheless. Toilets and sinks used in all commercial industries have potential to reduce water consumption.

Commercial per capita water use has experienced a modest decline over the past decade. As previously mentioned, water conservation mechanisms for commercial users are more limited than those for residential use. For this reason, a very modest water conservation index was developed for commercial users, with a very limited water use decline is expected. Again, three water use trends (current, improved & optimal) were developed and then applied to the historical commercial per capita water use figure. The optimal conservation estimate based on recent decline trends, current conservation assumes no additional conservation reductions and improved conservation is split half way between optimal and current numbers. Commercial conservation is expected to have a limited effect on overall future water use reductions.

The Conservation Plan recommended multiple intermediate and long term water conservation practices for commercial water users. In Table 3-4, commercial water consumption has only marginally reduced compared to the years since 2007. For the purposes of future conservation planning, a maximum reduction of 17 percent in commercial per capita water sales will be assumed for the intermediate and long term commercial conservation recommendations in the Conservation Plan that are implemented for MWU’s 4,847 commercial customers.

Based on the findings of this report, the effect of future commercial conservation efforts are shown in Table 3-10. Three values – current conservation trend, improved conservation trend and optimal conservation trend – are shown in Table 3-10 for years 2020 through 2040 on five year increments. The commercial indices are trended in Figure 3-5. Total projected commercial sales based on Table 3-10 are shown in Table 3-11 and graphically in Figure 3-6.

Table 3-10 – Commercial Per-Capita Water Conservation Index

Year	Current Conservation	Improved Conservation	Optimal Conservation
2015	1.00	1.00	1.00
2020	1.00	0.98	0.97
2025	1.00	0.97	0.93
2030	1.00	0.95	0.90
2035	1.00	0.93	0.87
2040	1.00	0.92	0.83

Table 3-11 – Future Commercial Sales (gpcd)

Year	Current Conservation	Improved Conservation	Optimal Conservation
2020	22.5	22.1	21.7
2025	22.5	21.7	21.0
2030	22.5	21.4	20.2
2035	22.5	21.0	19.5
2040	22.5	20.6	18.7

1. Based on drought year 2012.
2. Based on commercial conservation index.

Figure 3-5: Commercial Per Capita Water Use Trends

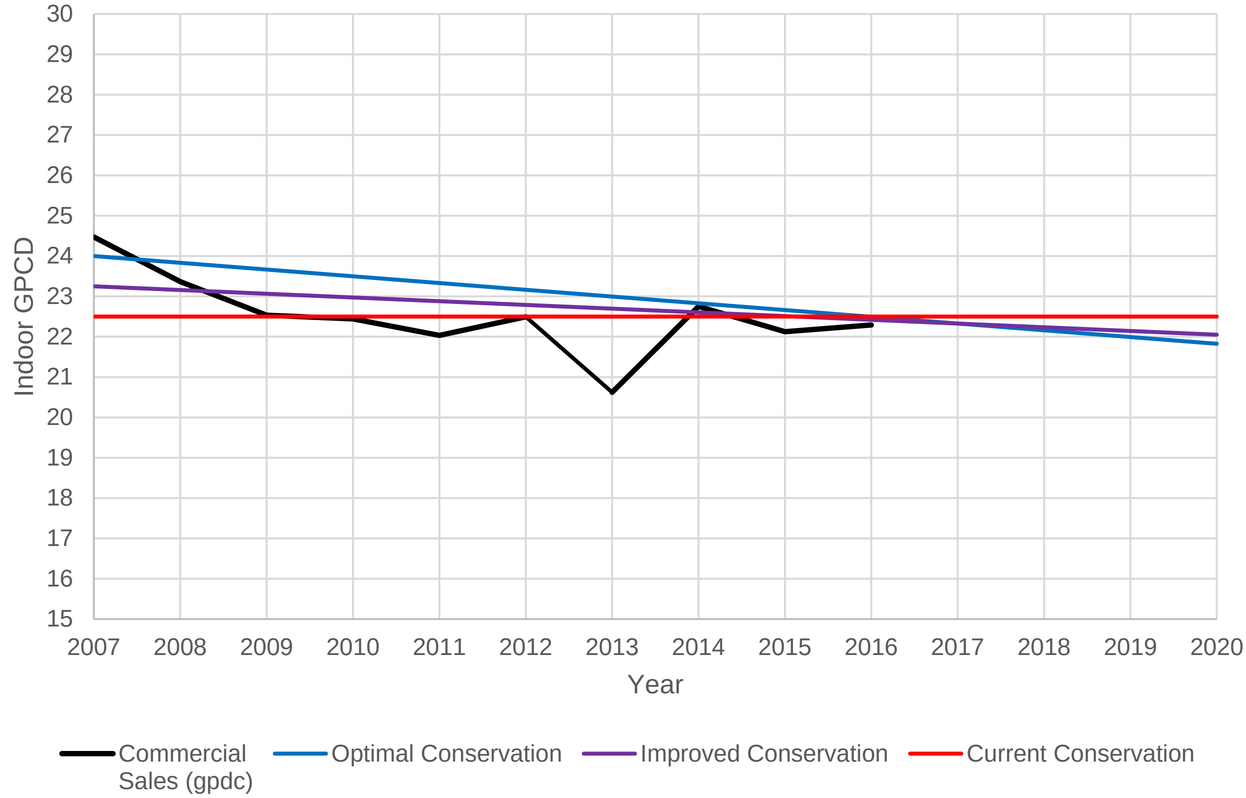
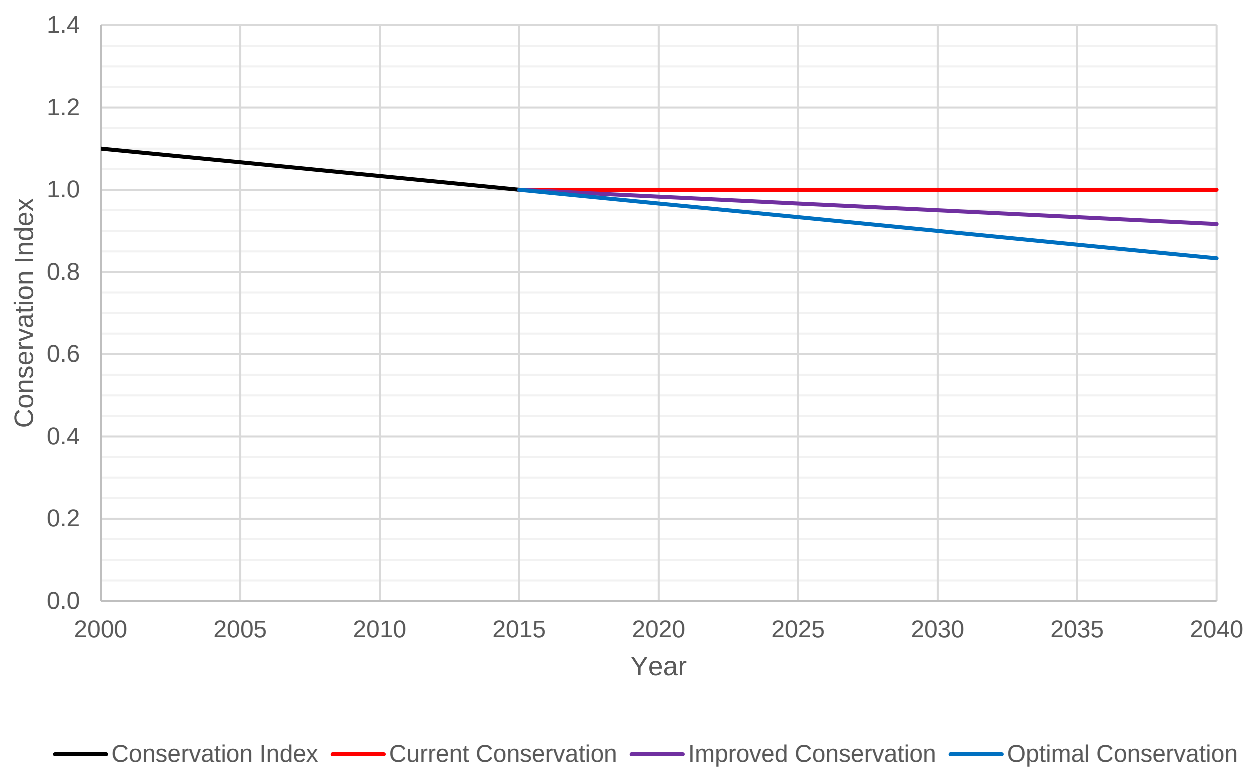


