City of Norfolk, Nebraska
Water Master Plan Update 2022
March 2023
B&V Project 198699

Norfolk
NEBRASKA
right at home.

BLACK & VEATCH
Building a world of difference.®

(Blank Page)

City of Norfolk, Nebraska
Water Master Plan Update 2022
March 2023

Prepared by
Black & Veatch Corporation
Denver, Colorado
B&V Project 198699

Norfolk NEBRASKA right at home.

BLACK & VEATCH Building a world of difference.

(Blank Page)

Table of Contents

Table of Contents (Continued)

List of Tables

List of Figures

Executive Summary

This Executive Summary presents the major findings and recommendations of the Norfolk, Nebraska, Water Master Plan 2022 Update.

ES 1.0 Demographics, Per Capita Water Use Rates, and Water Demands

Medium-term (2030) and long-term (2040) demographic projections, per capita water use rates, and demand projections determined for this study are summarized in Table ES-1. The medium and long-term demographic projections are based on the City's *Comprehensive Plan, Update 2017.* In addition to the medium and long-term water demands, future water requirements in the Amendment 4 development areas were prepared and are included in Table ES-1.

Historical and projected population and water demands are shown on Figure ES-1. Despite stable City population during the period 2005 through 2015, average day and maximum day demands and per capita water use rates declined. This decline is in part the result of the Energy Policy and Conservation Act of 1992 (effective 1994) and the Energy Independence and Security Act of 2007, which set water use standards for faucets, toilets, and water use appliances.

Table ES-1 Historical and Projected Population, Per Capital Water Use Rates, and Demands

YEAR/ ALTERNATIVE 4 DEMAND SCENARIO	POPULATION	AVERAGE DAY PER CAPITA WATER USE RATE (GPCD)	DEMAND (MGD)	
			Average Day	Maximum Day
1990	21,476	180	3.87	8.74
1995	22,922	182	4.18	9.09
2000	23,516	204	4.79	8.86
2005	24,255	207	5.02	9.44
2010	24,210	165	4.00	6.70
2015	24,384	159	3.87	7.36
2020	24,955	185	4.63	9.39
2030	26,574	218	5.80	11.72
2040	28,193	241	6.78	13.70
Amendment. 4, Scenario 2	-	-	7.82	15.81
Amendment 4, Scenario 4	-	-	8.65	17.48

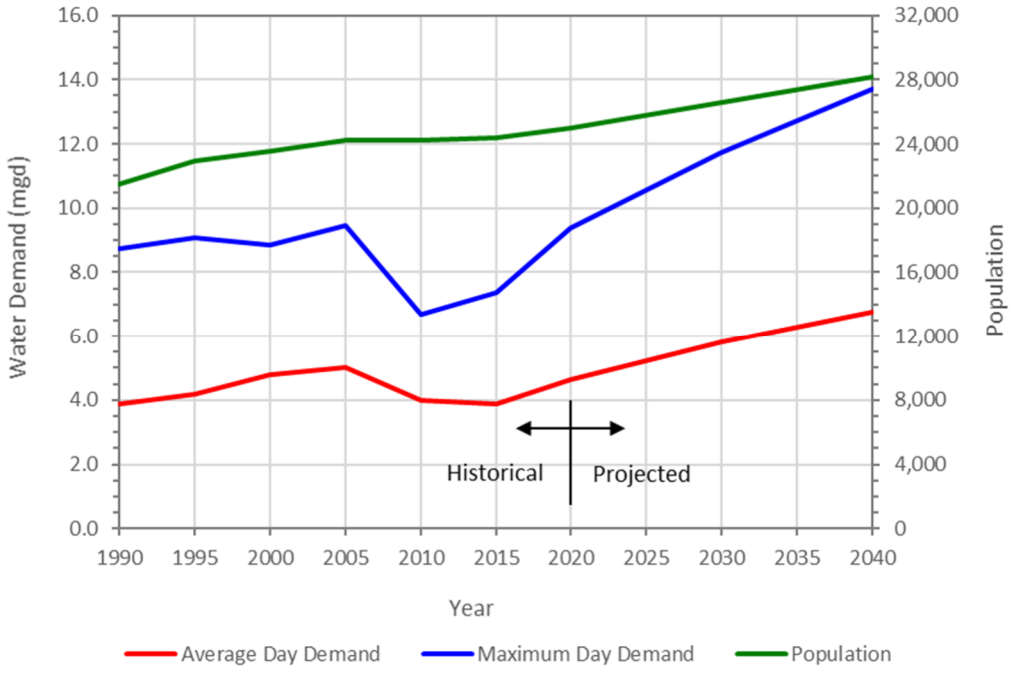


Figure ES-1 Historical and Projected Population and Water Demands

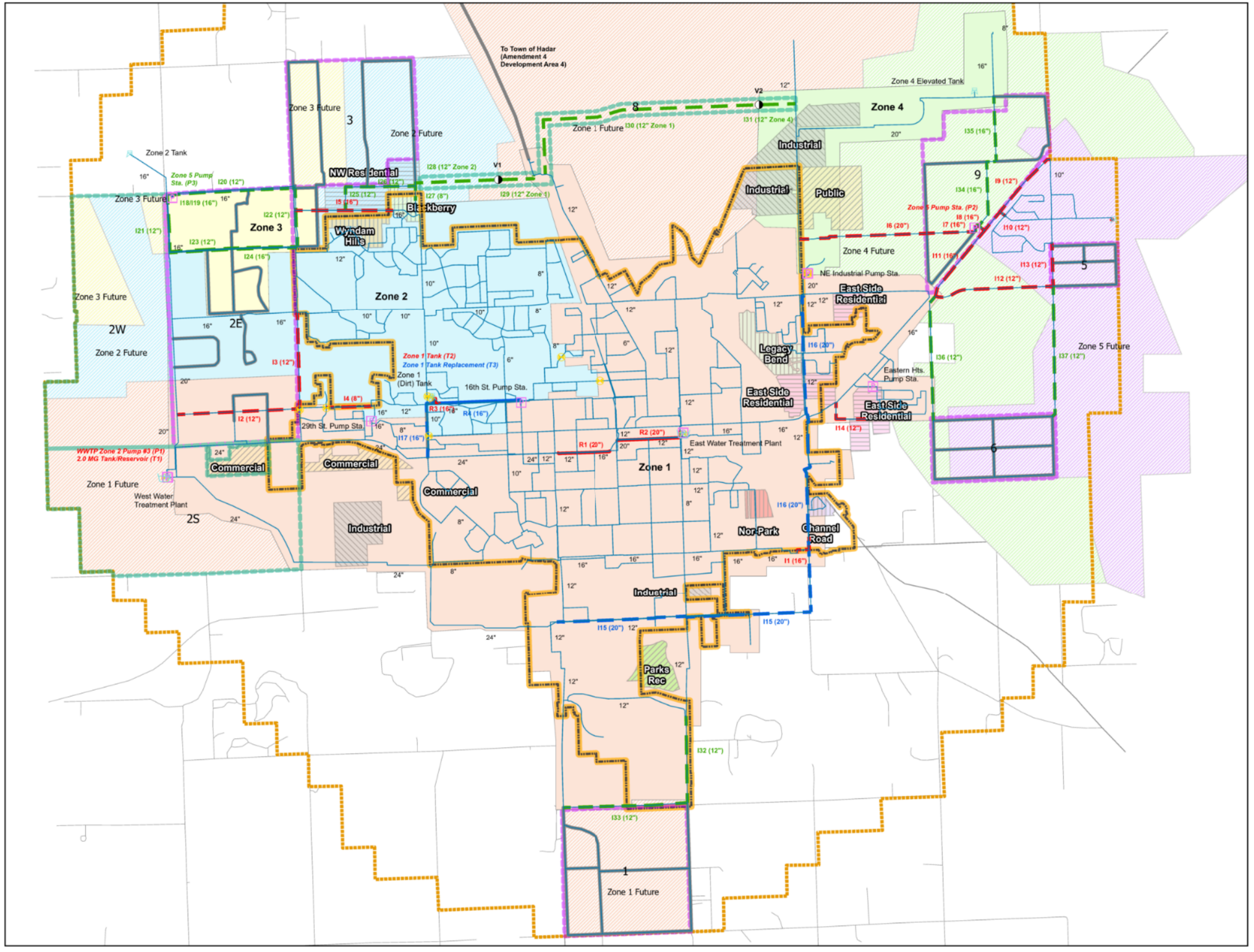
Year 2030 and 2040 maximum day demands are projected to increase from the current (2021) value of **9.6 mgd** to **11.7** and **13.7 mgd**, respectively. The Amendment 4 development areas will increase future water demands to **15.8 – 17.5 mgd**, Amendment 4 Scenarios 2 and 4, respectfully.

The medium-term (2030) and long-term (2040) demand projections include significant increases in industrial demands that will raise gross per capita water use rates to **218** and **241 gallons per capita per day** (gpcd), respectfully.

ES 2.0 Hydraulic Analyses, Recommended Improvements, and Capital Improvement Plan (CIP)

A total of **38** current conditions (2021), medium-term (2030) and long-term (2040) maximum day, 2030 winter day water age, 2030 system reliability, and Amendment 4 maximum day analyses were performed. From these analyses alternative improvements were evaluated and recommended improvement selected to develop the Capital Improvement Plan (CIP). Final recommended improvements included in the CIP are shown on Figure ES-2. Recommended improvements are broken down into the following categories and construction years.

- Pipes: "**R**" prefix represents Replacement Pipe, "**I**" prefix represents Improvement Pipe, "**D**" prefix represents Development Pipe.
- Pumps and Pump Stations: "**P**" prefix.
- Storage Facilities (Tanks/Reservoirs): "**T**" prefix.
- Medium-term 2030 Improvements color **Red**.
- Long-term 2040 Improvements color **Blue**.
- Amendment 4 Improvements color **Green**.



Water Master Plan Update
City of Norfolk, Nebraska
Capital Improvement Plan (CIP)
Figure ES-2

LEGEND

- Existing City Limits
- Extraterritorial Jurisdiction Area (ETJ)

Future Growth Areas

- Blackberry (SF Residential)
- Channel Rd (MF Residential)
- Commercial/Public
- East Side Area (SF Resid)
- Industrial
- Legacy Bend (SF) Residential)
- Northwest Area (SF Resid)
- Nor-Park (MF Residential)
- Parks/Recreation
- Wyndam Hills (SF Resid)

Amendment 4 Development Areas, Number, & Evaluation Type

- 2E — Detailed (Hydraulic Model)
- 2S — Qualitative
- 12" — Existing Pipe & Diameter (in)

Replacement, Improvement, & Development Mains. IDs & Diameters

- R1 (20") — 2030 Replacement
- R4 (16") — 2040 Replacement
- I1 (16") — 2030 Improvement
- I15 (20") — 2040 Improvement
- I18 (16") — Amendment 4 Impr
- Development Main
- Zone Boundary Valve

Norfolk NEBRASKA right at home.

BLACK & VEATCH Building a world of difference.

NORFOLK_INFOWATER_PRO40.aprx
February 14, 2023

(Blank Page)

The medium-term (2030) and long-term (2040) future growth areas and Amendment 4 development areas are also shown on Figure ES-2.

ES 2.1 Critical Distribution System Improvement Projects

While recommended improvements are located throughout the distribution system service area, six (6) critical improvement projects were given special consideration. Because of their importance in providing critical hydraulic capacity to support growth, these improvements involved evaluation of multiple alternatives. The critical improvement projects are summarized in Table ES-2.

Table ES-2 Critical Distribution System Improvement Projects

CRITICAL DISTRIBUTION SYSTEM IMPROVEMENTS	CONSTRUCTION STAGING	CIP IDS	COSTS ($)		ADVANTAGES/BENEFITS
			Construction	Project	
1. West WTP Increased Storage					
Second Ground Storage Tank (2 MG)	Medium-term (2030)	T1	$2,897,000	$4,592,000	- Increased treatment flexibility (filter backwash) - Increased Zones 1 & 2 operating flexibility (pump operations)
2. Zone 1 Increased Storage					
Second Zone 1 "Dirt Tank" (1 MG)	Medium-term (2030)	T2	$2,210,000	$3,503,000	- Lower Cost - Simple standard operations
3. Zone 1 Transmission Main					
Southern Alignment - Monroe Ave/Victory Rd	Long-term (2040)	I15, I16	$7,567,900	$11,995,100	- Supports expanded service to southeast Norfolk
4A. Zone 5 Pump Station					
Magnet Drive & Highway 35	TBD (Dependent on Zone 5 creation)	P2	$2,147,000	$3,403,000	- Adjacent to Zone 5 customers - Lower improvement mains costs
4B. Zone 5 Pump Station Support Piping (Zones 4 & 5)					
Magnet Drive, Highway 35		I6, I7, I8, I9, I10	$3,024,300	$4,793,600	
5. Zone 3 Pump Station					
49th Street & Eisenhower Ave	TBD (Dependent on Zone 3 creation)	P3	$2,625,000	$4,161,000	- Minimizes negative impact on Zone 2 operations and pressures
6. Zone 4 Northeast Loop					
North from future Zone 5 Pump Sta. to Eisenhower Ave; east 400 feet, north to Northeast Industrial Hwy	TBD (Dependent on Zone 4 Amendment 4 Development Area 9 growth)	I34, I35	$1,574,000	$2,494,800	- Shorter length, lower cost - Provides more economical service to Zone 4 Amendment 4 Development Area 9
Subtotal Medium-term (2030)			$5,107,000	$8,095,000	
Subtotal Long-term (2040)			$7,567,900	$11,995,100	
Subtotal To Be Determined (TBD)			$9,370,300	$14,852,400	
Total			$22,045,200	$34,942,500	

Medium-term (2030) Critical Improvement Projects. The medium-term (2030) critical improvement project construction and project costs are **$5,107,000** and **$8,095,000**, respectfully. It is noted that both 2030 critical improvement projects represent increased system storage. Current distribution system storage is equal to 5.5 million gallons (MG), which represents approximately **57%** of the current (2021) maximum day demand of 9.6 mgd. For comparison, well operated Colorado Front Range Utilities typically have the equivalent of 80% to 120% of maximum day demand in distribution system storage.

Long-term (2040) Critical Improvement Projects. The long-term (2040) critical improvement project construction and project costs are **$7,567,900** and **$11,995,100**, respectfully. The 2040 critical improvement projects consist of 20-inch transmission mains along Monroe Avenue and Victory Road which will support growth in the southeast and northeast parts of the system. These transmission mains will increase hydraulic capacity to the Northeast Industrial Pump Station, Zone 4, and future Zone 5.

Amendment 4 Based Critical Improvement Projects (Construction/Staging To Be Determined). The Amendment 4 based critical improvement project construction and project costs are **$9,370,300** and **$14,852,400**, respectively. These improvement project may be required in the medium-term (2030) and long-term (2040) planning periods depending upon localized development patterns and trends. Two (2) of the Amendment 4 based improvement projects include future pump stations (Zones 3 and 5) and support piping. While the future Zone 3 and Zone 5 Pump Stations are not critical with regards to immediate growth, they will be essential to providing future service to Woodland Park and expanding service to future Zones 3 and 5.

The Northeast Loop transmission mains will complete the Zone 4 Northeast Loop and support industrial and commercial growth in the far northeastern part of the service area.

Critical Improvement Projects Summary. The six critical improvement project construction and project costs are **$22,045,200** and **$34,942,500**, respectfully. The critical improvement projects costs represent approximately **37%** of the total CIP construction and project costs.

ES 2.2 Capital Improvement Plan (CIP) Construction and Project Costs

The system-wide CIP construction and project costs are given in Table ES-3. Pipeline/main, pump and pump station, and storage facility construction unit costs are based on recent construction project costs, bid tabs, etc. Historical project bid tabs and construction costs were adjusted to an October 2022 Construction Cost Index of 13,175.

Project costs include construction costs plus permitting, legal and contract administration, engineering/design/binding, construction/commissioning services, and contingency costs. The additional non-construction and contingency project costs are **28.5%** and **30%**, respectively. Total project cost markups are equal to **58.5%** of construction costs.

Table ES-3 CIP Construction and Project Costs Summary

ITEM	COST ($)		PROJECT COST PERCENT OF TOTAL (%)
	Construction	Project	
Pipelines/Mains			
2030 Replacement Mains	2,357,300	3,736,400	4.0%
2040 Replacement Mains	1,413,800	2,240,900	2.4%
2030 Improvement Mains	7,837,000	12,421,800	13.2%
2040 Improvement Mains	8,661,100	13,727,800	14.5%
Amendment 4 Improvement Mains	10,890,700	17,262,000	18.3%
Amendment 4 Development Mains	14,411,200	22,841,800	24.2%
Subtotal 2030 Mains	10,194,300	16,158,200	17.1%
Subtotal 2040 Mains	10,074,900	15,968,700	16.9%
Subtotal Amendment 4 Mains	25,301,900	40,103,800	42.5%
Subtotal Replacement, Improvement, & Development Mains	**45,571,100**	**72,230,700**	**76.5%**
Pumps & Pump Stations			
2030 Pumps & Pump Stations	2,629,000	4,167,000	4.4%
2040 Pumps & Pump Stations	0	0	0.0%
Amendment 4 Pumps & Pump Stations	2,625,000	4,161,000	4.4%
Subtotal Pumps & Pump Stations	**5,254,000**	**8,328,000**	**8.8%**
Tanks/Reservoirs			
2030 Tanks/Reservoirs	5,107,000	8,095,000	8.6%
2040 Tanks/Reservoirs	2,210,000	3,503,000	3.7%
Amendment 4 Tanks/Reservoirs	1,450,000	2,298,000	2.4%
Subtotal Tanks/Reservoirs	**8,767,000**	**13,896,000**	**14.7%**
Mains, Pumps, Tanks			
Subtotal 2030	17,930,300	28,420,200	30.1%
Subtotal 2040	12,284,900	19,471,700	20.6%
Subtotal Amendment 4	29,376,900	46,562,800	49.3%
TOTAL	**59,592,100**	**94,454,700**	**100.0%**

- Year 2030 pipeline/main, pump and pump station, and tank improvement construction and project costs are **$17,930,300** and **$28,420,200**. Year 2030 total project costs account for **30.1%** of 2030, 2040, and Amendment 4 total project costs.
- Year 2040 pipeline/main, pump and pump station, and tank improvement construction and project costs are **$12,284,900** and **$19,471,700**. Year 2040 total project costs account for **20.6%** of 2030, 2040, and Amendment 4 total project costs.
- Year 2030, 2040, and Amendment 4 total construction and project costs for pipelines/mains, pumps/pump stations, and tanks/reservoirs are **$59,592,100** and **$94,454,700**, respectively.