Figure 3-6: Projected Commercial Water Use Conservation Index



3.5.2.3 Public Water Conservation

MWU is working to maintain public authority water consumption. The Conservation Plan recommended multiple short term and intermediate term water conservation practices for municipal water users. In Table 3-4, public authority water consumption has reduced since 2007. This report assumes municipal users have already implemented the Conversation Plan recommendations based on the reduction in per capita water use since 2007. For the purposes of future conservation planning, a maximum reduction of 10 percent in public authority per capita water sales will be assumed for the MWU's 476 public authority water users.

Based on the findings of this report, the effect of future public authority conservation efforts is shown in Table 3-12. Three values – current conservation trend, improved conservation trend and optimal conservation trend – are shown in Table 3-12 for years 2020 through 2040 on five year increments. The optimal conservation estimate assumes a maximum 10 percent reduction by 2040 while the current conservation assumes no additional reduction and the improved conservation figure is the average of the current conservation and optimal conservation and the improved conservation trend is set between the other estimates.

Public customers are generally among the first to implement conservation measures. Thus a dramatic decrease in public sales is not expected as compared to residential sales.

Table 3-12 – Future Public Authority Sales (gpcd)

Year	Current Conservation	Improved Conservation	Optimal Conservation
2020	5.4	5.3	5.2
2025	5.4	5.3	5.1
2030	5.4	5.2	5.0
2035	5.4	5.2	4.9
2040	5.4	5.1	4.9

1. Based on drought year 2012.
2. Assumes 50 percent of difference between current conservation and optimal conservation.
3. Maximum decrease of 10 percent decrease in public sales.

3.5.2.4 Industrial Water Conservation

MWU is working to maintain industrial water consumption. Industrial water use is highly dependent on the production and processes of each industrial customer and water use can shift drastically with production. Industrial water use is also affected when large industrial customers come to or leave Madison.

For future water planning, future industrial sales are not expected to dramatically decrease with conservation efforts, as compared to residential. Future industrial sales will be projected to remain constant at 2016 levels with sales to Oscar Meyer removed. A future rate of 330,000 gpd will be projected for industrial sales with no adjustments for conservation. Any decrease in industrial sales will be considered negligible to total sales.

3.5.2.5 Non-Revenue Water Conservation

Non-Revenue water includes water that is not billed within the City's water billing system. This could be the result of leaks, un-metered connections, or water use in MWU facility processes or hydrant flushing. It is assumed that moving forward MWU's non-revenue water will be reduced on a per-capita basis due to better meter accounting and continued leak detection. Since non-revenue water has historically been a small percentage of overall water use, it is presumed that if future water use becomes more efficient, non-revenue water will also be reduced. Therefore, in an effort to develop a non-revenue water projection, per capita non-revenue water use estimates were projected based on historical per capita non-revenue. Using this methodology, current conservation, improved conservation and optimal conservation per capita water use figures can be developed for non-revenue water. No reduction with time is assumed.