ES 2.3 Improvement Selection and Staging – Special Considerations.

While the main, pump, and tank improvements are generally grouped within the medium-term (2030), long-term (2040), and Amendment 4 planning periods, localized growth patterns and Norfolk's transmission/distribution system operations and performance can play a major role in selecting the timing of future improvement design and construction.

Improvements with immediate, large benefits. Certain improvements will have immediate, large benefits justifying prompt design and construction.

- ***Improvement Main I1*** will close a gap between 16-inch and 12-inch mains along Omaha Avenue and Victory and increase hydraulic capacity to the east side of the City.

Localized growth based improvements. Certain improvements will be linked directly to service areas that "trigger" the need for their design and construction.

- The future Zone 5 Pump Station, ***Improvement P2***, will be dependent on future service to Woodland Park and/or Amendment 4 Development Area #5. Service to Woodland Park only would require ***Improvement Mains 16 through I10***; ***Improvement Mains I11 through I13*** may be deferred until development of Amendment 4 Development Area #5 occurs.
- The future Zone 3 Pump Station, ***Improvement P3***, and ***Zone 3 Improvement Mains*** will be dependent on development in future Zone 3 and Amendment 4 Development Areas 2E, 2W, and/or 3.

System-wide demand based improvements. Certain improvements will be driven by system-wide demand growth.

- The Zone 1 transmission mains, long-term (2040) ***Improvement Mains I15 and I16*** (20-inch), are projected to be required when system-wide maximum day demands reach approximately **13.7 mgd**. System-wide maximum day demands and potential growth trends should be closely monitored to allow adequate time and budgeting for this major improvement project.

1.0 Introduction

This Water Master Plan Update 2022 provides the City of Norfolk with a short-term, medium-term (2030), and long-term (2040) plan for improving and expanding its treated water distribution system. Additional potential development areas and system improvements were evaluated under Amendment 4 to the original scope of work.

This study includes evaluation of the City's distribution system transmission, pumping, and storage capacities and development of recommended improvements to meet future water demands. This study also included water age/quality and system reliability/redundancy evaluations.

The primary tool used to complete the evaluations and define improvements is the City's INFOWATER PRO distribution system hydraulic model. Historical metered sales, per capita water use rates, and demographics were evaluated and future water demand projections prepared as part of this study. The validated hydraulic model was used to perform hydraulic analyses to evaluate alternative water system improvements for the various design years and operating conditions. Project meetings with City staff were conducted to review the findings of hydraulic analyses and select the final recommended improvements.

The results of these evaluations will serve as the basis for the design, financing, and construction of facilities to meet the City's growth and anticipated water demands through and beyond 2040.

1.1 DESCRIPTION OF SYSTEM

The City of Norfolk, Nebraska operates two water treatment facilities; the East Water Treatment Plant (EWTP) and the West Water Treatment Plant (WWTP).

The EWTP was originally constructed in 1933 and is located in downtown Norfolk. It treats groundwater from the East Well Field, which is also located in downtown Norfolk. The EWTP is operated from April through October to supplement water production at the WWTP. During the rest of the year, the EWTP serves as emergency backup treatment to the WWTP and the EWTP clearwell is used for additional treated water storage. Both the EWTP and WWTP have undergone several improvements and/or expansions due to increasing treated water demands and regulatory requirements.

The WWTP was originally constructed in 1975 and is located 3.5 miles west of downtown Norfolk. It treats groundwater from the West Well Field, which is located directly south of the WWTP. Although the well field is in close proximity to the Elkhorn River, all eight wells have been determined to be free of surface water under the influence.

The Norfolk distribution system currently serves three (3) pressures zones, Zone 1, Zone 2 and Zone 4. Ground storage facilities serve Zones 1 and 2 while Zone 4 is served by an elevated storage tank constructed in 2020. This study includes evaluation of two (2) new pressure zones – Zones 3 and 5, located on the west and east sides of the City, respectively.

1.2 SCOPE OF WORK

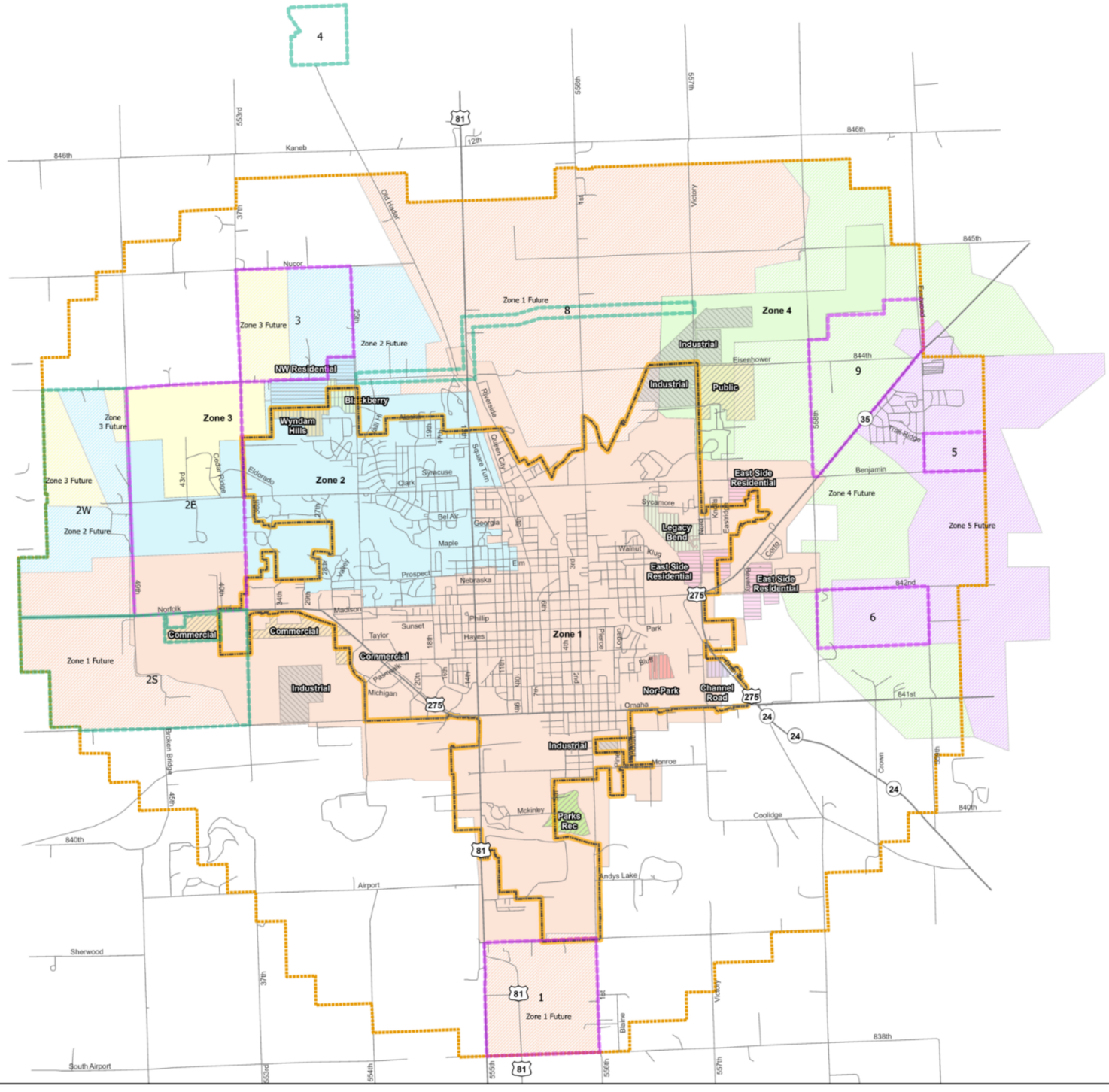
The March 20, 2018 agreement between the City of Norfolk (City) and Black & Veatch Corporation provides for "water system planning services" including hydraulic modeling, evaluations, and

master planning. Phases and amendments to the water system planning service are summarized below.

- **Phase 1, Northeast (NE) Loop.** The Phase 1 portion of the project included hydraulic analyses to determine/confirm the locations and sizes/capacities of the NE Loop Zone 4 transmission mains, new storage facilities, and improvements to the NE Industrial Pump Station. This work is presented in the *"NE Loop (Zone 4) Hydraulic Analyses Technical Memorandum" (November 2, 2018)*.
- **Phase 2 (Amendment 1), Water Master Plan 2022 Update.** Phase 2 (Amendment 1) includes preparation the City of Norfolk Water Master Plan 2022 Update. Tasks include (1) medium-term (2030) and long-term (2040) demand projections based on the City's Comprehensive Plan, (2) hydraulic modeling, (3) assessment of the WWTP and EWTP capacities, (4) hydrogeologic modeling of the West Wellfield aquifer, wellfield capacities, and field testing for a new collector well in the West Wellfield.
- **Amendments 2 and 3, Well 14 Aquifer Testing.** Amendments 2 and 3 included field service to (1) install additional monitoring wells and a larger aquifer test well for the proposed Well 14 location, (2) aquifer drawdown tests, and (3) aquifer testing documentation.
- **Amendment 4, Water System Expanded Service Area.** The Water Master Plan 2022 Update established the 2040 service area, population, and water demands in coordination with the City's *Comprehensive Plan, Update 2017*. The anticipated 2040 service area encompasses the existing City limits plus several areas of anticipated growth extending just outside the existing City limits. Subsequent to establishing the 2040 service area, developers have inquired with the City regarding potential extension of water and sewer utility service beyond the City limits but within the City's Extraterritorial Jurisdiction Area (EJA). Amendment 4 includes ten (10) "development areas" not included in the 2040 service area. "Qualitative" (conceptual) and "detailed" (hydraulic modeling) evaluations were performed for the ten development areas to identify the feasibility and infrastructure needed to extend water service to the development areas.

1.3 STUDY AREA

The study area for this investigation is shown on Figure 1-1. Future "growth areas" shown on Figure 1-1 are based on the Norfolk, Nebraska Comprehensive Plan Update 2017 and City input. Amendment 4 "development areas" shown on Figure 1-1 were developed by the City. The Comprehensive Plan based future growth areas and Amendment 4 development areas fall within the City Extraterritorial Jurisdiction Area (ETJ) which forms the outer boundary of the study area.



Water Master Plan Update 2020
City of Norfolk, Nebraska
Study Area
Figure 1-1

- Existing City Limits
- Extraterritorial Jurisdiction Area (ETJ)

Future Growth Areas

- Blackberry (Single Family Residential)
- Channel Rd (Multi-family Residential)
- Commercial/Public
- East Side Area (Single Family Resid)
- Industrial
- Legacy Bend (Single Family Residential)
- Northwest Area (Single Family Resid)
- Nor-Park (Multi-family Residential)
- Parks/Recreation
- Wyndam Hills (Single Family Resid)

Amendment 4 Development Areas & Numbers

- 2E — Hydraulic Model Evaluation
- 2S — Qualitative Evaluation

Distribution System Pressure Zones

- Zone 1
- Zone 2
- Zone 3
- Zone 4
- Zone 1 (Future)
- Zone 2 (Future)
- Zone 3 (Future)
- Zone 4 (Future)
- Zone 5 (Future)

Norfolk NEBRASKA right at home.

BLACK & VEATCH Building a world of difference.

NORFOLK_INFOWATER_PRO.aprx; January 25, 2023

(Blank Page)

1.4 PREVIOUS REPORTS

Previous reports and studies considered under this Water Master Plan 2022 Update include the following:

- *City of Norfolk, Nebraska, Water Facilities Master Plan Update*, Black & Veatch, April 2002
- *City of Norfolk, Nebraska, 2008 Water Master Plan Update*, Black & Veatch, September 2008
- *Norfolk, Nebraska, Comprehensive Plan Update 2017*, Olson Associates
- *Norfolk, Nebraska, Northeast Loop (Zone 4) Hydraulic Analyses Technical Memorandum*, Black & Veatch, January 19, 2019
- *City of Norfolk, NE, Task 452 – WTP Capacity Evaluation Technical Memorandum,* Black & Veatch, July 19, 2021
- *Technical Memorandum for the West Well Field Capacity Evaluation Monitoring Well Construction, and Initial Aquifer Interval Testing,* Layne, 2021.

1.5 ABREVIATIONS

AD	Average day
CIP	Capital improvement plan
Elev	Elevation
EPS	Extended period simulation
Ft	Feet
gpcd	Gallons per capita per day
gpm	Gallons per minute
GIS	Geographic Information System
HGL	Hydraulic grade line (hydraulic gradient)
Hp	Horsepower
MD	Maximum day
MD/AD	Maximum day to average day ratio
MG	Million gallons
mgd	Million gallons per day
MH	Maximum Hour
MH/AD	Maximum hour to average day ratio
MH/MD	Maximum hour to maximum day ratio
mi	Miles
PRV	Pressure reducing valve
psi	Pounds per square inch
SCADA	Supervisory control and data acquisition
U.S.	United States
WTP	Water treatment plant
%	Percent

2.0 Demographic and Demand Projections

The purpose of this section is to present the historical and future demographic and water demand projections that have been developed for Norfolk's 2020 Water Distribution System Master Plan (herein referred to as the "Master Plan"). Reliable future demand projections are required for the successful development of a Capital Improvements Plan (CIP), as well for general use by Norfolk in its day to day operations and strategic business decisions.

The following tasks were completed as part of the future demographic and demand projections.

- Obtain and review Norfolk's future demographic projections as contained in the Norfolk Comprehensive Plan 2017 Update (herein referred to as the "Comprehensive Plan") and developed by Norfolk staff for the 2019 Sanitary Sewer Master Plan Update.
- Obtain and review GIS based future land use and development areas.
- Review historical average day (AD), maximum day (MD), and maximum hour (MH) demands and MD/AD, and MH/AD demand factors.
- Obtain and evaluate MD operations (SCADA) data for the years 2018-2021. Select 24-hour MD demand and operating conditions for the INFOWATER model validation.
- Obtain and evaluate 2019, 2020, and 2021 residential, commercial, and industrial metered sales data. Allocate 2021 metered sales data to the updated INFOWATER model.
- Develop planning criteria, water use rates, demand factors, etc. for current and future conditions.
- Develop alternative short-term (10-year, 2030) and long-term (20-year, 2040) demographic and water demand projections (demand scenarios).
- Select a demand scenario to be used for the future hydraulic analyses and CIP development.

2.1 STUDY AREA

The future demographic and water demand projections study area for this investigation follow those contained in the Comprehensive Plan. The future demands study area is shown on Figure 1-1 (Section 1) and includes the area bounded by the Norfolk extraterritorial jurisdiction (ETJ) area.

For the Norfolk 2019 Sanitary Sewer Master Plan Update approximately 2,807 acres of available land were identified within the ETJ that may be developed in the future (Table 2-1). The Comprehensive Plan estimated that approximately 1,301 acres will need to be developed to support the increased 2040 population. Future land use areas/parcels were reviewed with the City to select growth areas that would yield the Comprehensive Plan total target acreages. [For the water master plan, 184 acres of rural residential land (listed in the Comprehensive Plan) was assumed to be developed as 61 acres of single family residential housing.]

Table 2-1 Future Growth Areas

GROWTH AREAS	2019 SANITARY SEWER MASTER PLAN UPDATE DEVELOPABLE AREAS (ACRES)	NORFOLK COMPREHENSIVE PLAN 2040 TARGET DEVELOPED AREAS (ACRES)	WATER MASTER PLAN FUTURE SERVICE AREAS (ACRES) (2)	
			2030	2040
Single Family Residential				
Blackberry	640	33.4	17.5	33.4
Wyndam Hills	44	43.8	22.9	43.8
Legacy Bend	92	92.5	40.7	77.7
East Side Residential	224	224.0	90.7	173.2
Northwest Residential			63.2	120.7
Rural Residential treated as Single Family Residential (1)	-	61.3	-	-
Subtotal	1,000	**455.0**	235.0	**448.8**
Multi-family Residential				
Channel Road	19	18.6	9.7	18.6
Nor-Park	23	23.3	12.2	23.3
Subtotal	42	**41.9**	21.9	**41.9**
Commercial/Public	462	**288.0**	149.4	**285.3**
Industrial	1,303	**377.3**	196.1	**374.4**
Parks/Recreation	-	**139.0**	72.8	**139.0**
Total	2,807	**1,301.2**	675.2	**1,289.3**

(1) Rural Residential (1 DU/Acre) required acreage (184 acres) converted to single family residential (3 DUs/Acre) required acreage (61.3 acres).
(2) Areas served identified on Figure 2-1, Study Area.

The City is currently in discussions with developers for several areas including Blackberry, Wyndham Hills, Legacy Bend, Channel Road, and Nor-Park, which are shown on Figure 2-1, as well as areas that were identified as likely for growth with no specific developer at this time (East Side and Northwest single family residential growth areas). There is existing development on the land assigned to Legacy Bend, Channel Road, and Nor-Park, but these areas are being redeveloped. Additional information on the projected development areas is included in Table 2-1.

2.2 HISTORICAL AND PROJECTED POPULATION

This section provides evaluation of the City's historical population and population projections for 2040.

2.2.1 Historical Population

U.S. Census Bureau census counts and estimates are shown on Figure 2-1. The most recent census count indicates that the Norfolk population in 2020 was 24,955 persons. The annual population growth rate between 2010 (population 24,210) and 2020 was 0.30%. The annual population growth rated during the second half of the last decade (2016-2020) was 0.62%.

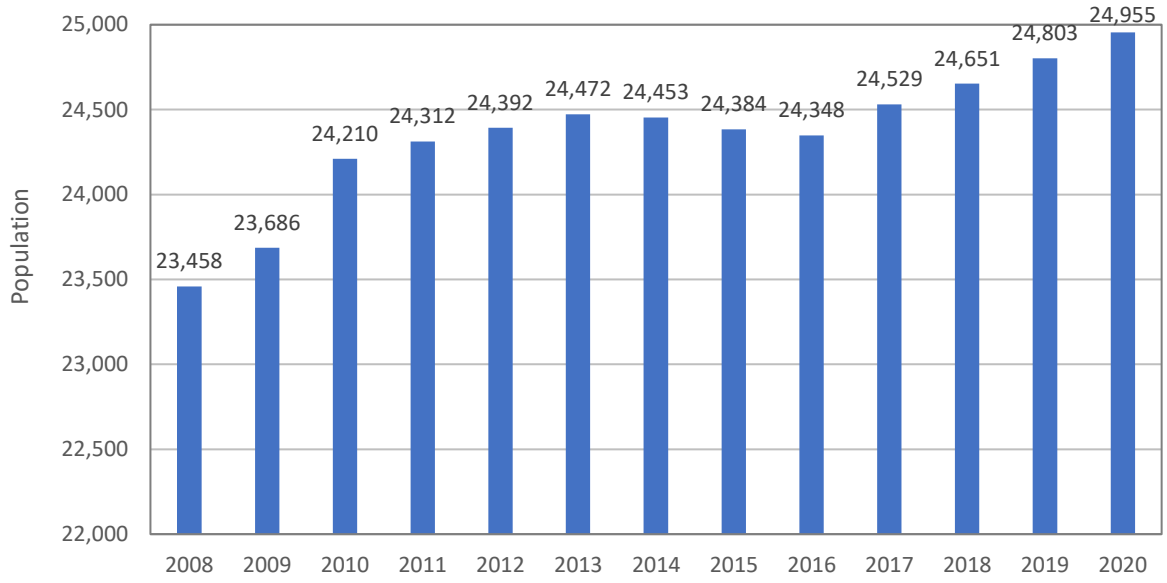


Figure 2-1 Historical Population – U.S. Census Counts and Estimates

2.2.2 Population Projections

Population projections included in this study are based on the projections included in the Comprehensive Plan. Various methods were used in the Comprehensive Plan to project population growth through 2040. The Linear population growth method was selected in the Comprehensive Plan as the preferred projection methodology and yielded a 2040 population of 28,193. This represents a population increase of 3,238 persons above the 2020 population of 24,955 and an annual population growth rate of 0.61% (2020 to 2040). The Comprehensive Plan annual population growth rate for the period 2020 to 2040 (0.61%) is approximately equal to the 2016-2020 annual growth rate of 0.62%.

In October 2021 Norfolk annexed approximately 11,766 acres. The annexed area added approximately 910 persons to the City's population.

2.3 1990-2021 HISTORICAL WATER USE AND PRECIPITATION

Historical water use for the 32-year period 1990-2021 is presented below. Special attention is given to water use characteristics for the 21-year period 2001-2021 and more recent 11-year period 2011-2021 for developing and selecting water use characteristics (design criteria) to be used in the development of the future 2030 and 2040 demand projections.

2.3.1 1990 2021 Historical Water Use

Historical water demands and population were evaluated to determine trends in water use characteristics in the Norfolk water system. Historical water use, population, and annual average per capita water use rates are given in Table 2-2. Historical AD, MD, and MH water use is shown on Figure 2-2. Historical MD/AD, MH/AD, and MH/MD demand factors are shown on Figure 2-3. Historical population and average day gross per capita water use rates (average day water demand divided by population) are shown on Figure 2-4.

The following observations are noted from information presented in Table 2-2and Figures 2-3 through and 2-5:

- The mean AD, MD, and MH demands for the 21-year period **2001-2021** were **4.4, 8.8, and 14.4 mgd**, respectively.
- The mean AD, MD, and MH demands for the 11-year period **2011-2021** were **4.3, 8.7, and 15.2 mgd**, respectively.
- The mean AD, MD, and MH demands for the most recent 2 years, **2020 and 2021**, were **4.6, 9.5, and 16.7**, respectively.
- The mean average day gross water use rate for the 11-year period **2011-2021** was **174** gallons per capita per day (gpcd). The mean average day for the most recent 2 years, **2020-2021**, was **183** gpcd.
- The mean MD/AD demand factor for the 11-year period **2011-2021** was **2.02**. The mean MD/AD demand factor for the most recent 2 years, **2020-2021**, was **2.08**.
- The mean MH/AD demand factors for the 11-year period **2011-2021** was **3.56**. The mean MH/AD demand factor for the most recent 2 years, **2020-2021**, was **3.65**.

Table 2-2 Historical Water Demands and Service Population

YEAR	DEMAND (MGD)							POPULATION (1)	AVE DAY GROSS PER CAPITA USE RATE (GPCD)	DEMAND FACTORS		
	Average Day	Maximum Day	Maximum Hour	Zone 1 Maximum Hour	Zone 2 Maximum Hour	Fall Day	Winter Day			MD/AD	MH/AD	MH/MD
1990	3.87	8.74						21,476	180	2.26		
1991	3.96	9.20						21,567	184	2.32		
1992	3.36	6.16						21,864	154	1.83		
1993	3.54	5.94						22,146	160	1.68		
1994	3.97	7.64						22,494	176	1.92		
1995	4.18	9.09						22,922	182	2.17		
1996	4.06	7.03						23,224	175	1.73		
1997	4.42	8.31						23,445	189	1.88		
1998	3.89	7.24						23,360	167	1.86		
1999	4.30	8.53						23,164	186	1.98		
2000	4.79	8.86						23,516	204	1.85		
2001	4.74	9.38	11.73					24,001	197	1.98	2.47	1.25
2002	5.25	10.95	14.73					24,255	216	2.09	2.81	1.35
2003	5.25	9.23	13.05					24,300	216	1.76	2.49	1.41
2004	4.90	8.84	12.55					24,261	202	1.80	2.56	1.42
2005	5.02	9.44	13.53					24,255	207	1.88	2.70	1.43
2006	4.47	9.57	14.40					24,150	185	2.14	3.22	1.50
2007	4.14	8.74	14.67					23,417	177	2.11	3.54	1.68
2008	4.11	9.35	14.18	9.00	6.39	3.04	3.38	23,458	175	2.27	3.45	1.52
2009	4.03	7.98	13.81	8.87	5.97	2.92	3.30	23,686	170	1.98	3.43	1.73
2010	4.00	6.70	11.74	6.82	6.08	3.44	2.91	24,210	165	1.67	2.93	1.75
2011	4.03	8.25	17.18	11.98	6.05	3.17	3.36	24,312	166	2.05	4.26	2.08
2012	5.12	10.28	17.54	13.90	6.74	3.72	3.82	24,392	210	2.01	3.43	1.71
2013	4.56	9.14	16.06	10.49	6.23	3.83	2.71	24,472	186	2.00	3.52	1.76
2014	4.17	7.56	12.28	9.63	6.36	3.63	3.11	24,453	171	1.81	2.94	1.62
2015	3.87	7.36	12.53	8.00	5.41	3.17	3.32	24,384	159	1.90	3.24	1.70
2016	4.01	7.79	13.23	8.71	6.51	3.18	3.03	24,348	165	1.94	3.30	1.70
2017	4.17	9.00	15.70	9.75	6.75	2.85	3.10	24,529	170	2.16	3.77	1.75
2018	4.16	8.68	14.69	9.49	6.39	3.41	3.23	24,651	169	2.08	3.53	1.69
2019	3.82	8.05	15.03	9.45	5.59	3.67	2.92	24,803	154	2.11	3.93	1.87
2020	4.63	9.39	16.69	9.96	6.81	4.31	3.04	24,955	185	2.03	3.61	1.78
2021	4.52	9.63	16.66	10.75	6.26	-	-	25,117	180	2.13	3.69	1.73
2030 (Projected) (2)	**5.80**	**11.72**	**20.68**					**26,574**	**218**	**2.02**	**3.56**	**1.76**
2040 (Projected) (2)	**6.78**	**13.70**	**24.17**					**28,193**	**241**	**2.02**	**3.56**	**1.76**
2001-2021 Average	4.43	8.82	14.38	9.77	6.25	3.41	3.17		182	2.00	3.28	1.64
2011-2021 Average	4.28	8.65	15.24	10.19	6.28	3.49	3.16		174	2.02	3.56	1.76
2020-2021 Average	4.57	9.51	16.68	10.36	6.53	4.31	3.04		183	2.08	3.65	1.75
Population Annual Growth Rate												
2010-2020								0.30%				
2016-2020								0.62%				
2020-2040								0.61%				

(1) 1990, 2000, 2010, 2020 population from U.S. Census counts. All other population data from U.S. Census estimates.
(2) 2030 and 2040 projected demands based on Demand Scenario 2.

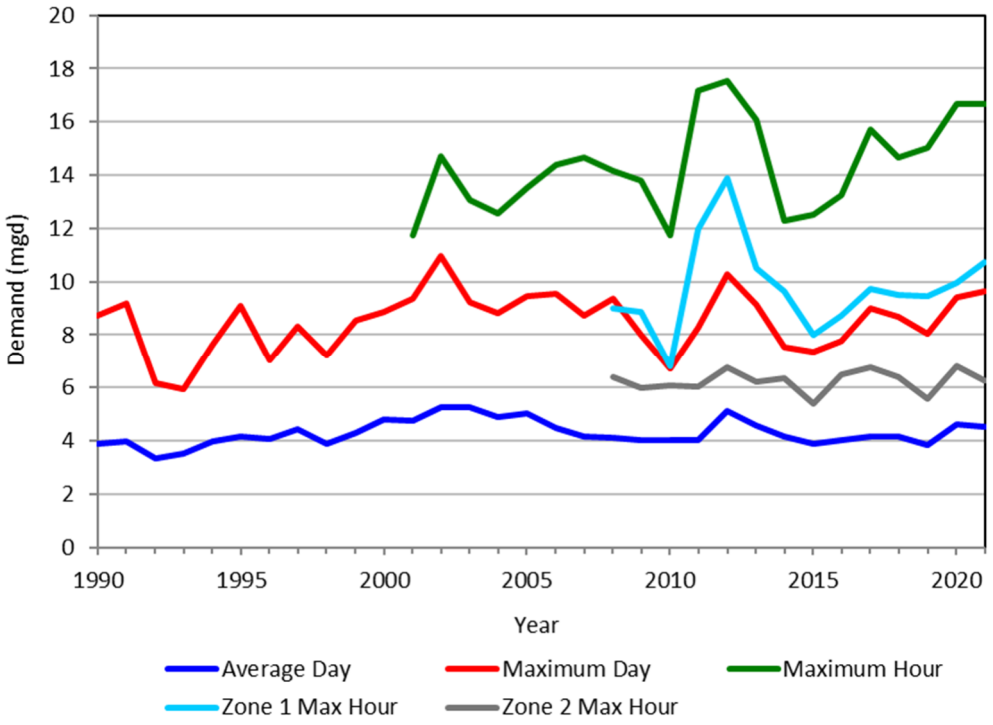


Figure 2-2 1990-2021 Historical Water Use

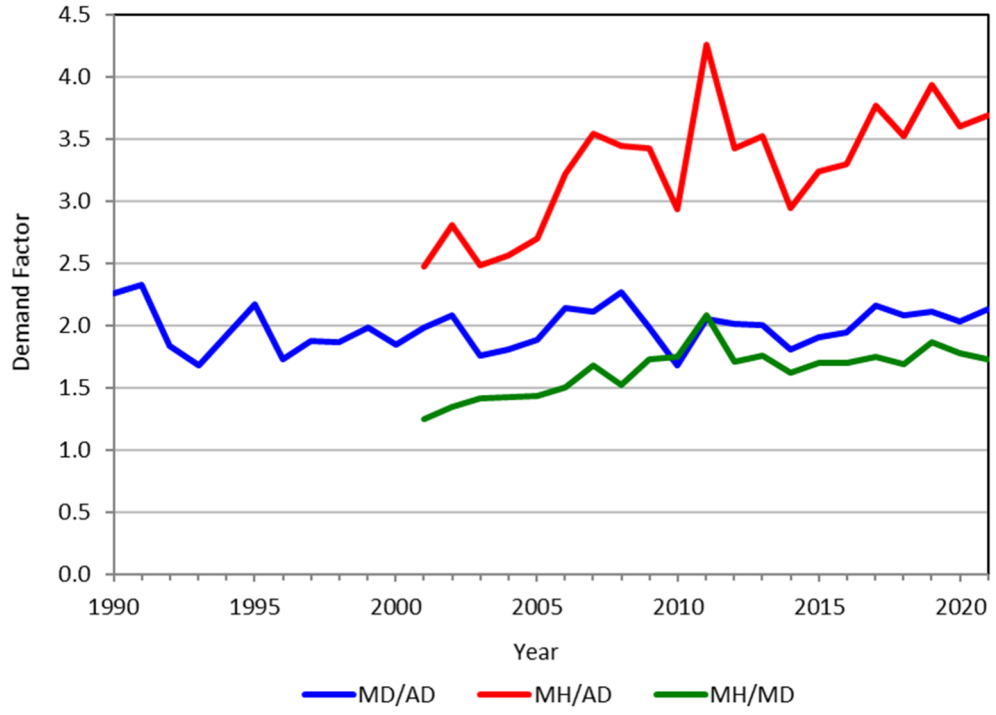


Figure 2-3 1990-2021 Historical MD/AD, MH/AD, and MH/MD Demand Factors

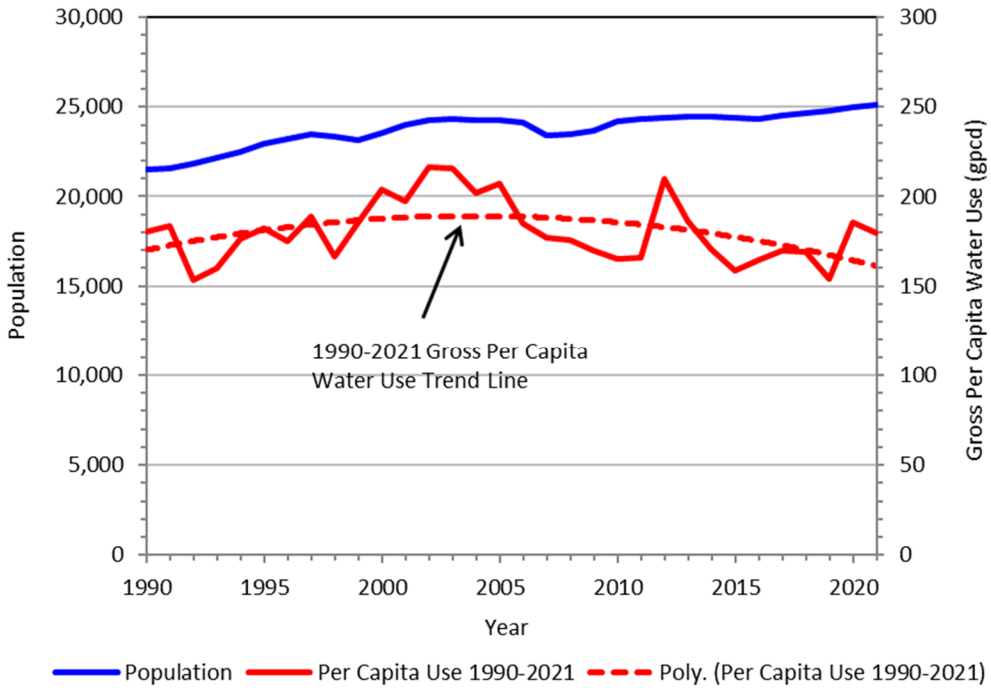


Figure 2-4 1990-2021 Historical Population and Average Day Gross Per Capita Water Use Rates

Summary of Major Historical Water Use Findings. Average day demands have declined slightly from their peak during the mid-2000's (Figure 2-2). This, combined with a steadily increasing Norfolk service population, has resulted in average day gross per capita water use rates declining beginning in the mid-2000's (Figure 2-4). The medium-term (2030) and long-term (2040) demand projections include significant increases in industrial demands that will raise gross per capita water use rates to 218 and 241 gallons per capita per day (gpcd), respectively.

The decline in gross per capita water use is in part the result of the Energy Policy and Conservation Act of 1992 (effective 1994) and the Energy Independence and Security Act of 2007, which set water use standards for faucets, toilets, and water use appliances. The City's general conservation efforts are also impacting gross per capita water use. The trend towards declining per capita water use experienced by Norfolk is consistent with water use trends experienced by other utilities across the nation.

MD/AD demand factors have remained stable during the period 2001-2021. MH/AD demand factors have shown a small increase within the last decade.

The Norfolk water use characteristics discussed above are considered and used in the future demand scenarios presented later herein.

2.3.2 2019-2021 Precipitation and Water Use

Norfolk monthly precipitation of year 2019-2021 is given in Table 2-3 and shown on Figure 2-5.

Table 2-3 Norfolk 2019-2021 Monthly Precipitation

MONTH	PRECIPITATION (IN)			
	Year			
	2019	2020	2021	Normal
Jan	0.16	0.99	0.74	0.59
Feb	1.04	0.15	0.57	0.76
Mar	2.98	3.01	5.64	1.77
Apr	2.26	0.21	1.66	2.65
May	4.92	4.60	2.33	4.00
June	2.57	0.65	3.40	4.37
July	2.82	2.52	3.10	2.98
Aug	3.77	1.94	3.75	3.50
Sept	1.51	1.61	1.78	2.37
Oct	1.93	0.56	2.03	2.15
Nov	2.02	1.96	0.16	1.22
Dec	1.10	0.50	0.50	0.84
Total	**27.08**	**18.70**	**25.66**	**27.20**

Source: NOAA/National Weather Service

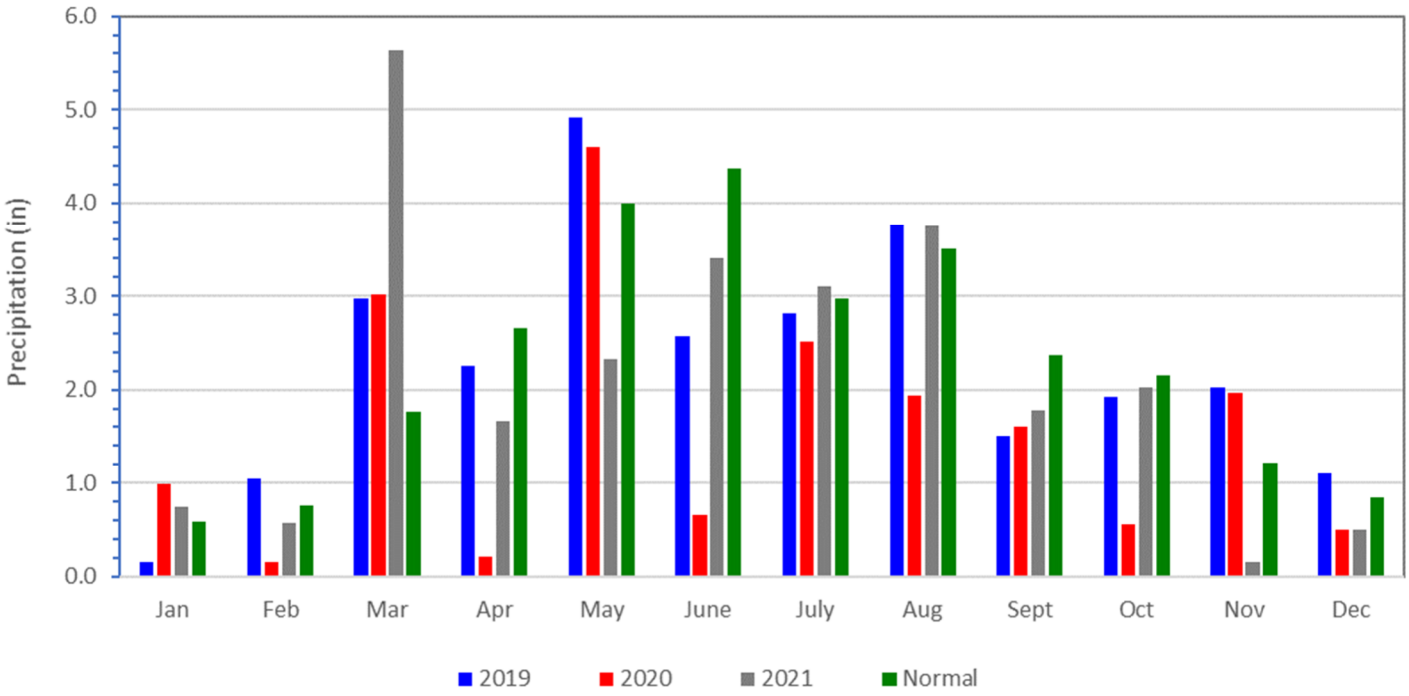


Figure 2-5 Norfolk 2019-2021 Monthly Precipitation

Norfolk annual precipitation in years 2019 and 2021, 27.1 and 25.7 inches, respectively, were close to the normal annual precipitation of 27.2 inches. Year 2020 was a "dry" year with only 18.7 inches of precipitation. Year 2021 precipitation during the summer months (June, July, August) was fairly close to the normal precipitation experienced during these months.