Table 3-13 – Future Non-Revenue Water (gpcd)

Year	Current Conservation	Improved Conservation	Optimal Conservation
2020	16.4	13.5	12.2
2025	16.4	13.5	12.2
2030	16.4	13.5	12.2
2035	16.4	13.5	12.2
2040	16.4	13.5	12.2

1. Current conservation non-revenue water equals the maximum per capita non-revenue water use in the past 5 years (2015).
2. Improved conservation non-revenue water equals the average per capita non-revenue water use in the past 5 years (2013).
3. Optimal conservation non-revenue water equals the minimum per capita non-revenue water use in the past 5 years (2012)

3.5.2.6 University of Wisconsin Water Conservation

UW-Madison is the largest customer served by MWU and the water needs of UW-Madison is critical to long term water needs planning. In Table 3-2, UW-Madison varied in its average day water use from a low of 2.10 mgd in 2015 to a high of 2.96 mgd in 2008. Historical sales information for UW-Madison Supplemental historical enrollment and water use data is in Figure H-2 in Appendix 3B.

The University of Wisconsin – Madison has been actively implementing water conservation for the past several years as shown in Figure H-2. In addition to water demands for the University buildings, there is also a Cogeneration Facility on campus that typically uses cooling water from Lake Mendota, but could put a demand as large as 2 mgd on the system during a drought when lake levels are inadequate to supply cooling water.

As shown in Figure H-2 in 3B, UW-Madison has reduced drastically in water use, even with the steady increase in enrollment. For planning purposes, the vast majority of conservation opportunity at UW-Madison is assumed to be already accomplished. Future projections for sales to UW-Madison are shown in Table 3-14.

Table 3-14 – Future Sales to UW Madison (mgd)

Year	Current Conservation	Improved Conservation	Optimal Conservation
2020	43,873	2.81	2.61
2025	44,663	2.86	2.66
2030	45,452	2.91	2.71
2035	46,241	2.96	2.75
2040	47,031	3.01	2.80

1. Based on drought year 2012 with 64.0 gpd/person.
2. Assumes 50 percent of difference between current conservation and optimal conservation.
3. Linear increase in enrollment from 2016 to 2040 is assumed.
4. Assumes average non-drought use rate of 55.1 gpd/person from 2013-2016, assuming lawn sprinkling will be reduced.
5. Historical data is available in Appendix 3B.

3.5.2.7 Maximum Day Conservation

The previous sections discussed average day demands and the potential for MWU to reduce average day demands across the system. This section will discuss conservation practices and how they relate to maximum day demands.

Historical demand and climate data were previously discussed in Table 3-3 and are graphically shown in Appendix 3A. Years 2007 and 2012 each experienced a period of approximately one month with little to no rain. Consequently, daily demand continued to increase to the maximum day, after which significant rainfall brought the daily demands quickly back to the usual trend based on surrounding years.

For conservation planning purposes, two scenarios will be assumed for maximum day reduction: 1) no restrictions on outdoor water use during drought and 2) restrictions on outdoor water use during drought. The Current Conservation scenario and the Improved Conservation scenario will assume no restrictions are made to outdoor water used during a drought year. The Optimal Conservation scenario will assume MWU utilizes its authority to restrict outdoor water use on a drought year.

Table 3-15 shows the difference between Current Conservation and Improved Conservation versus Optimal Conservation. Improved Conservation includes reductions in average day water use as previously discussed, but does not include any reductions in outdoor drought water use, such as lawn watering. Optimal Conservation includes all indoor and outdoor reductions. The values in Table 3-15 are added to all demands previously discussed. For instance, an additional 85.9 gpcd will be added to the future average day sales to produce the total future maximum day sales in the Current Conservation and Improved Conservation scenarios. Reductions in outdoor drought water use for Optimal Conservation are assumed to be achieved gradually over the planning period.

Table 3-15 – Future Additional Demand on Maximum Day (gpcd)

Year	Current Conservation	Improved Conservation	Optimal Conservation
2020	85.9	85.9	85.9
2025	85.9	85.9	79.0
2030	85.9	85.9	72.1
2035	85.9	85.9	65.2
2040	85.9	85.9	58.2

1. Based on drought year 2012.
2. Assumes the additional demand due to drought maximum day is constant.
3. Assumes all potential and practical conservation practices are in place, particularly system-wide minimization of outdoor water use. By year 2040, all goals for reductions in outdoor water use are assumed to be achieved.