2.4 2019 METERED SALES

Individual customer 2019 bi-monthly metered sales data was obtained for 7,583 residential, 1,324 commercial, and 4 industrial customers (8,911 total customers). Individual customer/meter locations were identified in GIS and customers assigned to Norfolk's three existing pressure zones. Year 2019 bi-monthly residential, commercial, and industrial metered sales data is summarized in Table 2-4.

Total annual metered sales data for years 2020 and 2021 was obtained and combined with the 2019 bi-monthly metered sales data to compare annual metered sales for the 3-year period 2019-2021 (Table 2-5). Residential, commercial, and industrial annual metered sales as a percentage of total annual sales is shown on Figure 2-6.

Table 2-4 2019 Bi-monthly Metered Sales by User Class and Non-revenue Water

MONTH/ PRESSURE ZONE	METERED SALES (MGD)			
	Residen-tial (1)	Commer-cial (1)	Indust-rial (1)	Total
Metered Sales by Month				
Jan - Feb	0.907	0.654	0.756	2.316
Mar - Apr	1.056	0.940	0.727	2.722
May - June	1.422	0.963	0.743	3.128
July - Aug	2.573	1.399	0.759	4.731
Sept - Oct	2.285	1.761	0.695	4.740
Nov - Dec	1.161	1.075	0.638	2.873
Total/Average	1.574	1.135	0.719	3.428
Percent of Total (%)	45.9%	33.1%	21.0%	100.0%
Annual Sales by Zone (mgd)				
Zone 1 (mgd)	0.896	1.040	0.719	2.656
Zone 2 (mgd)	0.637	0.083	0.000	0.720
Zone 4 (mgd)	0.000	0.001	0.000	0.001
Zones 1-4 Total (mgd)	1.534	1.124	0.719	3.378
Annual Sales by Zone (% of Total)				
Zone 1 (%)	58.4%	92.5%	100.0%	78.6%
Zone 2 (%)	41.6%	7.4%	0.0%	21.3%
Zone 4 (%)	0.0%	0.1%	0.0%	0.0%
Zones 1-4 Total (%)	100.0%	100.0%	100.0%	100.0%
Finished Water Production				3.822
Non-revenue Water (mgd)				0.394
Non-revenue Water (%)				10.30%
Meter Location NOT Found (mgd)	0.040	0.011	0.000	0.051
Meter Location NOT Found (%)	2.53%	0.95%	0.00%	1.47%
(1) 7,583 Residential, 1,324 Commercial, 4 Industrial (8,911 Total) Customers				

Table 2-5 2019-2021 Annual Metered Sales by User Class and Non-revenue Water

DESCRIPTION/ YEAR	METERED SALES (MGD)				PERCENT OF ANNUAL TOTAL (%)			
	Residen-tial	Commer-cial	Indust-rial	Total (mgd) (1)	Residen-tial	Commer-cial	Indust-rial	Total (1)
Metered Sales (mgd)								
2019	1.57	1.14	0.72	3.43	45.9%	33.1%	21.0%	100.0%
2020	2.17	1.25	0.67	4.08	53.1%	30.5%	16.3%	100.0%
2021	2.02	1.27	0.68	3.96	50.9%	32.0%	17.1%	100.0%
2019-2021 Average	1.92	1.22	0.69	3.82	50.0%	31.9%	18.1%	100.0%
Finished Water Production (mgd)								
2019				3.82				
2020				4.63				
2021				4.52				
2019-2021 Average				4.32				
Non-revenue Water (mgd)								
2019				0.39				
2020				0.55				
2021				0.55				
2019-2021 Average				0.50				
Non-revenue Water (%)								
2019				10.3%				
2020				11.9%				
2021				12.3%				
2019-2021 Average				11.5%				
(1) 2019 Sales excluding "Deduct" Meters								

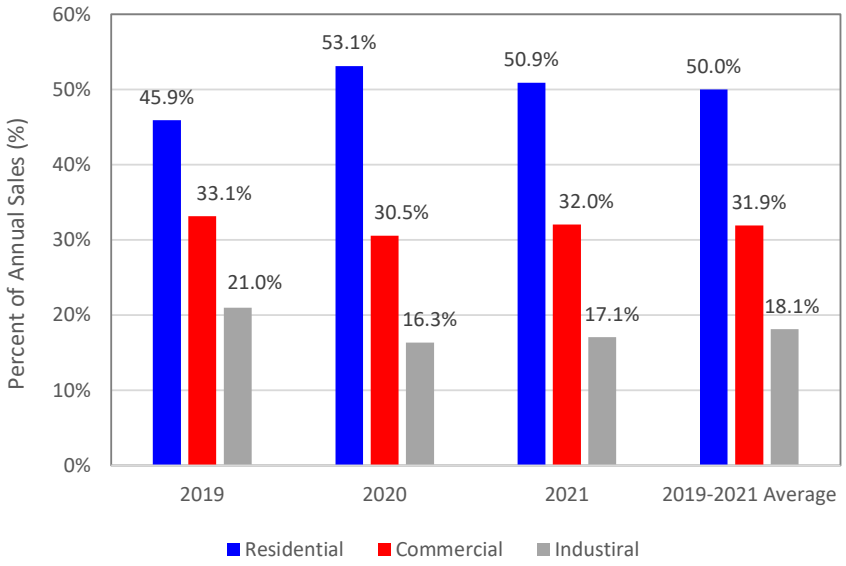


Figure 2-6 2019-2021 Metered Sales by Customer Class as Percentage of Total Sales (Annual)

Major findings of the 2019 metered sales data evaluation are given below:

- Annual metered sales in 2020 and 2021, **4.08 mgd** and **3.96 mgd**, respectively, was higher than annual metered sales in 2019 (**3.43 mgd**). Similarly, annual water treatment plant (WTP) production in 2020 and 2021, **4.63, 4.52 mgd**, respectively, was higher than WTP production in 2019 (**3.82 mgd**).
- It is noted that residential sales increase from **45.9%** of total sales in 2019 to **53.1%** of total sales in 2020. Commercial sales decrease from **33.1%** of total sales in 2019 to **30.5%** in 2020. This may be a result of the 2020 COVID pandemic with many office employees shifting to work at home status. There is somewhat of a recovery/return to the 2019 residential and commercial sales split (percent of total annual sales basis) in 2021.
- Industrial sales remain relatively constant during the period 2019-2021.
- For the 3-year period 2019-2021, residential, commercial, and industrial sales account for **50.0%, 31.9%, and 18.1%** of total annual sales, respectively.
- For year 2019, Zones 1, 2, and 4 account for **78.6%, 21.3%, and less than 0.1%** of total annual sales.
- For year 2019, Zone 1 accounts for **58.4%, 92.5%, and 100.0%** of residential, commercial, and industrial sales.
- For year 2019, Zone 2 accounts for **41.6%, 7.4%, and 0.0%** of residential, commercial, and industrial sales.
- Non-revenue water (the difference between water delivered to the distribution system and metered sales) averaged **0.50 mgd** (**11.5%** of WTP production) for the 3-year period 2019-2021.

2.4.1 Non-revenue (Unaccounted-for) Water

Non-revenue water ranged from **0.39-0.55 mgd**, **9.8%-12.3%** of WTP production, for the 3-year period 2019-2021. Average non-revenue water for the 3-year period was **11.5%** of WTP production.

The Norfolk 2002 Master Plan included a non-revenue (unaccounted-for) water use estimate equal to **11.1%**. The 2002 Master Plan metered sales evaluation was based on meter routes and did not exclude deduct meters. This may have caused "double counting" of flows through the deduct meters and a minor underestimate of non-revenue water.

Overall, the average 2019-2021 non-revenue water estimate of **11.5%** is close to the 2002 Master Plan non-revenue water estimate (**11.1%**) and indicates non-revenue water has not increased within the Norfolk water system during the past two decades and remains at a low/acceptable rate.

2.5 MAXIMUM DAY HOURLY DEMANDS AND DEMAND FACTORS FOR MODEL VALIDATION AND FUTURE HYDRAULIC ANALYSES

Maximum day (MD) hourly SCADA data was obtained for 2017-2019 and 2021 to determine hourly Zones 1 and 2 and system total demands and demand factors. Following review of the 2017-2021 MD demands and discussions with the City, **July 27, 2021** was selected to develop hourly demands, demand factors (hourly demand divided by average day demand), and operating conditions for validation of the updated Norfolk hydraulic model based on the following considerations.

- Year 2021 represents the most current demand and operating conditions.
- Year 2021 average day AD, MD, and MH demands are approximately equal to the most recent 3-year period, 2019-2021, mean AD, MD, and MH demands.
- Year 2021 demands (metered sales) and operating conditions include service to Zone 4 customers (Regional Center, Norfolk Iron & Metal, Nucor Steel).

July 27, 2021 MD hourly demands and demand factors are given in Table 2-6 and shown on Figures 2-7 and 2-8. The updated hydraulic model will be validated using a 24-hour Extended Period Simulation (EPS) analysis for the July 27, 2021 MD demand and operating conditions.

Table 2-6 July 27, 2021 Maximum Day Hourly Demands and Demand Factors

HOUR	DEMAND (MGD)			DEMAND FACTORS (1)		
	Zone 1	Zone 2	Total	Zone 1	Zone 2	Total
0	5.18	2.62	7.81	1.49	2.45	1.71
1	5.74	2.63	8.37	1.65	2.46	1.84
2	6.94	2.35	9.29	1.99	2.20	2.04
3	8.32	2.90	11.22	2.38	2.72	2.46
4	9.63	2.81	12.44	2.76	2.62	2.73
5	9.85	4.82	14.68	2.82	4.51	3.22
6	9.98	5.39	15.37	2.86	5.04	3.37
7	9.12	5.30	14.42	2.61	4.96	3.16
8	9.36	3.67	13.04	2.68	3.44	2.86
9	7.85	3.76	11.61	2.25	3.52	2.55
10	7.41	2.81	10.22	2.12	2.62	2.24
11	6.93	2.33	9.26	1.99	2.18	2.03
12	6.31	2.42	8.73	1.81	2.26	1.92
13	6.10	1.66	7.76	1.75	1.55	1.70
14	6.04	1.47	7.51	1.73	1.37	1.65
15	6.37	0.58	6.94	1.82	0.54	1.52
16	5.48	1.34	6.83	1.57	1.26	1.50
17	5.73	1.34	7.07	1.64	1.26	1.55
18	5.91	1.73	7.64	1.69	1.62	1.68
19	6.54	1.92	8.46	1.87	1.80	1.86
20	6.70	2.94	9.64	1.92	2.75	2.11
21	6.64	3.00	9.64	1.90	2.80	2.12
22	6.68	3.23	9.91	1.91	3.02	2.17
23	5.91	2.62	8.53	1.69	2.45	1.87
Average	7.11	2.73	9.85	2.04	2.56	2.16

(1) Hourly demands divided by hydraulic model average day demands.

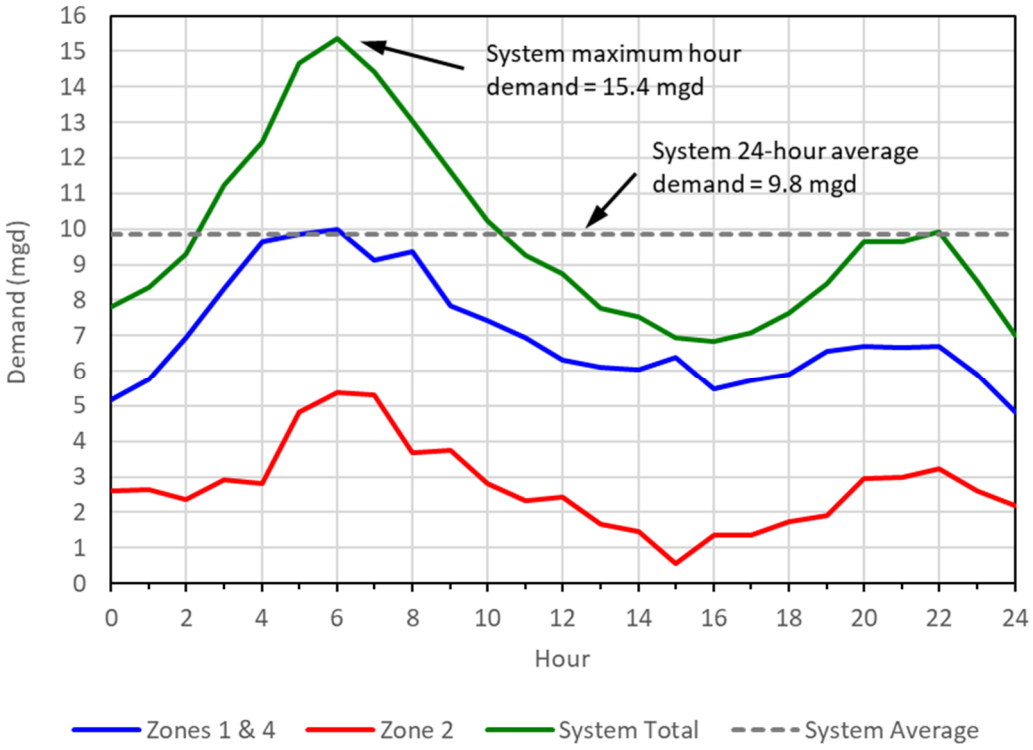


Figure 2-7 July 27, 2021 Maximum Day Hourly Demands

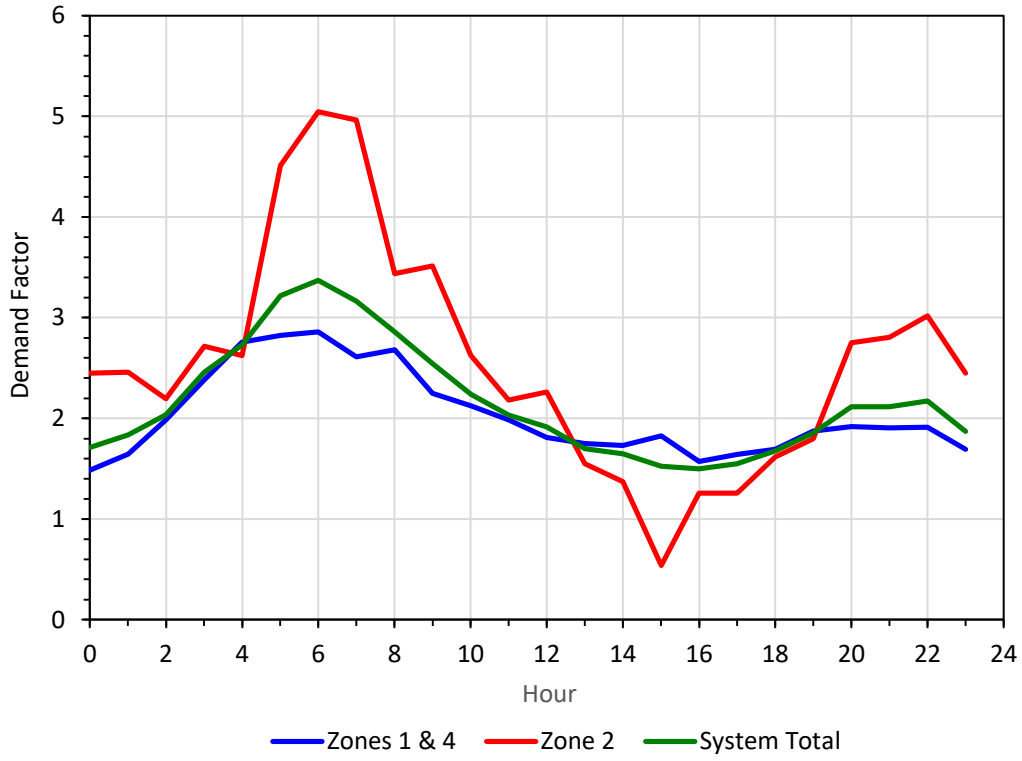


Figure 2-8 July 27, 2021 Maximum Day Hourly Demand Factors

It is noted that here are minor differences between the July 27, 2021 MD (**9.8 mgd**) and MH (**15.4 mgd**) demands shown on Figure 2-8 and those given in Table 2-2 (MD and MH demands **9.6** and **16.7 mgd**, respectively). The difference is attributable to the City's daily SCADA reports being based on a 24-hour **8 a.m. to 8 a.m.** operating period. The hourly SCADA needed to be converted to a 24-hour **12 a.m. to 12 a.m.** period for use in the hydraulic model.

2.6 FUTURE (2030/2040) DEMAND PROJECTIONS

The long-term 2040 demand projections are based on 1,289 acres of new residential, commercial/public, and industrial development to support a population increase of 3,381 persons (2040 population of 28,193) as forecast in the Comprehensive Plan. Additionally, the future demand projections include service to 1,800 persons in the Woodland Park subdivision, bringing the 2040 service population to approximately 30,000 persons.

Alternative future planning criteria, including water use rates, unaccounted-for water, and MD/AD and MH/AD demand factors were used to develop alternative "demand scenarios".

Four (4) demand scenarios were developed and the computed 2040 AD, MD, and MH demands and gross water use rates are summarized in Table 2-7, shown on Figure 2-9, and discussed below. Historical and future population and gross water use rates (average day demand divided by population) are shown on Figure 2-10. Detailed summary tables for the four demand scenarios for 2040 and 2030, including planning criteria, are included in Appendix A (Tables A-1 and A-2, respectively).

Demand Scenario 1 (Existing Conditions Extended to 2040). Demand Scenario 1 replicates current population densities, water use rates (water usage per acre) within the future 1,289 developed acres, 2019 metered sales, and 2019 MD/AD and MH/AD demand factors.

A number of computations were performed to support development of Demand Scenario 1. Residential land use was determined to equal 2,743 acres within the current City Limits. This area combined with a 2019 population of 24,812 yields an overall residential population density of approximately 9.0 persons per acre. The 2010 U.S. Census indicated Norfolk had approximately 2.31 persons per household (dwelling unit). These figures yield a residential density of about **3.9 dwelling units (DU) per acre**. A residential density of 3.9 DUs per acre would generally be categorized between "Suburban Residential" (1-3 DUs per acre) and "Urban Residential" (4-7 DUs per acre).

Similarly, existing commercial and industrial areas within the City Limits were determined to be 1,337 and 228 acres, respectively. Dividing 2019 annual metered sales by the above acreages yields commercial and industrial water use (sales) per acre rates of **849 and 3,148 gallons per day (gpd)/acre**.

Demand Scenario 1 (and all other Demand Scenarios) incorporated non-revenue-water equal to **10.3%** of WTP production (equal to the non-revenue water percentage for year 2019).

Demand Scenario 1 incorporates MD/AD and MH/AD demand factors of **2.11 and 3.93**, respectively (equal to the 2019 MD/AD and MH/AD values).

Demand Scenario 1 yields 2040 AD, MD, and MH demands of **6.1, 12.8, and 23.9 mgd**, respectively.

Table 2-7 2040 Demand Projections (Demand Scenarios 1-4)

EXISTING & FUTURE GROWTH AREAS/ CUSTOMER CLASSES	DEMAND SCENARIO 1					DEMAND SCENARIO 2					DEMAND SCENARIO 3					DEMAND SCENARIO 4				
	2040 Demand (mgd)			Average Day Demand % of Total	Gross Water Use Rate (gpcd)	2040 Demand (mgd)			Average Day Demand % of Total	Gross Water Use Rate (gpcd)	2040 Demand (mgd)			Average Day Demand % of Total	Gross Water Use Rate (gpcd)	2040 Demand (mgd)			Average Day Demand % of Total	Gross Water Use Rate (gpcd)
	Aver-age Day	Maxi-mum Day	Maxi-mum Hour			Aver-age Day	Maxi-mum Day	Maxi-mum Hour			Aver-age Day	Maxi-mum Day	Maxi-mum Hour			Aver-age Day	Maxi-mum Day	Maxi-mum Hour		
1. Existing Zones 1 & 2 (2019/2021 Sales)																				
Residential	1.75	3.70	6.90	28.9%		2.33	4.70	8.30	34.3%		2.33	4.89	8.30	34.3%		2.32	4.70	8.30	37.8%	
Commercial	1.27	2.67	4.98	20.8%		1.37	2.76	4.87	20.2%		1.37	2.87	4.87	20.2%		1.37	2.76	4.87	22.2%	
Industrial	0.80	1.69	3.15	13.2%		0.77	1.57	2.76	11.4%		0.77	1.63	2.76	11.4%		0.77	1.57	2.76	12.6%	
Subtotal	**3.82**	**8.05**	**15.03**	**62.9%**	**154**	**4.47**	**9.03**	**15.93**	**65.9%**	**180**	**4.47**	**9.39**	**15.93**	**65.9%**	**180**	**4.47**	**9.03**	**15.93**	**72.6%**	**180**
2. Zone 4 Customers (2021 Sales)																				
Norfolk Iron & Metal	0.004	0.008	0.015	0.1%		0.004	0.008	0.014	0.1%		0.004	0.008	0.014	0.1%		0.004	0.008	0.014	0.1%	
Nucor Steel (Potable)	0.070	0.147	0.275	1.2%		0.070	0.141	0.249	1.0%		0.070	0.147	0.249	1.0%		0.070	0.141	0.249	1.1%	
Regional Center	0.017	0.035	0.065	0.3%		0.017	0.033	0.059	0.2%		0.017	0.035	0.059	0.2%		0.017	0.033	0.059	0.3%	
Subtotal	**0.090**	**0.191**	**0.355**	**1.5%**	**-**	**0.090**	**0.183**	**0.321**	**1.3%**	**-**	**0.090**	**0.190**	**0.322**	**1.3%**		**0.090**	**0.183**	**0.322**	**1.5%**	**-**
Existing Zones 1, 2, 4	**3.91**	**8.24**	**15.39**	**64.4%**		**4.56**	**9.21**	**16.26**	**67.2%**		**4.56**	**9.58**	**16.26**	**67.2%**		**4.56**	**9.21**	**16.26**	**74.1%**	
3. Future Growth Areas																				
Blackberry	0.02	0.05	0.08	0.4%		0.03	0.06	0.10	0.4%		0.03	0.06	0.10	0.4%		0.03	0.06	0.10	0.5%	
Channel Road	0.01	0.03	0.05	0.2%		0.02	0.03	0.06	0.2%		0.02	0.03	0.06	0.2%		0.02	0.03	0.06	0.3%	
Commercial/Public	0.27	0.57	1.06	4.4%		0.29	0.59	1.04	4.3%		0.29	0.61	1.04	4.3%		0.29	0.59	1.04	4.7%	
East Side Residential	0.11	0.23	0.44	1.8%		0.15	0.30	0.52	2.2%		0.15	0.31	0.52	2.2%		0.15	0.30	0.52	2.4%	
Industrial	1.31	2.77	5.17	21.6%		1.25	2.53	4.46	18.5%		1.25	2.63	4.46	18.5%		0.63	1.27	2.23	10.2%	
Legacy Bend	0.05	0.10	0.20	0.8%		0.07	0.13	0.23	1.0%		0.07	0.14	0.23	1.0%		0.07	0.13	0.23	1.1%	
Northwest Residential	0.08	0.16	0.30	1.3%		0.10	0.21	0.37	1.5%		0.10	0.22	0.37	1.5%		0.10	0.21	0.37	1.7%	
Nor-Park	0.01	0.03	0.06	0.2%		0.02	0.04	0.07	0.3%		0.02	0.04	0.07	0.3%		0.02	0.04	0.07	0.3%	
Parks/Recreation	0.10	0.21	0.40	1.7%		0.10	0.20	0.36	1.5%		0.10	0.21	0.36	1.5%		0.10	0.20	0.36	1.6%	
Wyndam Hills	0.03	0.06	0.11	0.5%		0.04	0.08	0.13	0.5%		0.04	0.08	0.13	0.5%		0.04	0.08	0.13	0.6%	
Subtotal	**2.00**	**4.21**	**7.86**	**32.9%**	**451**	**2.06**	**4.16**	**7.35**	**30.4%**	**611**	**2.06**	**4.33**	**7.35**	**30.4%**	**611**	**1.43**	**2.90**	**5.11**	**23.3%**	**425**
4. Woodland Park	**0.16**	**0.34**	**0.63**	**2.6%**		**0.16**	**0.32**	**0.57**	**2.4%**		**0.16**	**0.34**	**0.57**	**2.4%**		**0.16**	**0.32**	**0.57**	**2.6%**	
TOTAL	**6.07**	**12.79**	**23.88**	**100.0%**	**196**	**6.78**	**13.70**	**24.17**	**100.0%**	**226**	**6.78**	**14.24**	**24.17**	**100.0%**	**226**	**6.15**	**12.44**	**21.94**	**100.0%**	**205**

Demand Scenario 1: Historical water use rates and residential densities per acre; 2019 demand factors, MD/AD = 2.11, MH/AD = 3.93
Demand Scenario 2: Target 2040 population increase of 3,381 persons; 2021 metered sales, 3,000 gpd/acre Industrial use rate; MD/AD = 2.02, MH/AD = 3.56
Demand Scenario 3: Same as Demand Scenario 2 except MD/AD = 2.08
Demand Scenario 4: Same as Demand Scenario 2 except Industrial water use rate = 1,500 gpd/acre

(Blank Page)

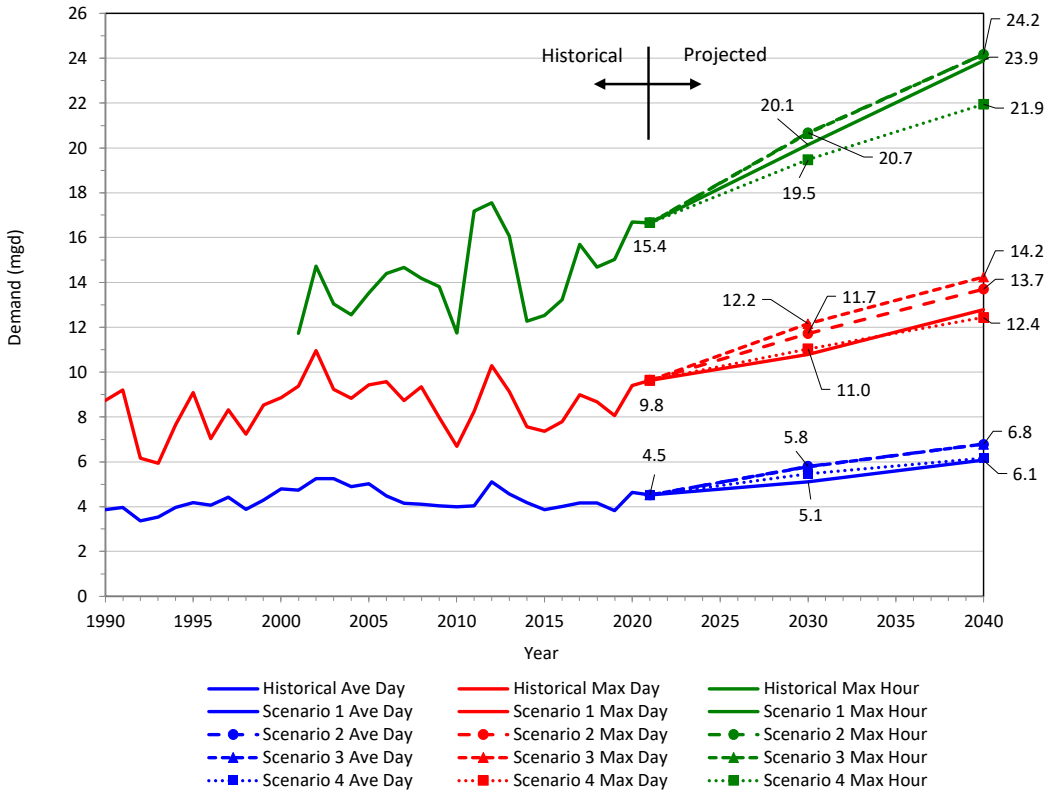


Figure 2-9 Historical and Future Demands (Demand Scenarios)

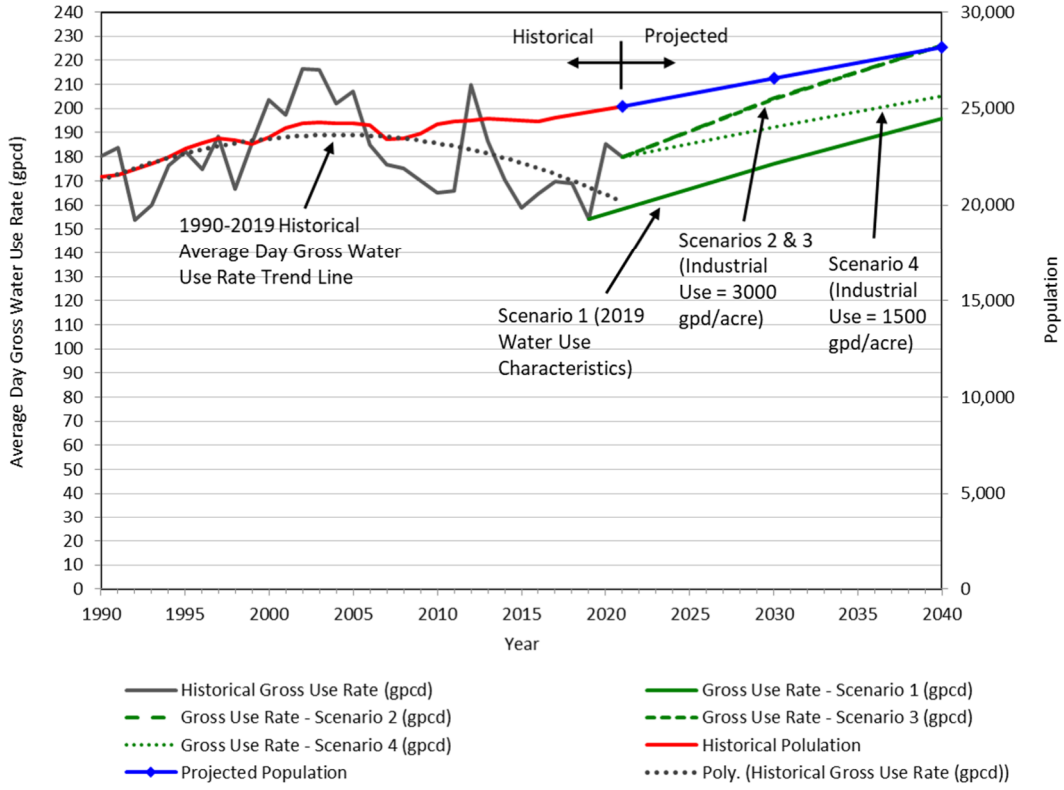


Figure 2-10, Historical and Projected Population and Gross Water Use Rates

It is noted that the Demand Scenario 1 residential dwelling units per acre (3.9 DUs per acre) combined with a 2040 residential acreage increase of 491 acres and 2.31 persons per dwelling unit yields a 2040 population increase of approximately **4,434 persons**, which exceeds the 2040 target population increase of **3,390**.

Demand Scenario 2 (Hit 2040 Target Population Increase, 3,000 gpd/acre Industrial Water Use Rate, 2011-2021 Average MD/AD and MH/AD Demand Factors).

Under Demand Scenario 2 the future residential density was reduced to **3.0 DUs per acre** (from 3.9). This places future residential development in the Suburban Residential category (1-3 DUs per acre). A future residential density of 3.0 DUs per acre yields a 2040 population increase of **3,377** persons, very close to the 2040 target population increase of **3,390** persons.

Demand Scenario 2 also includes a slightly lower industrial water use rate of **3,000 gpd/acre** (versus 3,148 gpd/acre; Demand Scenario 1). [An industrial water use rate of 3,000 gpd/acre was used in the 2008 Water Master Plan.] Demand Scenario 2 includes MD/AD and MH/AD demand factor of **2.02 and 3.56**, respectively, equal to the most recent 11-year, 2011-2021, average MD/AD and MH/AD demand factors.

Demand Scenario 2 yields 2040 AD, MD, and MH demands of **6.8, 13.7, and 24.2 mgd**, respectively.

Demand Scenario 3 (MD/AD Demand Factor equal to 2.10). Demand Scenario 3 is the same as Demand Scenario 2 except the MD/AD demand factor is increased to 2.10, approximately equal to the average MD/AD demand factor for the most current two years, 2020-2021.

Demand Scenario 3 yields 2040 AD, MD, and MH demands of **6.8, 14.2, and 24.2 mgd**, respectively.

Demand Scenario 4 (1,500 gpd/acre Industrial Use Rate). Demand Scenario 4 is the same as Demand Scenario 2 except the industrial water use rate was reduced to **1,500 gpd/acre**. Demand Scenario 4 represents the same future industrial area (acreage) with a reduced industrial water use rate.

Demand Scenario 4 yields 2040 AD, MD, and MH demands of **6.2, 12.4, and 21.9 mgd**, respectively.

Demand Scenarios 1-4 General Discussion. Historical AD, MD, and MH demands and Demand Scenarios 1-4 2040 AD, MD, and MH demand projections are shown on Figure 2-10 and summarized below:

- The 2040 AD demand projections range from **6.1 to 6.8 mgd**.
- The 2040 MD demand projections range from **12.4 to 14.2 mgd**.
- The 2040 MH demand projections range from **21.9 to 24.2 mgd**.
- The gross water use rates in the future growth areas ranged from **425 to 610 gpcd**. The high gross water use rates in the future growth areas reflect the high percentage of industrial water use in these areas. The high gross water use rates in the future growth areas will cause 2040 overall system-wide gross water use rates (existing service area plus future growth areas) to range from **226 gpcd** (Demand Scenarios 2 and 3) to **196 gpcd** (Demand Scenario 1). This is a significant increase compared to the 2020 and 2021 overall system-wide gross water use rates of **185 and 180 gpcd**, respectively.

- The future growth areas are projected to account for **23.3%** (Demand Scenario 4) to **32.9%** (Demand Scenario 1) of 2040 total average day demands.

2.7 SELECTED DEMAND SCENARIO (DEMAND SCENARIO 2) 2030 AND 2040 DEMANDS

Project meetings were conducted with the City to discuss Demand Scenarios 1-4. During the project meetings the City selected and Black & Veatch concurred with the selection of Demand Scenario 2 for the hydraulic analyses, raw water, and treatment requirements for this study.

The Demand Scenario 2 medium-term (2030) and long-term (2040) AD, MD, MH, and gross water use rates are summarized in Table 2-8.

Demand Scenarios 3 and 4 are minor modifications (sensitivity analyses) of selected Demand Scenario 2.