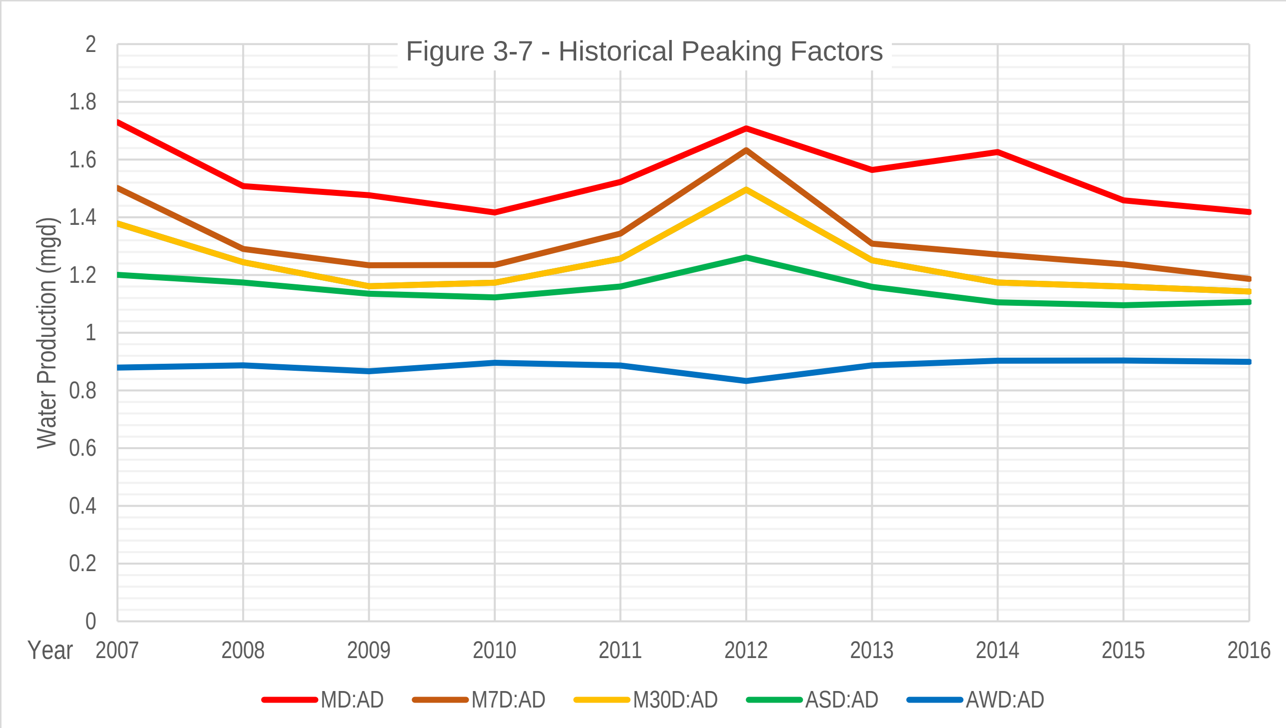
3.5.3 Historical Peaking Factors

In order to determine historical system peaking factors, pumping data from years 1997 to 2016 were evaluated. Peaking factors for each year of data were calculated and summarized in Table 3-16 and are shown in Figure 3-7 for the following conditions:

- MD Demand versus AD Demand (MD:AD ratio)
- ASD Demand versus AD Demand (ASD:AD ratio)
- AWD Demand versus AD Demand (AWD:AD ratio)
- M7D Demand versus AD Demand (M7D:AD ratio)
- M10D Demand versus AD Demand (M10D:AD ratio)
- M30D Demand versus AD Demand (M30D:AD ratio)

Table 3-16 – Historical Peaking Factors from Rounder Spreadsheets

Year	MD:AD	M7D:AD	M10D:AD	M30D:AD	ASD:AD	AWD:AD
2007	1.73	1.50	1.46	1.38	1.20	0.88
2008	1.51	1.29	1.29	1.24	1.17	0.89
2009	1.48	1.23	1.23	1.16	1.14	0.87
2010	1.42	1.24	1.22	1.17	1.12	0.90
2011	1.52	1.34	1.32	1.26	1.16	0.89
2012	**1.71**	**1.63**	**1.58**	**1.50**	**1.26**	**0.83**
2013	1.56	1.31	1.27	1.25	1.16	0.89
2014	1.63	1.27	1.23	1.17	1.11	0.90
2015	1.46	1.24	1.20	1.16	1.10	0.90
2016	1.42	1.19	1.20	1.14	1.11	0.90
Average	1.54	1.32	1.30	1.24	1.15	0.88
Maximum	1.73	1.63	1.58	1.50	1.26	0.90
Minimum	1.42	1.19	1.20	1.14	1.10	0.83
Standard Dev.	0.11	0.14	0.13	0.11	0.05	0.02
90th Percentile	1.71	1.51	1.47	1.39	1.21	0.90
90 % Confidence	1.70	1.52	1.48	1.40	1.22	0.91



3.6 Future System-Wide Demands

Future water demands may be projected from historical water use, historical population, planned community growth and conservation planning efforts. Historical water sales on a per capita basis were established in Table 3-4. Historical maximum day to average day ratios were shown in Table 3-1 and Table 3-16. Estimates for future water use considering conservation planning were shown in Table 3-9, Table 3-11 and Table 3-12. Future system-wide average day water demands are shown in Table 3-17. The data is graphically shown in Figure 3-8.

Table 3-17 – Future Total Average Day Demand on Drought Years (mgd)

Year	Current Conservation	Improved Conservation	Optimal Conservation
	Low[4] – High[4]	Low[4] – High[4]	Low[4] – High[4]
2020	29.9 – 31.8	28.3 – 30.1	27.0 – 28.7
2025	30.6 – 33.6	28.3 – 31.1	26.1 – 28.7
2030	31.3 - 35.6	28.2 – 32.1	25.5 – 28.9
2035	32.0 – 37.7	28.1 – 33.1	25.1 – 29.4
2040	32.8 – 39.9	28.1 – 34.1	24.9 – 30.3

1. Drought year water needs with current conservation measures.
2. Drought water needs with planned additional conservation measures.
3. Drought water needs with all practical conservation measures. This shows the level of effort required by MWU to suppress the future average day to be approximately equal to the average day in 2016.
4. Low and High population projections from Table 2-3.

Likewise to average day demands, future maximum day demands may also be projected based on the information discussed previously. Table 3-18 provides the forecast of the future maximum day demand for the three conservation scenarios. On top of the decreasing gpcd values in Table 3-18 as conservation increases, the MD:AD ratio is assumed to decrease with conservation in Table 3-18. The data is graphically shown in Figure 3-9.

3.7 Water Needs Per Service Zone

Using a combination of historical rounder pumping records and AMI data in GIS, historical and future water needs for each service zone were calculated and projected.

3.7.1 Service Zone Peaking Factors

Using the historical pumping spreadsheets from 2007 to 2016, total pumpage into and out of each service zone was calculated to determine historical peaking factors per service zone. The results of this analysis are shown in Appendix 3D for the MD, M7D, M10D, M30D, ASD and AWD ratios for each service zone.

Figure 3-8: Historical & Projected Drought Year Average Day Demands

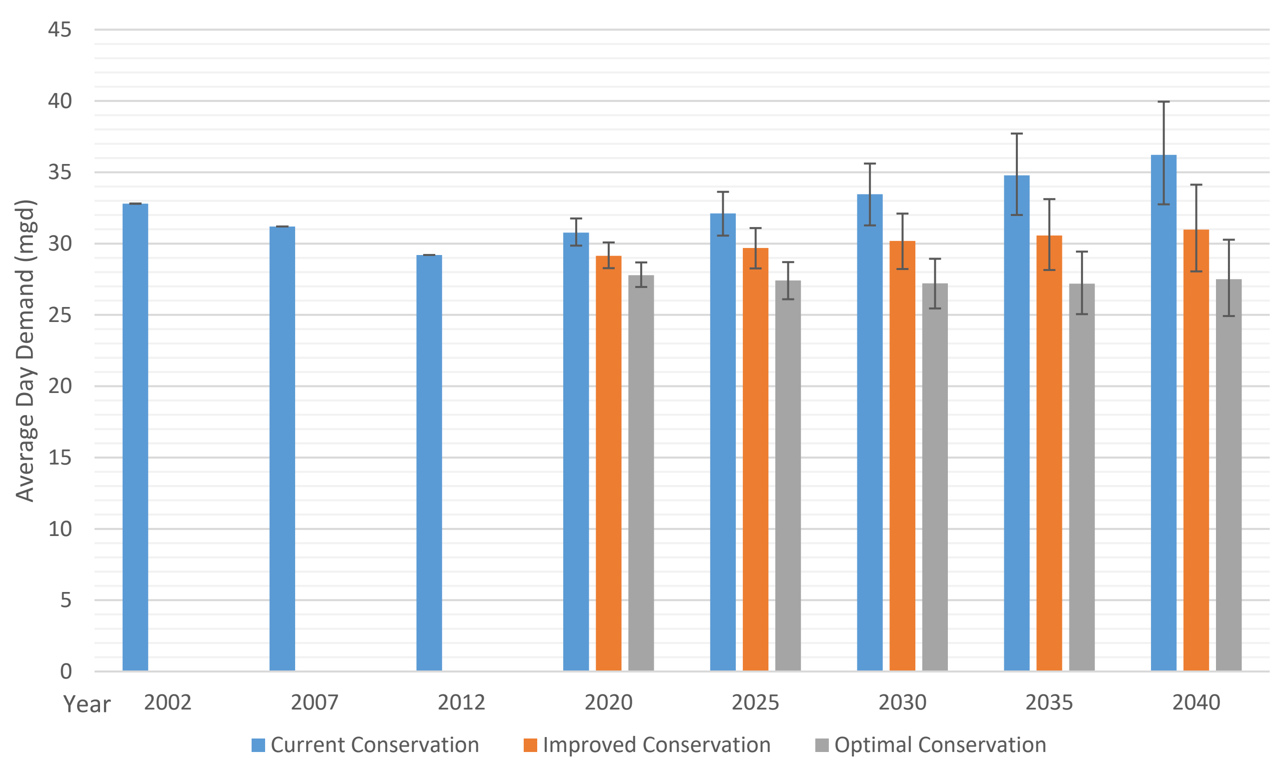
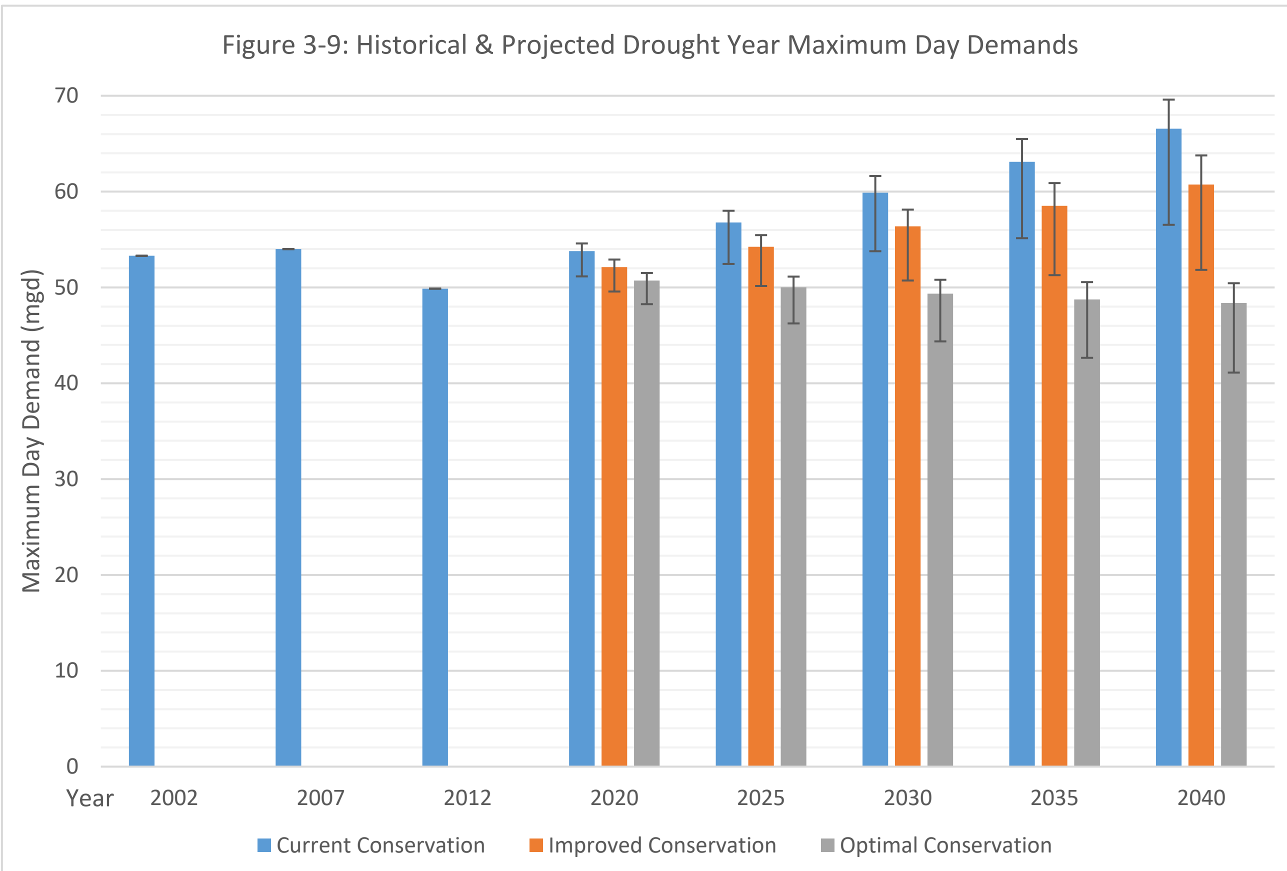