- Demand Scenario 3 includes a slightly higher MD/AD demand factor (2.11) compared to Demand Scenario 2 (MD/AD = 2.02). Demand Scenario 3 results in a slightly higher 2040 MD demand of **14.2 mgd**, compared to the Demand Scenario 2 MD demand of **13.7 mgd**. The Demand Scenario 3 MD demand projection is indicative of MD demands that may be experienced during extended hot, dry conditions.
- Demand Scenario 4 includes a reduced future industrial water use rate of 1,500 gpd/acre, compared to 3,000 gpd/acre used for Demand Scenario 2. Demand Scenario 4 results in a lower 2040 MD demand of **12.4 mgd**, compared to the Demand Scenario 2 MD demand of **13.7 mgd**. The Demand Scenario 4 MD demand is indicative of the MD demands that may be experienced if future industrial growth is less water intensive than predicted under Demand Scenario 2.
- Demand Scenarios 3 and 4 represent potential upper and lower ranges ("bookends") of the Demand Scenario 2 demand projections used for the hydraulic analyses and improvements evaluations performed for this study.
- All the future Demand Scenarios predict a reversal to the downward trend in AD gross water use rates as shown on Figure 2-10. This is due to the large increase in industrial acres to be developed as predicted in the Comprehensive Plan. The 2020 and 2021 gross water use rates are **185 and 180 gpcd**, respectively. Demand Scenario 2 will have a 2040 gross water use rate of **226 gpcd**. The higher future gross water use rate reflects the City's ability to acquire and provide service to future industrial customers. Demand Scenario 4 (with a reduced industrial water use rate [1,500 gpd/acre]) yields a 2040 gross water use rate of **205 gpcd** – which is above but closer to the current gross water use rates.

Table 2-8 Demand Scenario 2 (Selected) Future Demand Projections and Gross Water Use Rates

EXISTING SERVICE & FUTURE GROWTH AREAS/ CUSTOMER CLASSES	DEMAND SCENARIO 2									
	Medium-term 2030					Long-term 2040				
	Demand (mgd)			Average Day Demand % of Total	Gross Water Use Rate (gpcd)	Demand (mgd)			Average Day Demand % of Total	Gross Water Use Rate (gpcd)
	Aver-age Day	Maxi-mum Day	Maxi-mum Hour			Aver-age Day	Maxi-mum Day	Maxi-mum Hour		
1. Existing Zones 1 & 2 (2019/2021 Sales)										
Residential	2.33	4.70	8.30	40.1%		2.33	4.70	8.30	34.3%	
Commercial	1.37	2.76	4.87	23.6%		1.37	2.76	4.87	20.2%	
Industrial	0.77	1.57	2.76	13.4%		0.77	1.57	2.76	11.4%	
Subtotal	**4.47**	**9.03**	**15.93**	**77.1%**	**180**	**4.47**	**9.03**	**15.93**	**65.9%**	**180**
2. Zone 4 Customers (2021 Sales)										
Norfolk Iron & Metal	0.004	0.008	0.014	0.1%		0.004	0.008	0.014	0.1%	
Nucor Steel (Potable)	0.070	0.141	0.249	1.2%		0.070	0.141	0.249	1.0%	
Regional Center	0.017	0.033	0.059	0.3%		0.017	0.033	0.059	0.2%	
Subtotal	**0.090**	**0.183**	**0.322**	**1.6%**		**0.090**	**0.183**	**0.322**	**1.3%**	
Existing Zones 1, 2, 4	**4.560**	**9.214**	**16.255**	**78.6%**		**4.560**	**9.214**	**16.255**	**67.2%**	
3. Future Growth Areas										
Blackberry	0.01	0.03	0.05	0.3%		0.03	0.06	0.10	0.4%	
Channel Road	0.01	0.02	0.03	0.1%		0.02	0.03	0.06	0.2%	
Commercial/Public	0.15	0.31	0.54	2.6%		0.29	0.59	1.04	4.3%	
East Side Residential	0.08	0.16	0.27	1.3%		0.15	0.30	0.52	2.2%	
Industrial	0.66	1.33	2.34	11.3%		1.25	2.53	4.46	18.5%	
Legacy Bend	0.03	0.07	0.12	0.6%		0.07	0.13	0.23	1.0%	
Northwest Residential	0.05	0.11	0.19	0.9%		0.10	0.21	0.37	1.5%	
Nor-Park	0.01	0.02	0.04	0.2%		0.02	0.04	0.07	0.3%	
Parks/Recreation	0.05	0.11	0.19	0.9%		0.10	0.20	0.36	1.5%	
Wyndam Hills	0.02	0.04	0.07	0.3%		0.04	0.08	0.13	0.5%	
Subtotal	**1.08**	**2.18**	**3.85**	**18.6%**	**610**	**2.06**	**4.16**	**7.35**	**30.4%**	**610**
4. Woodland Park	**0.16**	**0.32**	**0.57**	**2.8%**		**0.16**	**0.32**	**0.57**	**2.4%**	
TOTAL	**5.80**	**11.72**	**20.68**	**100.0%**	**204**	**6.78**	**13.70**	**24.17**	**100.0%**	**226**

2.8 AMENDMENT 4 DEVELOPMENT AREAS AND DEMANDS

The water distribution system master plan update established 2040 service area, population projections, and water demand forecasts in coordination with the City's Comprehensive Plan. The 2040 service area encompasses the existing City limits plus areas of anticipated growth extending outside of the existing City limits. Subsequent to establishing the 2040 service area, developers have inquired with the City about potential extension of water and sewer utility service further from the City limits but within the City's Extraterritorial Jurisdiction Area (EJA).

2.8.1 Amendment 4 Development Areas

Amendment 4 to the Water Master Plan 2022 Update includes ten (10) "development areas" not included in the 2040 service area, as shown on Figure 1-1 (Section 1). "Qualitative" (conceptual) and "detailed" hydraulic modeling was performed for the 10 development areas to identify the feasibility and infrastructure needed to extend water service to the development areas.

The Amendment 4 development area acreages and average day and maximum day demands are given in Table 2-9. A "high level" approach as summarized below as used compute water demands in the development areas.

- **80 percent** of the gross development area acreage was assumed to represent residential/commercial/public development and generate future water demands. [20% of the gross development area acreage was assumed to be dedicated to roads, parks, etc.]
- An overall combined (residential/commercial/public) water use of 793 gallons per day (gpd) per acre was used to determine average day water use. A water use rate of **793 gpd/acre** is based on the future 2040 areas served (acreages) and computed 2040 demands within these areas.
- A maximum day to average day (MD/AD) demand factor of **2.02** was used to determine maximum day demands in the Amendment 4 development area. This is the same MD/AD demand factor used to compute the 2030 and 2040 maximum day demands.
- The Amendment 4 total average day and maximum day demands in the "qualitative" development areas are **1.4 and 2.8 mgd**, respectively.
- The Amendment 4 total average day and maximum day demands in the "detailed" hydraulic analyses development areas are **2.3 and 4.6 mgd**, respectively.
- The total 2030 and 2040 Comprehensive Plan based maximum day demands plus the Amendment 4 detailed hydraulic analyses maximum day demands are **16.3 and 18.3 mgd** respectively.

(Blank Page)

Table 2-9 Amendment 4 Development Areas

DEVELOPMENT AREA NUMBER	REVIEW CATEGORY	AREA (ACRES)	ADJUSTED AREA (ACRES) (1)	ADJUSTED (80%) AREAS BY ZONE (ACRES)						AVE DAY GPD PER ACRE (2)	FUTURE DEMANDS & DEMAND FACTORS				
				1	2	3	4	5	Total		Average Day (gpm)	Average Day (mgd)	MD/AD	Maximum Day (gpm)	Maximum Day (mgd)
1	DETAILED	638	510	510	0	0	0	0	510	793	281	0.40	2.02	568	0.82
2E	DETAILED	1,275	1,020	261	382	377	0	0	1,020	793	562	0.81	2.02	1,135	1.64
2S	QUALITATIVE	1,141	913	913	0	0	0	0	913	793	503	0.72	2.02	1,016	1.46
2W	QUALITATIVE	1,034	827	226	387	214	0	0	827	793	455	0.66	2.02	921	1.33
3	DETAILED	605	484	0	259	225	0	0	484	793	267	0.38	2.02	539	0.78
4 (3)	DETAILED	-									35	0.05	2.02	71	0.10
5	DETAILED	115	92	0	0	0	0	92	92	793	50	0.07	2.02	102	0.15
6	DETAILED	318	254	0	0	0	0	254	254	793	140	0.20	2.02	283	0.41
8	QUALITATIVE	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	DETAILED	576	461	2	0	0	459	0	461	793	254	0.37	2.02	513	0.74
Total Qualitative		2,175	1,740								**958**	**1.38**		**1,937**	**2.79**
Total Detailed		3,527	2,822								**1,589**	**2.29**		**3,211**	**4.62**
TOTAL		5,702	4,562								**2,547**	**3.67**		**5,148**	**7.41**
2030 Comprehensive Plan based Total												5.80			11.72
2040 Comprehensive Plan based Total												6.78			13.70
Total 2030 Comprehensive Plan plus Amendment 4 Detailed Analysis Areas												**8.09**			**16.34**
Total 2040 Comprehensive Plan plus Amendment 4 Detailed Analysis Areas												**9.07**			**18.32**

(1) Adjusted Area equal to 80% of total area.
(2) 793 GPD/ACRE based on 2040 Development Areas Resid, Comm, Public/Parks demands and acreages. Uses Adjusted Area (80% of Total Area).
(3) Town of Hadar water demand based on 2020 population of 280 persons and gross water use of 180 gpcd.

(Blank Page)

2.8.2 Amendment 4 Demand Scenarios

It is noted that the 2040 Comprehensive Plan based maximum day demands plus the Amendment 4 detailed hydraulic analyses maximum day demands is **19.1 mgd**. This is almost twice the City's current maximum day demand. During discussions with the City it was decided that the Amendment 4 detailed hydraulic analyses would be performed for a maximum day demand of **16 mgd** – equal to the future West Water Treatment Plant capacity of **14.5 mgd** plus an East Water Treatment Plant operating capacity of **1.5 mgd**. The exception to this is Amendment 4 Demand Scenario 4 which was performed for a maximum day demand of 17.5 mgd. Where necessary, development areas acreages were adjusted (reduced) to hit the target maximum day demand of 16.0 mgd.

Five (5) Amendment 4 detailed hydraulic analyses scenarios are summarized in Table 2-10. Additional information on the Amendment 4 detailed hydraulic analyses scenarios is given in Appendix A, Table A-3.

Table 2-10 Amendment 4 Detailed Hydraulic Analyses/Scenarios

AMENDMENT 4 DETAILED HYDRAULIC ANALYSES SCENARIOS	DESCRIPTION	AMENDMENT 4 DEVELOPMENT AREAS	AREA ADJUST-MENT (1)	DEMAND (MGD)	
				Aver-age Day	Maxi-mum Day
1	West, north, south Development Areas. Adjusted to hit max day 16.0 mgd target demand.	1, 2E, 3	71%	7.9	16.0
2	South, east Development Areas.	1, 5, 6, 9	100%	7.8	15.8
3	Balanced (east, west, north, south Development Areas). Adjusted to hit max day 16.0 mgd target demand.	1, 2E, 3, 5, 6	61%	7.9	16.0
4	Balanced (east, west, north, south Development Areas). Adjusted to hit max day 16.0 mgd target demand.	1, 2E, 3, 5, 6	100%	8.7	17.5
5	Town of Hadar	4	100%	6.8	13.8

(1) Development Areas acreage adjustment (percent of total area) to hit target maximum day demand (16.0 mgd).

- **Demand Scenario 1** includes development areas on the west, north and south sides of the City. Acreages for Development Areas 1, 2E, and 3 were reduced to **71%** of the total area to hit the target maximum day demand of 16 mgd.
- **Demand Scenario 2** includes development areas on the south and east sides of the City (Development Areas 1, 5, 6, and 9). **No** acreage adjustments were made to the Demand Scenario 2 acreages and the estimated maximum day demand is 15.8 mgd.
- **Demand Scenario 3** includes development areas on the east, west, north and south sides of the City. Because Demand Scenario 3 includes development areas on all sides of the City it is characterized as a "balanced" development strategy/scenario. Demand Scenario 3 included Development Areas 1, 2E, 3, 5, and 6. Acreages for these development areas were reduced to **61%** of the total area to hit the target maximum day demand of 16 mgd.
- **Demand Scenario 4** is the same as Demand Scenario 3 with the exception that **no** development area acreage adjustments were made. This results in a total maximum day demand of **17.5 mgd**. Demand Scenario 4 represent a conservative ("high end") demand estimate to assure that future water system improvements are not undersized.

- **Demand Scenario 5** represent future service to the Town of Hadar (Development Area 4). Because the Town of Hadar represents a small increase in system-wide demand, the Demand Scenario 5 maximum day demand is **13.8 mgd**, about 0.1 mgd above the Comprehensive Plan based 2040 demand of 13.7 mgd.

Results of the Amendment 4 qualitative and detailed hydraulic analyses are presented in Section 5.

APPENDIX A

Future 2030/2040 Demand Scenarios 1-4

Amendment 4 Scenarios 1-4 Demands

(Blank Page)

Table A-1, Historical/Existing Data, Planning Criteria, and 2040 Demographics and Demand Projections (Demand Scenarios)

Existing Service & Future Growth Areas/ Customer Classes	User Class (1)	2019 Historical										Current Water Use Characteristics & Future Planning Criteria						Future Demographics			Future Demands									
		Growth Area Acreage		2019/2021 Metered Sales & Demand				U.S. 2010 Census Persons Per House-hold	2019 Population & Residential Density			Usage per Acre (gpd/ acre)	Residen-tial Persons Per Dwelling Unit	Residen-tial Dwelling Units per Acre	Unac-counted for Water (%)	Demand Factors		2040 Increas-ed Acres	2040 Population		2040 Average Day Sales		2040 Unaccounted-for Water		2040 Demand (Sales + Unaccounted-for)					Aver-age Day Gross Use Rate (gpcd) (5)
																								Average Day			Maxi-mum Day (mgd)	Maxi-mum Hour (mgd)		
		(acres)	(Per-cent of Total)	Sales (mgd)	(Per-cent of Total)	Sales per Acre (gpd/ acre)	Average Day Demand (mgd) (2)		Popula-tion Est.	Popula-tion Density (persons/ acre)	Residen-tial Dwelling Units per Acre					MD/ AD	MH/ AD		Exist-ing/ Future	Target	(gpm)	(mgd)	(gpm)	(mgd)	(gpm)	(mgd)	Per-cent of TOTAL			
Scenario 1 - Historical Water Use Rates and Residential Densities per Acre; 2019 MD/AD and MH/AD Demand Factors																														
1. Existing Zones 1 & 2 (2019 Sales)																														
Residential		2,743.5		1.574	45.9%	**574**	1.754	2.31	24,803	9.04	3.91	574	2.31	3.91	10.30%	2.11	3.93				1,096	1.57	126	0.18	1,222	1.75	28.9%	3.70	6.90	
Commercial		1,337.1		1.135	33.1%	**849**	1.266					849			10.30%	2.11	3.93				791	1.14	91	0.13	881	1.27	20.9%	2.67	4.98	
Industrial		228.5		0.719	21.0%	**3,148**	0.802					3,148			10.30%	2.11	3.93				501	0.72	58	0.08	558	0.80	13.2%	1.69	3.15	
Subtotal		4,309.0		3.428	100.0%		3.822												24,803	24,803	**2,387**	**3.43**	**274**	**0.39**	**2,661**	**3.82**	**63.0%**	**8.05**	**15.03**	**154**
2. Zone 4 Customers (2021 Sales)																														
Norfolk Iron & Metal				0.003											10.30%	2.11	3.93				2.4	0.00	0	0.00	3	0.00	0.1%	0.01	0.02	
Nucor Steel (Potable)				0.063											10.30%	2.11	3.93				43.6	0.06	5	0.01	49	0.07	1.2%	0.15	0.28	
Regional Center				0.015											10.30%	2.11	3.93				10.3	0.01	1	0.00	11	0.02	0.3%	0.03	0.07	
Subtotal				0.081																	**56.3**	**0.08**	**6**	**0.01**	**62.7**	**0.09**	**1.5%**	**0.19**	**0.36**	
Subtotal Existing Zones 1, 2, 4																					**2,444**	**3.51**	**281**	**0.40**	**2,724.1**	**3.91**	**64.5%**	**8.24**	**15.39**	
3. Future Growth Areas																														
Blackberry	Resid	33.4	2.6%									574	2.31	3.91	10.30%	2.11	3.93	33.4	302		13	0.02	2	0.00	15	0.02	0.4%	0.05	0.08	
Channel Road	Resid	18.6	1.4%									574	2.31	3.91	10.30%	2.11	3.93	18.6	168		7	0.01	1	0.00	8	0.01	0.2%	0.03	0.05	
Commercial/Public	Comm	285.3	22.1%									849			10.30%	2.11	3.93	285.3			168	0.24	19	0.03	188	0.27	4.4%	0.57	1.06	
East Side Residential	Resid	173.2	13.4%									574	2.31	3.91	10.30%	2.11	3.93	173.2	1,565		69	0.10	8	0.01	77	0.11	1.8%	0.23	0.44	
Industrial	Ind	374.4	29.0%									3,148			10.30%	2.11	3.93	374.4			818	1.18	94	0.14	912	1.31	21.6%	2.77	5.17	
Legacy Bend	Resid	77.7	6.0%									574	2.31	3.91	10.30%	2.11	3.93	77.7	702		31	0.04	4	0.01	35	0.05	0.8%	0.10	0.20	
Northwest Residential	Resid	120.7	9.4%									574	2.31	3.91	10.30%	2.11	3.93	120.7	1,091		48	0.07	6	0.01	54	0.08	1.3%	0.16	0.30	
Nor-Park	Resid	23.3	1.8%									574	2.31	3.91	10.30%	2.11	3.93	23.3	210		9	0.01	1	0.00	10	0.01	0.2%	0.03	0.06	
Parks/Recreation	Park	139.0	10.8%									**650**			10.30%	2.11	3.93	139.0			63	0.09	7	0.01	70	0.10	1.7%	0.21	0.40	
Wyndam Hills	Resid	43.8	3.4%									574	2.31	3.91	10.30%	2.11	3.93	43.8	396		17	0.03	2	0.00	19	0.03	0.5%	0.06	0.11	
Subtotal		1289.3	100.0%															1,289.3	**4,434**	**3,390**	**1,245**	**1.79**	**143**	**0.21**	**1,388**	**2.00**	**32.9%**	**4.21**	**7.86**	**451**
4. Woodland Park (3)															10.30%	2.11	3.93		1,800		**100**	**0.14**	**11**	**0.02**	**111**	**0.16**	**2.6%**	**0.34**	**0.63**	
TOTAL (4)																			**29,237**	**28,193**	**3,788**	**5.45**	**435**	**0.63**	**4,223**	**6.07**	**100.0%**	**12.79**	**23.88**	
TOTAL (with Woodland Pk)																			**31,037**											**196**
Scenario 2 - Target 2040 Population Increase of 3,381 Persons, 2021 Sales, 3,000 gpd/acre Industrial Use Rate; MD/AD = 2.02, MH/AD = 3.56																														
1. Existing Zones 1 & 2 (2021 Sales)	**Adj Factor =**																													
Residential	**1.3270**	2,743.5		**2.088**	60.9%	**761**	2.328	2.31	24,803	9.04	3.91	761	2.31	3.91	10.30%	2.02	3.56				1,454	2.09	167	0.24	1,621	2.33	34.4%	4.70	8.30	
Commercial	**1.0800**	1,337.1		**1.226**	35.8%	**917**	1.367					917			10.30%	2.02	3.56				854	1.23	98	0.14	952	1.37	20.2%	2.76	4.87	
Industrial	**0.9662**	228.5		**0.695**	20.3%	**3,042**	0.775					3,042			10.30%	2.02	3.56				484	0.70	56	0.08	540	0.77	11.4%	1.57	2.76	
Subtotal		4,309.0		**4.009**	116.9%		4.469												24,803	24,803	**2,792**	**4.01**	**321**	**0.46**	**3,113**	**4.47**	**66.0%**	**9.03**	**15.93**	**180**
2. Zone 4 Customers (2021 Sales)																														
Norfolk Iron & Metal				0.003											10.30%	2.02	3.56				2.4	0.00	0	0.00	3	0.00	0.1%	0.01	0.01	
Nucor Steel (Potable)				0.063											10.30%	2.02	3.56				43.6	0.06	5	0.01	49	0.07	1.2%	0.14	0.25	
Regional Center				0.015											10.30%	2.02	3.56				10.3	0.01	1	0.00	11	0.02	0.3%	0.03	0.06	
Subtotal				0.081																	**56.3**	**0.08**	**6**	**0.01**	**62.7**	**0.09**	**1.5%**	**0.18**	**0.32**	
Subtotal Existing Zones 1, 2, 4																					**2,848**	**4.09**	**327**	**0.47**	**3,175.2**	**4.56**	**67.5%**	**9.21**	**16.26**	
3. Future Growth Areas																														
Blackberry	Resid	33.4	2.6%									761	2.31	2.98	10.30%	2.02	3.56	33.4	230		18	0.03	2	0.00	20	0.03	0.4%	0.06	0.10	
Channel Road	Resid	18.6	1.4%									761	2.31	2.98	10.30%	2.02	3.56	18.6	128		10	0.01	1	0.00	11	0.02	0.2%	0.03	0.06	
Commercial/Public	Comm	285.3	22.1%									917			10.30%	2.02	3.56	285.3			182	0.26	21	0.03	203	0.29	4.3%	0.59	1.04	
East Side Residential	Resid	173.2	13.4%									761	2.31	2.98	10.30%	2.02	3.56	173.2	1,192		92	0.13	11	0.02	102	0.15	2.2%	0.30	0.52	
Industrial	Ind	374.4	29.0%									3,000			10.30%	2.02	3.56	374.4			780	1.12	90	0.13	869	1.25	18.4%	2.53	4.46	
Legacy Bend	Resid	77.7	6.0%									761	2.31	2.98	10.30%	2.02	3.56	77.7	535		41	0.06	5	0.01	46	0.07	1.0%	0.13	0.23	
Northwest Residential	Resid	120.7	9.4%									761	2.31	2.98	10.30%	2.02	3.56	120.7	831		64	0.09	7	0.01	71	0.10	1.5%	0.21	0.37	
Nor-Park	Resid	23.3	1.8%									761	2.31	2.98	10.30%	2.02	3.56	23.3	160		12	0.02	1	0.00	14	0.02	0.3%	0.04	0.07	
Parks/Recreation	Park	139.0	10.8%									**650**			10.30%	2.02	3.56	139.0			63	0.09	7	0.01	70	0.10	1.5%	0.20	0.36	
Wyndam Hills	Resid	43.8	3.4%									761	2.31	2.98	10.30%	2.02	3.56	43.8	301		23	0.03	3	0.00	26	0.04	0.5%	0.08	0.13	
Subtotal		1289.3	100.0%															1,289.3	**3,377**	**3,390**	**1,284**	**1.85**	**147**	**0.21**	**1,431**	**2.06**	**30.3%**	**4.16**	**7.35**	**610**
4. Woodland Park (3)															10.30%	2.02	3.56		1,800		**100**	**0.14**	**11**	**0.02**	**111**	**0.16**	**2.4%**	**0.32**	**0.57**	
TOTAL (4)																			**28,180**	**28,193**	**4,232**	**6.08**	**486**	**0.70**	**4,718**	**6.78**	**100.2%**	**13.70**	**24.17**	
TOTAL (with Woodland Pk)																			**29,980**											**226**

Red numbers represent Planning Criteria. **Bold Blue** numbers represent numbers for which existing system values are not available. **Green Bold** numbers represent 2040 increased population served and 2040 increased service population target.

Shaded cells represent planning criteria changed for the particular Demand Scenario. (1) Resid = Residential, Comm = Commercial, Ind = Industrial. (2) Demand equals sales plus Unaccounted-for water.

(3) Woodland Park Residential water use estimated to be 80 gpcd. (4) 2040 Population excludes Woodland Park. (5) Includes Woodland Park demand and population.

Table A-1, Historical/Existing Data, Planning Criteria, and 2040 Demographics and Demand Projections (Demand Scenarios)

Existing Service & Future Growth Areas/ Customer Classes	User Class (1)	2019 Historical										Current Water Use Characteristics & Future Planning Criteria						Future Demographics			Future Demands									
		Growth Area Acreage		2019 Metered Sales & Demand				U.S. 2010 Census Persons Per House-hold	2019 Population & Residential Density			Usage per Acre (gpd/ acre)	Residen-tial Persons Per Dwelling Unit	Residen-tial Dwelling Units per Acre	Unac-counted for Water (%)	Demand Factors		2040 Increas-ed Acres	2040 Population		2040 Average Day Sales		2040 Unaccounted-for Water		2040 Demand (Sales + Unaccounted-for)					Aver-age Day Gross Use Rate (gpcd) (5)
		(acres)	(Per-cent of Total)	Sales (mgd)	(Per-cent of Total)	Sales per Acre (gpd/ acre)	Average Day Demand (mgd) (2)		Popula-tion Est.	Popula-tion Density (persons/ acre)	Residen-tial Dwelling Units per Acre					MD/ AD	MH/ AD		Exist-ing/ Future	Target	(gpm)	(mgd)	(gpm)	(mgd)	Average Day (gpm)	Average Day (mgd)	Per-cent of TOTAL	Maxi-mum Day (mgd)	Maxi-mum Hour (mgd)	
Scenario 3 - Target 2040 Population Increase of 3,381 Persons, 2021 Sales, 3,000 gpd/acre Industrial Use Rate, MD/AD = 2.10, MH/AD = 3.56																													
1. Existing Zones 1 & 2 (2021 Sales)	**Adj Factor =**																												
Residential	**1.3270**	2,743.5		**2.088**	52.1%	**761**	2.328	2.31	24,803	9.04	3.91	761	2.31	3.91	10.30%	2.10	3.56				1,454	2.09	167	0.24	1,621	2.33	34.4%	4.89	8.30	
Commercial	**1.0800**	1,337.1		**1.226**	30.6%	**917**	1.367					917			10.30%	2.10	3.56				854	1.23	98	0.14	952	1.37	20.2%	2.87	4.87	
Industrial	**0.9662**	228.5		**0.695**	17.3%	**3,042**	0.775					3,042			10.30%	2.10	3.56				484	0.70	56	0.08	540	0.77	11.4%	1.63	2.76	
Subtotal		4,309.0		**4.009**	100.0%		4.469												24,803	24,803	**2,792**	**4.01**	**321**	**0.46**	**3,113**	**4.47**	**66.0%**	**9.39**	**15.93**	**180**
2. Zone 4 Customers (2021 Sales)																													
Norfolk Iron & Metal				0.003											10.30%	2.10	3.56				2.4	0.00	0	0.00	3	0.00	0.1%	0.01	0.01	
Nucor Steel (Potable)				0.063											10.30%	2.10	3.56				43.6	0.06	5	0.01	49	0.07	1.0%	0.15	0.25	
Regional Center				0.015											10.30%	2.10	3.56				10.3	0.01	1	0.00	11	0.02	0.2%	0.03	0.06	
Subtotal				0.081																	**56.3**	**0.08**	**6**	**0.01**	**62.7**	**0.09**	**1.3%**	**0.19**	**0.32**	
Subtotal Existing Zones 1, 2, 4																					**2,848**	**4.09**	**327**	**0.47**	**3,175.2**	**4.56**	**67.3%**	**9.58**	**16.26**	
3. Future Growth Areas																													
Blackberry	Resid	33.4	2.6%									761	2.31	2.98	10.30%	2.10	3.56	33.4	230		18	0.03	2	0.00	20	0.03	0.4%	0.06	0.10	
Channel Road	Resid	18.6	1.4%									761	2.31	2.98	10.30%	2.10	3.56	18.6	128		10	0.01	1	0.00	11	0.02	0.2%	0.03	0.06	
Commercial/Public	Comm	285.3	22.1%									917			10.30%	2.10	3.56	285.3			182	0.26	21	0.03	203	0.29	4.3%	0.61	1.04	
East Side Residential	Resid	173.2	13.4%									761	2.31	2.98	10.30%	2.10	3.56	173.2	1,192		92	0.13	11	0.02	102	0.15	2.2%	0.31	0.52	
Industrial	Ind	374.4	29.0%									3,000			10.30%	2.10	3.56	374.4			780	1.12	90	0.13	869	1.25	18.4%	2.63	4.46	
Legacy Bend	Resid	77.7	6.0%									761	2.31	2.98	10.30%	2.10	3.56	77.7	535		41	0.06	5	0.01	46	0.07	1.0%	0.14	0.23	
Northwest Residential	Resid	120.7	9.4%									761	2.31	2.98	10.30%	2.10	3.56	120.7	831		64	0.09	7	0.01	71	0.10	1.5%	0.22	0.37	
Nor-Park	Resid	23.3	1.8%									761	2.31	2.98	10.30%	2.10	3.56	23.3	160		12	0.02	1	0.00	14	0.02	0.3%	0.04	0.07	
Parks/Recreation	Park	139.0	10.8%									**650**			10.30%	2.10	3.56	139.0			63	0.09	7	0.01	70	0.10	1.5%	0.21	0.36	
Wyndam Hills	Resid	43.8	3.4%									761	2.31	2.98	10.30%	2.10	3.56	43.8	301		23	0.03	3	0.00	26	0.04	0.5%	0.08	0.13	
Subtotal		1289.3	100.0%															1,289.3	**3,377**	**3,390**	**1,284**	**1.85**	**147**	**0.21**	**1,431**	**2.06**	**30.3%**	**4.33**	**7.35**	**610**
4. Woodland Park (3)															10.30%	2.10	3.56		1,800		**100**	**0.14**	**11**	**0.02**	**111**	**0.16**	**2.4%**	**0.34**	**0.57**	
TOTAL (4)																			**28,180**	**28,193**	**4,232**	**6.08**	**486**	**0.70**	**4,718**	**6.78**	**100.0%**	**14.24**	**24.17**	
TOTAL (with Woodland Pk)																			**29,980**											**226**
Scenario 4 - Target 2040 Population Increase of 3,381 Persons, 2021 Sales, 1,500 gpd/acre Industrial Use Rate, MD/AD = 2.02, MH/AD = 3.56																													
1. Existing Zones 1 & 2 (2021 Sales)	**Adj Factor =**																												
Residential	**1.3270**	2,743.5		**2.088**	52.1%	**761**	2.328	2.31	24,803	9.04	3.91	761	2.31	3.91	10.30%	2.02	3.56				1,454	2.09	167	0.24	1,621	2.33	37.8%	4.70	8.30	
Commercial	**1.0800**	1,337.1		**1.226**	30.6%	**917**	1.367					917			10.30%	2.02	3.56				854	1.23	98	0.14	952	1.37	22.2%	2.76	4.87	
Industrial	**0.9662**	228.5		**0.695**	17.3%	**3,042**	0.775					3,042			10.30%	2.02	3.56				484	0.70	56	0.08	540	0.77	12.6%	1.57	2.76	
Subtotal		4,309.0		**4.009**	100.0%		4.469												24,803	24,803	**2,792**	**4.01**	**321**	**0.46**	**3,113**	**4.47**	**72.7%**	**9.03**	**15.93**	**180**
2. Zone 4 Customers (2021 Sales)																													
Norfolk Iron & Metal				0.003											10.30%	2.02	3.56				2.4	0.00	0	0.00	3	0.00	0.1%	0.01	0.01	
Nucor Steel (Potable)				0.063											10.30%	2.02	3.56				43.6	0.06	5	0.01	49	0.07	1.0%	0.14	0.25	
Regional Center				0.015											10.30%	2.02	3.56				10.3	0.01	1	0.00	11	0.02	0.2%	0.03	0.06	
Subtotal				0.081																	**56.3**	**0.08**	**6**	**0.01**	**62.7**	**0.09**	**1.3%**	**0.18**	**0.32**	
Subtotal Existing Zones 1, 2, 4																					**2,848**	**4.09**	**327**	**0.47**	**3,175.2**	**4.56**	**74.0%**	**9.21**	**16.26**	
3. Future Growth Areas																													
Blackberry	Resid	33.4	2.6%									761	2.31	2.98	10.30%	2.02	3.56	33.4	230		18	0.03	2	0.00	20	0.03	0.5%	0.06	0.10	
Channel Road	Resid	18.6	1.4%									761	2.31	2.98	10.30%	2.02	3.56	18.6	128		10	0.01	1	0.00	11	0.02	0.3%	0.03	0.06	
Commercial/Public	Comm	285.3	22.1%									917			10.30%	2.02	3.56	285.3			182	0.26	21	0.03	203	0.29	4.7%	0.59	1.04	
East Side Residential	Resid	173.2	13.4%									761	2.31	2.98	10.30%	2.02	3.56	173.2	1,192		92	0.13	11	0.02	102	0.15	2.4%	0.30	0.52	
Industrial	Ind	374.4	29.0%									1,500			10.30%	2.02	3.56	374.4			390	0.56	45	0.06	435	0.63	10.2%	1.27	2.23	
Legacy Bend	Resid	77.7	6.0%									761	2.31	2.98	10.30%	2.02	3.56	77.7	535		41	0.06	5	0.01	46	0.07	1.1%	0.13	0.23	
Northwest Residential	Resid	120.7	9.4%									761	2.31	2.98	10.30%	2.02	3.56	120.7	831		64	0.09	7	0.01	71	0.10	1.7%	0.21	0.37	
Nor-Park	Resid	23.3	1.8%									761	2.31	2.98	10.30%	2.02	3.56	23.3	160		12	0.02	1	0.00	14	0.02	0.3%	0.04	0.07	
Parks/Recreation	Park	139.0	10.8%									**650**			10.30%	2.02	3.56	139.0			63	0.09	7	0.01	70	0.10	1.6%	0.20	0.36	
Wyndam Hills	Resid	43.8	3.4%									761	2.31	2.98	10.30%	2.02	3.56	43.8	301		23	0.03	3	0.00	26	0.04	0.6%	0.08	0.13	
Subtotal		1289.3	100.0%															1,289.3	**3,377**	**3,390**	**894**	**1.29**	**103**	**0.15**	**996**	**1.43**	**23.3%**	**2.90**	**5.11**	**425**
4. Woodland Park (3)															10.30%	2.02	3.56		1,800		**100**	**0.14**	**11**	**0.02**	**111**	**0.16**	**2.6%**	**0.32**	**0.57**	
TOTAL (4)																			**28,180**	**28,193**	**3,842**	**5.52**	**441**	**0.63**	**4,283**	**6.15**	**99.9%**	**12.44**	**21.94**	
TOTAL (with Woodland Pk)																			**29,980**											**205**

Red numbers represent Planning Criteria. **Bold Blue** numbers represent numbers for which existing system values are not available. **Green Bold** numbers represent 2040 increased population served and 2040 increased service population target.

Shaded cells represent planning criteria changed for the particular Demand Scenario.

(1) Resid = Residential, Comm = Commercial, Ind = Industrial. (2) Demand equals sales plus Unaccounted-for water.

(3) Woodland Park Residential water use estimated to be 80 gpcd. (4) 2040 Population excludes Woodland Park. (5) Includes Woodland Park demand and population.