Table 3-18 – Future Total Maximum Day Demand on Drought Years (mgd)

Year	MD:AD Ratio	Current Conservation	MD:AD Ratio	Improved Conservation	MD:AD Ratio	Optimal Conservation
		Low[4] – High[4]		Low[4] – High[4]		Low[4] – High[4]
2020	1.72	51.2 – 54.6	1.76	49.6 – 52.9	1.79	48.3 – 51.5
2025	1.72	52.5 – 58.0	1.78	50.2 – 55.5	1.78	46.2 – 51.1
2030	1.73	53.8 – 61.6	1.80	50.7 – 58.1	1.75	44.3 – 50.8
2035	1.73	55.1 – 65.5	1.83	51.3 – 60.9	1.71	42.6 – 50.5
2040	1.73	56.5 – 69.6	1.86	51.8 – 63.8	1.66	41.0 – 50.4

1. Drought year water needs with current conservation measures.
2. Drought water needs with planned additional conservation measures.
3. Drought water needs with all practical conservation measures. This shows the level of effort required by MWU to suppress the future average day to be approximately equal to the average day in 2016.
4. Low and High population projections from Table 2-3.



3.7.2 Service Zone Diurnal Peaking Factors

MWU provided 24 hour sales data from the recently implemented Advanced Metering Infrastructure (AMI). MWU provided hourly sales for all water meters in the system for the days shown on Table 3-19. Table 3-19 shows how the system as a whole varies in system-wide diurnal variations.

In order to determine typical service zone diurnal peaking factors, the days shown on Table 3-19 were analyzed by service zone. Peaking factors for each service zone in each of the days in Table 3-19 were calculated and are shown in Appendix 3C. The individual diurnal curves in Appendix 3C were incorporated into the water modeling efforts of this Water Master Plan.

Table 3-19 – AMI Maximum Day Diurnal Peak Factors

Date	Represents	Day of Week	Peak Ratio (MH:AH)	Minimum Ratio (MinH:AH)	Total Sales (mg)
2/25/2016	AWD (Weekday)	Thursday	1.53	0.48	22.40
2/27/2016	AWD (Weekend)	Saturday	1.55	0.45	21.78
6/15/2016	ASD (Weekday)	Wednesday	1.41	0.29	24.96
6/18/2015	ASD (Weekend)	Saturday	1.39	0.54	25.50
7/27/2014	Maximum Day	Sunday	1.38	0.61	26.80
7/14/2016	Calibration Day (Macro)	Friday	1.32	0.60	28.83
AH: Average hourly demand of that particular day, or total demand divided by 24 MH: Maximum hour of that particular day MinH: Minimum hour of that particular day					

3.7.3 Future Average Day Water Projections Per Service Zone

For proper water supply planning, each service zone must be individually projected for future water needs. Historical pumping records, 2016 AMI sales records and TAZ population and employment projections, from previous tables, were used to project the water needs of each service zone by year 2040.

Projections for each service zone are shown in Table 3-20 for year 2020 and Table 3-21 for year 2040. Projection breakdowns for each service zone in 5-year increments are shown in Appendix 3E. Residential, commercial, public and non-revenue demands in each service zone were calculated according to the equations below. Industrial demands were assumed constant from 2016 for each service zone: Oscar Meyer was removed from service Zone 6e. The total Industrial demand system wide projected forward was approximately 330,000 gallons per day, predominantly in Service Zones 4 and 6e. Increases are calculated from base design year of 2012, the design drought year. Total sales for each category was calculated in Table 3-17, according to the overall per-capita rates in Tables 3-9, 3-11, 3-12 and 3-13.

Demands for each service zones were calculated as follows:

$$\mathit{Service\ Zone\ Residential\ Sales\ Increase} = \%\ \mathit{of\ TAZ\ Population\ Increase\ x\ Total\ Residential\ Sales\ Increase}$$

$$\mathit{Service\ Zone\ Commercial\ Sales\ Increase} = \%\ \mathit{of\ TAZ\ Employment\ Increase\ x\ Total\ Public\ Sales\ Increase}$$

$$\mathit{Service\ Zone\ Public\ Sales\ Increase} = \%\ \mathit{of\ TAZ\ Employment\ Increase\ x\ Total\ Public\ Sales\ Increase}$$

$$\mathit{Service\ Zone\ Non\ Revenue\ Water\ Increase} = \%\ \mathit{of\ TAZ\ Population\ Increase\ x\ Total\ Non\ Revenue\ Water\ Increase}$$

$$\mathit{Service\ Zone\ UW\ Madison\ Sales\ Increase} = \%\ \mathit{of}\ 2016\ \mathit{UW\ Madison\ Sales\ x\ Total\ UW\ Madison\ Sales\ Increase}$$

$$\begin{aligned}\mathit{Service\ Zone\ Total\ Water\ Needs} &= \mathit{Service\ Zone\ Residential\ Sales\ Increase} + \mathit{Service\ Zone\ Commercial\ Sales\ Increase}\\ &+ \mathit{Service\ Zone\ Public\ Sales\ Increase} + \mathit{Service\ Zone\ Non\ Revenue\ Water\ Increase}\\ &+ \mathit{Service\ Zone\ UW\ Madison\ Sales\ Increase}\\ &+ \mathit{Service\ Zone}\ 2012\ \mathit{Total\ Pumpage\ x\ Conservation\ Factor}\end{aligned}$$

Table 3-20 – Summary of Year 2020 Average Day Demand Projections per Service Zone

Year	Current Conservation	Improved Conservation	Optimal Conservation
	Low[4] – High[4]	Low[4] – High[4]	Low[4] – High[4]
3	2.32 – 2.84	2.20 – 2.69	2.10 – 2.56
4	1.48 – 1.63	1.42 – 1.57	1.38 – 1.52
5	0.27 – 0.27	0.25 – 0.26	0.24 – 0.25
6e	6.85 – 7.08	6.58 – 6.80	6.38 – 6.59
6w	11.16 – 11.59	10.40 – 10.81	9.76 – 10.14
7	2.56 – 2.62	2.43 – 2.50	2.32 – 2.38
8	3.22 – 3.42	3.07 – 3.26	2.95 -3.13
9	0.76 – 0.77	0.72 – 0.73	0.69 – 0.70
10	1.26 – 1.55	1.19 – 1.46	1.14 – 1.40
Total	29.9 – 31.8	28.3 – 30.1	27.0 – 28.7

1. See Appendix 3E for project breakdowns per service zone.
2. See assumptions in Table 3-17.

Table 3-21 – Summary of Year 2040 Average Day Demand Projections per Service Zone

Service Zone	Current Conservation	Improved Conservation	Optimal Conservation
	Low Growth – High Growth	Low Growth – High Growth	Low Growth – High Growth
3	3.11 – 5.07	2.60 – 4.24	2.27 – 3.72
4	0.70 – 2.28	1.51 – 2.00	1.38 – 1.82
5	0.27 – 0.29	0.22 – 0.24	0.19 – 0.20
6e	7.10 – 7.96	6.23 – 6.98	5.68 – 6.35
6w	12.05 – 13.67	10.38 – 11.72	9.16 – 10.33
7	2.60 – 2.86	2.16 – 2.38	1.88 – 2.08
8	3.48 – 4.24	2.94 – 3.58	2.59 – 3.16
9	0.76 – 0.80	0.62 – 0.65	0.53 – 0.56
10	1.69 – 2.79	1.41 – 2.33	1.24 – 2.04
Total	32.8 – 39.9	28.1 – 34.1	24.9 – 30.3

1. See Appendix 3E for project breakdowns per service zone.
2. See assumptions in Table 3-17.

3.7.4 Future Maximum Day Projections Per Service Zone

For proper water system capacity analysis, future maximum day demands must be projected so that facilities can be designed to accommodate the largest expected demand events. Similarly to average day projections in the previous section, maximum day projections for years 2020 and 2040 are summarized in Table 3-22 and Table 3-23 with projection breakdowns in Appendix 3F. Maximum day demands have the potential to occur on different days in each service zone. Therefore, the total system maximum day demand (total of water pumped on the biggest day of water use) is not simply the sum of service zone maximum days, but is the total of the water pumped for that given day. While it is likely that certain service zone maximum day demands could occur on this same day as the total system maximum day, it is not an assumption that can be made. Therefore, the examination of historical maximum day demand pumping records for each service zone is essential for the projection of these same demands. The table below summarizes the projected maximum day demand potential for each service zone individually. These figures are not additive and should be considered stand-alone numbers for individual analysis of each service zone.

Table 3-22 – Summary of Year 2020 Maximum Day Demand Projections per Service Zone

Service Zone	Current Conservation	Improved Conservation	Optimal Conservation
	Low Growth – High Growth	Low Growth – High Growth	Low Growth – High Growth
3	3.90 – 4.78	3.78 – 4.62	3.68 – 4.50
4	2.58 – 2.90	2.53 – 2.83	2.49 – 2.79
5	0.85 – 0.88	0.84 – 0.86	0.83 – 0.85
6e	11.46 – 11.81	11.19 – 11.54	10.99 – 11.33
6w	17.33 – 18.11	16.57 – 17.33	15.93 – 16.66
7	5.23 – 5.34	5.11 – 5.21	5.00 – 5.10
8	7.91 – 8.51	7.77 – 8.35	7.65 – 8.22
9	1.40 – 1.42	1.36 – 1.38	1.33 – 1.35
10	2.45 – 3.05	2.38 – 2.97	2.33 – 2.91

1. See Appendix 3F for project breakdowns per service zone.
2. The total of all individual service zone max day demand projections is higher than the total system maximum day demand projection.

Table 3-23 – Summary of Year 2040 Maximum Day Demand Projections per Service Zone

Service Zone	Current Conservation	Improved Conservation	Optimal Conservation
	Low Growth – High Growth	Low Growth – High Growth	Low Growth – High Growth
3	5.27 – 8.60	4.76 – 7.78	3.62 – 5.93
4	3.07 – 4.26	2.87 – 3.99	2.47 – 3.40
5	0.88 – 0.96	0.83 – 0.91	0.72 – 0.79
6e	11.91 – 13.27	11.05 – 12.30	9.00 – 10.02
6w	18.79 – 21.75	17.11 – 19.81	13.31 – 15.35
7	5.34 – 5.75	4.90 – 5.27	3.63 – 3.93
8	8.81 – 11.06	8.28 – 10.41	7.19 – 9.04
9	1.41 – 1.48	1.27 – 1.33	0.91 – 0.95
10	3.40 – 5.71	3.11 – 5.25	2.52 – 4.24

1. See Appendix 3F for project breakdowns per service zone.
2. The total of all individual service zone max day demand projections is higher than the total system maximum day demand projection.

3.8 Water Needs Per Hydraulic Region

Future water facility needs are defined by their ability to serve the water system as a whole. For example, a water storage facility located on the far western edge of the water system cannot be expected to provide service to the far eastern edge of the system. While it is reasonable to assume that some facilities have the ability to provide service to multiple service zones, the combination of specific zones must be defined so that future supply and storage facilities can be sized to serve the defined area. As previously discussed, the Madison Water System is divided into separate service zones. The existing service zones, as shown in the schematic in Appendix 3A of Chapter 1-2 (*Operation Evaluation Report*), are interconnected to each other in various degrees depending on location. As currently constructed and for purposes of this analysis, the Madison Water System can be described as consisting of four separate hydraulic regions, based on the existing interconnections between service zones. The hydraulic regions (regions) are listed below:

1. Region A – Zone 3, Zone 5 & Zone 6e.
2. Region B – Zone 4.
3. Region C – Zone 6w, Zone 7 & Zone 9.
4. Region D – Zone 8 & Zone 10.

These four separate hydraulic regions represents the basic structure of how the existing system requires water supply. In essence, each region must contain appropriate supply and storage facilities to meet the needs of that defined region.

Using a combination of historical rounder pumping records and AMI data in GIS, historical and future water needs for each region were calculated and projected to establish projected water needs for each defined region. These projections will be utilized to define water supply and storage needs for each region. This provide a reasonable balance between allowing facilities to service multiple service zones, thereby providing redundancy and maintaining facilities within a reasonable proximity to the point of use.

3.8.1 Region Peaking Factors

Using the historical pumping spreadsheets from 2007 to 2016, total pumpage into and out of each region was calculated to determine historical peaking factors per region. The results of this analysis are shown in Appendix 3G for the MD, M7D, M10D, M30D, ASD and AWD ratios for each region.

3.8.2 Future Average Day Water Projections Per Region

In accordance with defining future regional water needs, water use projections were developed for each region. Similarly to service zones, historical pumping records, 2016 AMI sales records and TAZ population and employment projections, from previous tables, were used to project the water needs of each region through year 2040.

Projections for each region are shown in Table 3-24 for year 2020 and Table 3-25 for year 2040. Projection breakdowns for each service zone in 5-year increments are shown in Appendix 3H. Average day demands per region equal the sum of all average day demands of the corresponding service zones from Appendix 3E.

Table 3-24 – Summary of Year 2020 Average Day Demand Projections per Region

Service Zone	Current Conservation	Improved Conservation	Optimal Conservation
	Low Growth – High Growth	Low Growth – High Growth	Low Growth – High Growth
A	9.44 – 10.19	9.04 – 9.75	8.72 – 9.40
B	1.48 – 1.63	1.42 – 15.7	1.38 – 1.52
C	14.48 – 14.98	13.56 – 14.04	12.77 – 13.23
D	4.47 – 4.96	4.23 – 4.72	4.09 – 4.53
Total	29.9 – 31.8	28.3 – 30.1	27.0 – 28.7

1. See Appendix 3H for project breakdowns per region.
2. See assumptions in Table 3-17.

Table 3-25 – Summary of Year 2040 Average Day Demand Projections per Region

Service Zone	Current Conservation	Improved Conservation	Optimal Conservation
	Low Growth – High Growth	Low Growth – High Growth	Low Growth – High Growth
A	10.47 – 13.31	9.04 – 11.46	8.14 – 10.27
B	1.70 – 2.28	1.51 – 2.00	1.38 – 1.82
C	15.41 – 17.33	13.15 – 14.76	11.57 – 12.98
D	5.17 – 7.03	4.35 – 5.91	3.83 – 5.20
Total	32.8 – 39.9	28.1 – 34.1	24.9 – 30.3

1. See Appendix 3H for project breakdowns per region.
2. See assumptions in Table 3-17.

3.8.3 Future Maximum Day Projections Per Region

Accordingly, future maximum day demands must also be projected for each region. Similar to average day projections in the previous section, maximum day projections for years 2020 and 2040 are summarized in Table 3-26 and Table 3-27 with projection breakdowns in Appendix 3I. Maximum day demand projections for each region are unique to that region. In essence, the actual day of maximum water use for each region may differ from the day identified for the entire system. In other words, the total of all four regional MDD projections will be greater than the system wide MDD projection since it would be the combination of four separate events rather than a single event. Therefore the regional MDD projections should only be utilized when examining each region individually.

Table 3-26 – Summary of Year 2020 Maximum Day Demand Projections per Region

Service Zone	Current Conservation	Improved Conservation	Optimal Conservation
	Low Growth – High Growth	Low Growth – High Growth	Low Growth – High Growth
A	15.65 – 16.92	15.25 – 16.48	14.93 – 16.14
B	2.58 – 2.90	2.53 – 2.83	2.49 – 2.79
C	23.71 – 24.61	22.79 – 23.66	22.00 – 22.85
D	9.72 – 10.95	9.51 – 10.71	9.34 – 10.51

1. See Appendix 3I for project breakdowns per region.
2. See assumptions in Table 3-17.

Table 3-27 – Summary of Year 2040 Maximum Day Demand Projections per Region

Service Zone	Current Conservation	Improved Conservation	Optimal Conservation
	Low Growth – High Growth	Low Growth – High Growth	Low Growth – High Growth
A	17.53 – 22.38	16.10 – 20.53	12.82 – 16.29
B	3.07 – 4.26	2.87 – 3.99	2.47 – 3.40
C	25.28 – 28.68	23.01 – 26.11	17.59 – 19.90
D	11.61 – 16.28	10.79 – 15.17	9.11 – 12.79

1. See Appendix 3I for project breakdowns per region.
2. See assumptions in Table 3-17.

3.9 Summary

Chapter 3 provides the water needs projections for future water facility planning. For water supply planning, the projections for the hydraulic regions will be used later for defining water supply facility needs. The projections developed for each individual service zone will be utilized for determining storage needs for each of the same. The water use figures defined as “improved conservation” will be utilized later in this plan to establish future facility needs and provide a baseline projected water system demand for future facility modeling.