Table A-2, Historical/Existing Data, Planning Criteria, and 2030 Demographics and Demand Projections (Demand Scenarios)

Existing Service & Future Growth Areas/ Customer Classes	User Class (1)	2019 Historical										Current Water Use Characteristics & Future Planning Criteria						Future Demographics			Future Demands									
		Growth Area Acreage		2019 Metered Sales & Demand				U.S. 2010 Census Persons Per House-hold	2019 Population & Residential Density			Usage per Acre (gpd/ acre)	Residen-tial Persons Per Dwelling Unit	Residen-tial Dwelling Units per Acre	Unac-counted for Water (%)	Demand Factors		2030 Increas-ed Acres	2030 Population		2030 Average Day Sales		2030 Unaccounted-for Water		2030 Demand (Sales + Unaccounted-for)					Aver-age Day Gross Use Rate (gpcd) (5)
		(acres)	(Per-cent of Total)	Sales (mgd)	(Per-cent of Total)	Sales per Acre (gpd/ acre)	Average Day Demand (mgd) (2)		Popula-tion Est.	Popula-tion Density (persons/ acre)	Residen-tial Dwelling Units per Acre					MD/ AD	MH/ AD		Exist-ing/ Future	Target	(gpm)	(mgd)	(gpm)	(mgd)	Average Day (gpm)	Average Day (mgd)	Per-cent of TOTAL	Maxi-mum Day (mgd)	Maxi-mum Hour (mgd)	
Scenario 1 - Historical Water Use Rates and Residential Densities per Acre; 2019 MD/AD and MH/AD Demand Factors																													
1. Existing Zones 1 & 2 (2019 Sales)																													
Residential		2,743.5		1.574	45.9%	**574**	1.754	2.31	24,803	9.04	3.91	574	2.31	3.91	10.30%	2.11	3.93				1,096	1.57	126	0.18	1,222	1.75	34.3%	3.70	6.90	
Commercial		1,337.1		1.135	33.1%	**849**	1.266					849			10.30%	2.11	3.93				791	1.14	91	0.13	881	1.27	24.7%	2.67	4.98	
Industrial		228.5		0.719	21.0%	**3,148**	0.802					3,148			10.30%	2.11	3.93				501	0.72	58	0.08	558	0.80	15.7%	1.69	3.15	
Subtotal		4,309.0		3.428	100.0%		3.822												24,803	24,803	**2,387**	**3.43**	**274**	**0.39**	**2,661**	**3.82**	**74.7%**	**8.05**	**15.03**	**154**
2. Zone 4 Customers (2021 Sales)																													
Norfolk Iron & Metal				0.003											10.30%	2.11	3.93				2.4	0.00	0	0.00	3	0.00	0.1%	0.01	0.02	
Nucor Steel (Potable)				0.063											10.30%	2.11	3.93				43.6	0.06	5	0.01	49	0.07	1.4%	0.15	0.28	
Regional Center				0.015											10.30%	2.11	3.93				10.3	0.01	1	0.00	11	0.02	0.3%	0.03	0.07	
Subtotal				0.081																	**56.3**	**0.08**	**6**	**0.01**	**62.7**	**0.09**	**1.8%**	**0.19**	**0.36**	
Subtotal Existing Zones 1, 2, 4																					**2,444**	**3.51**	**281**	**0.40**	**2,724.1**	**3.91**	**76.5%**	**8.24**	**15.39**	
3. Future Growth Areas																													
Blackberry	Resid	33.4	2.6%									574	2.31	3.91	10.30%	2.11	3.93	17.5	158		7	0.01	1	0.00	8	0.01	0.2%	0.02	0.04	
Channel Road	Resid	18.6	1.4%									574	2.31	3.91	10.30%	2.11	3.93	9.7	88		4	0.01	0	0.00	4	0.01	0.1%	0.01	0.02	
Commercial/Public	Comm	285.3	22.1%									849			10.30%	2.11	3.93	149.4			88	0.13	10	0.01	98	0.14	2.8%	0.30	0.56	
East Side Residential	Resid	173.2	13.4%									574	2.31	3.91	10.30%	2.11	3.93	90.7	820		36	0.05	4	0.01	40	0.06	1.1%	0.12	0.23	
Industrial	Ind	374.4	29.0%									3,148			10.30%	2.11	3.93	196.1			429	0.62	49	0.07	478	0.69	13.4%	1.45	2.71	
Legacy Bend	Resid	77.7	6.0%									574	2.31	3.91	10.30%	2.11	3.93	40.7	368		16	0.02	2	0.00	18	0.03	0.5%	0.05	0.10	
Northwest Residential	Resid	120.7	9.4%									574	2.31	3.91	10.30%	2.11	3.93	63.2	572		25	0.04	3	0.00	28	0.04	0.8%	0.09	0.16	
Nor-Park	Resid	23.3	1.8%									574	2.31	3.91	10.30%	2.11	3.93	12.2	110		5	0.01	1	0.00	5	0.01	0.2%	0.02	0.03	
Parks/Recreation	Park	139.0	10.8%									**650**			10.30%	2.11	3.93	72.8			33	0.05	4	0.01	37	0.05	1.0%	0.11	0.21	
Wyndam Hills	Resid	43.8	3.4%									574	2.31	3.91	10.30%	2.11	3.93	22.9	207		9	0.01	1	0.00	10	0.01	0.3%	0.03	0.06	
Subtotal		1289.3	100.0%															675.4	**2,323**	**1,776**	**652**	**0.94**	**75**	**0.11**	**727**	**1.05**	**20.4%**	**2.21**	**4.12**	**451**
4. Woodland Park (3)															10.30%	2.11	3.93		1,800		**100**	**0.14**	**11**	**0.02**	**111**	**0.16**	**3.1%**	**0.34**	**0.63**	
TOTAL (4)																			**27,126**	**26,579**	**3,196**	**4.59**	**367**	**0.53**	**3,563**	**5.12**	**100.0%**	**10.79**	**20.14**	
TOTAL (with Woodland Pk)																			**28,926**											**177**
Scenario 2 - Target 2030 Population Increase of 1,771 Persons, 2021 Sales, 3,000 gpd/acre Industrial Use Rate, MD/AD = 2.02, MH/AD = 3.56																													
1. Existing Zones 1 & 2 (2021 Sales)	**Adj Factor =**																												
Residential	**1.3270**	2,743.5		**2.088**	60.9%	**761**	2.328	2.31	24,803	9.04	3.91	761	2.31	3.91	10.30%	2.02	3.56				1,454	2.09	167	0.24	1,621	2.33	40.2%	4.70	8.30	
Commercial	**1.0800**	1,337.1		**1.226**	35.8%	**917**	1.367					917			10.30%	2.02	3.56				854	1.23	98	0.14	952	1.37	23.6%	2.76	4.87	
Industrial	**0.9662**	228.5		**0.695**	20.3%	**3,042**	0.775					3,042			10.30%	2.02	3.56				484	0.70	56	0.08	540	0.77	13.4%	1.57	2.76	
Subtotal		4,309.0		**4.009**	116.9%		4.469												24,803	24,803	**2,792**	**4.01**	**321**	**0.46**	**3,113**	**4.47**	**77.1%**	**9.03**	**15.93**	**180**
2. Zone 4 Customers (2021 Sales)																													
Norfolk Iron & Metal				0.003											10.30%	2.02	3.56				2.4	0.00	0	0.00	3	0.00	0.1%	0.01	0.01	
Nucor Steel (Potable)				0.063											10.30%	2.02	3.56				43.6	0.06	5	0.01	49	0.07	1.4%	0.14	0.25	
Regional Center				0.015											10.30%	2.02	3.56				10.3	0.01	1	0.00	11	0.02	0.3%	0.03	0.06	
Subtotal				0.081																	**56.3**	**0.08**	**6**	**0.01**	**62.7**	**0.09**	**1.8%**	**0.18**	**0.32**	
Subtotal Existing Zones 1, 2, 4																					**2,848**	**4.09**	**327**	**0.47**	**3,175.2**	**4.56**	**78.9%**	**9.21**	**16.26**	
3. Future Growth Areas																													
Blackberry	Resid	33.4	2.6%									761	2.31	2.98	10.30%	2.02	3.56	17.5	121		9	0.01	1	0.00	10	0.01	0.3%	0.03	0.05	
Channel Road	Resid	18.6	1.4%									761	2.31	2.98	10.30%	2.02	3.56	9.7	67		5	0.01	1	0.00	6	0.01	0.1%	0.02	0.03	
Commercial/Public	Comm	285.3	22.1%									917			10.30%	2.02	3.56	149.4			95	0.14	11	0.02	106	0.15	2.6%	0.31	0.54	
East Side Residential	Resid	173.2	13.4%									761	2.31	2.98	10.30%	2.02	3.56	90.7	624		48	0.07	6	0.01	53	0.08	1.3%	0.16	0.27	
Industrial	Ind	374.4	29.0%									3,000			10.30%	2.02	3.56	196.1			409	0.59	47	0.07	455	0.66	11.3%	1.33	2.34	
Legacy Bend	Resid	77.7	6.0%									761	2.31	2.98	10.30%	2.02	3.56	40.7	280		22	0.03	2	0.00	24	0.03	0.6%	0.07	0.12	
Northwest Residential	Resid	120.7	9.4%									761	2.31	2.98	10.30%	2.02	3.56	63.2	435		33	0.05	4	0.01	37	0.05	0.9%	0.11	0.19	
Nor-Park	Resid	23.3	1.8%									761	2.31	2.98	10.30%	2.02	3.56	12.2	84		6	0.01	1	0.00	7	0.01	0.2%	0.02	0.04	
Parks/Recreation	Park	139.0	10.8%									**650**			10.30%	2.02	3.56	72.8			33	0.05	4	0.01	37	0.05	0.9%	0.11	0.19	
Wyndam Hills	Resid	43.8	3.4%									761	2.31	2.98	10.30%	2.02	3.56	22.9	158		12	0.02	1	0.00	14	0.02	0.3%	0.04	0.07	
Subtotal		1289.3	100.0%															675.4	**1,769**	**1,776**	**672**	**0.97**	**77**	**0.11**	**750**	**1.08**	**18.6%**	**2.18**	**3.85**	**610**
4. Woodland Park (3)															10.30%	2.02	3.56		1,800		**100**	**0.14**	**11**	**0.02**	**111**	**0.16**	**2.8%**	**0.32**	**0.57**	
TOTAL (4)																			**26,572**	**26,579**	**3,621**	**5.20**	**416**	**0.60**	**4,036**	**5.80**	**100.2%**	**11.72**	**20.68**	
TOTAL (with Woodland Pk)																			**28,372**											**204**

Red numbers represent Planning Criteria. **Bold Blue** numbers represent numbers for which existing system values are not available. **Green Bold** numbers represent 2040 increased population served and 2040 increased service population target.

Shaded cells represent planning criteria changed for the particular Demand Scenario.

(1) Resid = Residential, Comm = Commercial, Ind = Industrial. (2) Demand equals sales plus Unaccounted-for water.

(3) Woodland Park Residential water use estimated to be 80 gpcd. (4) 2040 Population excludes Woodland Park. (5) Includes Woodland Park demand and population.

Table A-2, Historical/Existing Data, Planning Criteria, and 2030 Demographics and Demand Projections (Demand Scenarios)

Existing Service & Future Growth Areas/ Customer Classes	User Class (1)	2019 Historical										Current Water Use Characteristics & Future Planning Criteria						Future Demographics			Future Demands								
		Growth Area Acreage		2019 Metered Sales & Demand				U.S. 2010 Census Persons Per House-hold	2019 Population & Residential Density			Usage per Acre (gpd/ acre)	Residen-tial Persons Per Dwelling Unit	Residen-tial Dwelling Units per Acre	Unac-counted for Water (%)	Demand Factors		2030 Increas-ed Acres	2030 Population		2030 Average Day Sales		2030 Unaccounted-for Water		2030 Demand (Sales + Unaccounted-for)				Aver-age Day Gross Use Rate (gpcd) (5)
		(acres)	(Per-cent of Total)	Sales (mgd)	(Per-cent of Total)	Sales per Acre (gpd/ acre)	Average Day Demand (mgd) (2)		Popula-tion Est.	Popula-tion Density (persons/ acre)	Residen-tial Dwelling Units per Acre					MD/ AD	MH/ AD		Exist-ing/ Future	Target	(gpm)	(mgd)	(gpm)	(mgd)	Average Day (gpm)	Average Day (mgd)	Per-cent of TOTAL	Maxi-mum Day (mgd)	Maxi-mum Hour (mgd)	
Scenario 3 - Target 2030 Population Increase of 1,771 Persons, 2021 Sales, 3,000 gpd/acre Industrial Use Rate, MD/AD = 2.10, MH/AD = 3.56																												
1. Existing Zones 1 & 2 (2021 Sales)	**Adj Factor**																											
Residential	**1.3270**	2,743.5		**2.088**	52.1%	**761**	2.328	2.31	24,803	9.04	3.91	761	2.31	3.91	10.3%	2.10	3.56				1,454	2.09	167	0.24	1,621	2.33	40.2%	4.89	8.30	
Commercial	**1.0800**	1,337.1		**1.226**	30.6%	**917**	1.367					917			10.3%	2.10	3.56				854	1.23	98	0.14	952	1.37	23.6%	2.87	4.87	
Industrial	**0.9662**	228.5		**0.695**	17.3%	**3,042**	0.775					3,042			10.3%	2.10	3.56				484	0.70	56	0.08	540	0.77	13.4%	1.63	2.76	
Subtotal		4,309.0		**4.009**	100.0%		4.469												24,803	24,803	**2,792**	**4.01**	**320**	**0.46**	**3,112**	**4.47**	**77.2%**	**9.39**	**15.93**	**180**
2. Zone 4 Customers (2021 Sales)																												
Norfolk Iron & Metal				0.003												2.10	3.56				2.4	0.00	0	0.00	2	0.00	0.1%	0.01	0.01	
Nucor Steel (Potable)				0.063												2.10	3.56				43.6	0.06	0	0.00	44	0.06	1.1%	0.13	0.22	
Regional Center				0.015												2.10	3.56				10.3	0.01	0	0.00	10	0.01	0.3%	0.03	0.05	
Subtotal				0.081																	**56.3**	**0.08**	**0**	**0.00**	**56.3**	**0.08**	**1.4%**	**0.17**	**0.29**	
Subtotal Existing Zones 1, 2, 4																					**2,848**	**4.09**	**320**	**0.46**	**3,168.7**	**4.55**	**78.6%**	**9.56**	**16.22**	
3. Future Growth Areas																												
Blackberry	Resid	33.4	2.6%									761	2.31	2.98	10.3%	2.10	3.56	17.5	121		9	0.01	1	0.00	10	0.01	0.3%	0.03	0.05	
Channel Road	Resid	18.6	1.4%									761	2.31	2.98	10.3%	2.10	3.56	9.7	67		5	0.01	1	0.00	6	0.01	0.1%	0.02	0.03	
Commercial/Public	Comm	285.3	22.1%									917			10.3%	2.10	3.56	149.4			95	0.14	11	0.02	106	0.15	2.6%	0.32	0.54	
East Side Residential	Resid	173.2	13.4%									761	2.31	2.98	10.3%	2.10	3.56	90.7	624		48	0.07	6	0.01	53	0.08	1.3%	0.16	0.27	
Industrial	Ind	374.4	29.0%									3,000			10.3%	2.10	3.56	196.1			409	0.59	47	0.07	455	0.66	11.3%	1.38	2.34	
Legacy Bend	Resid	77.7	6.0%									761	2.31	2.98	10.3%	2.10	3.56	40.7	280		22	0.03	2	0.00	24	0.03	0.6%	0.07	0.12	
Northwest Residential	Resid	120.7	9.4%									761	2.31	2.98	10.3%	2.10	3.56	63.2	435		33	0.05	4	0.01	37	0.05	0.9%	0.11	0.19	
Nor-Park	Resid	23.3	1.8%									761	2.31	2.98	10.3%	2.10	3.56	12.2	84		6	0.01	1	0.00	7	0.01	0.2%	0.02	0.04	
Parks/Recreation	Park	139.0	10.8%									**650**			10.3%	2.10	3.56	72.8			33	0.05	4	0.01	37	0.05	0.9%	0.11	0.19	
Wyndam Hills	Resid	43.8	3.4%									761	2.31	2.98	10.3%	2.10	3.56	22.9	158		12	0.02	1	0.00	14	0.02	0.3%	0.04	0.07	
Subtotal		1289.3	100.0%															675.4	**1,769**	**1,776**	**672**	**0.97**	**77**	**0.11**	**750**	**1.08**	**18.6%**	**2.27**	**3.85**	**610**
4. Woodland Park (3)															10.3%	2.10	3.56		1,800		**100**	**0.14**	**11**	**0.02**	**111**	**0.16**	**2.8%**	**0.34**	**0.57**	
TOTAL (4)																			**26,572**	**26,579**	**3,621**	**5.20**	**409**	**0.59**	**4,030**	**5.79**	**100.0%**	**12.16**	**20.64**	
TOTAL (with Woodland Pk)																			**28,372**											**204**
Scenario 4 - Target 2030 Population Increase of 1,771 Persons, 2021 Sales, 1,500 gpd/acre Industrial Use Rate, MD/AD = 2.02, MH/AD = 3.56																												
1. Existing Zones 1 & 2 (2021 Sales)	**Adj Factor**																											
Residential	**1.3270**	2,743.5		**2.088**	52.1%	**761**	2.328	2.31	24,803	9.04	3.91	761	2.31	3.91	10.3%	2.02	3.56				1,454	2.09	167	0.24	1,621	2.33	42.6%	4.70	8.30	
Commercial	**1.0800**	1,337.1		**1.226**	30.6%	**917**	1.367					917			10.3%	2.02	3.56				854	1.23	98	0.14	952	1.37	25.0%	2.76	4.87	
Industrial	**0.9662**	228.5		**0.695**	17.3%	**3,042**	0.775					3,042			10.3%	2.02	3.56				484	0.70	56	0.08	540	0.77	14.2%	1.57	2.76	
Subtotal		4,309.0		**4.009**	100.0%		4.469												24,803	24,803	**2,792**	**4.01**	**320**	**0.46**	**3,112**	**4.47**	**81.9%**	**9.03**	**15.93**	**180**
2. Zone 4 Customers (2021 Sales)																												
Norfolk Iron & Metal				0.003												2.02	3.56				2.4	0.00	0	0.00	2	0.00	0.1%	0.01	0.01	
Nucor Steel (Potable)				0.063												2.02	3.56				43.6	0.06	0	0.00	44	0.06	1.1%	0.13	0.22	
Regional Center				0.015												2.02	3.56				10.3	0.01	0	0.00	10	0.01	0.3%	0.03	0.05	
Subtotal				0.081																	**56.3**	**0.08**	**0**	**0.00**	**56.3**	**0.08**	**1.4%**	**0.16**	**0.29**	
Subtotal Existing Zones 1, 2, 4																					**2,848**	**4.09**	**320**	**0.46**	**3,168.7**	**4.55**	**83.3%**	**9.19**	**16.22**	
3. Future Growth Areas																												
Blackberry	Resid	33.4	2.6%									761	2.31	2.98	10.3%	2.02	3.56	17.5	121		9	0.01	1	0.00	10	0.01	0.3%	0.03	0.05	
Channel Road	Resid	18.6	1.4%									761	2.31	2.98	10.3%	2.02	3.56	9.7	67		5	0.01	1	0.00	6	0.01	0.2%	0.02	0.03	
Commercial/Public	Comm	285.3	22.1%									917			10.3%	2.02	3.56	149.4			95	0.14	11	0.02	106	0.15	2.8%	0.31	0.54	
East Side Residential	Resid	173.2	13.4%									761	2.31	2.98	10.3%	2.02	3.56	90.7	624		48	0.07	6	0.01	53	0.08	1.4%	0.16	0.27	
Industrial	Ind	374.4	29.0%									1,500			10.3%	2.02	3.56	196.1			204	0.29	23	0.03	228	0.33	6.0%	0.66	1.17	
Legacy Bend	Resid	77.7	6.0%									761	2.31	2.98	10.3%	2.02	3.56	40.7	280		22	0.03	2	0.00	24	0.03	0.6%	0.07	0.12	
Northwest Residential	Resid	120.7	9.4%									761	2.31	2.98	10.3%	2.02	3.56	63.2	435		33	0.05	4	0.01	37	0.05	1.0%	0.11	0.19	
Nor-Park	Resid	23.3	1.8%									761	2.31	2.98	10.3%	2.02	3.56	12.2	84		6	0.01	1	0.00	7	0.01	0.2%	0.02	0.04	
Parks/Recreation	Park	139.0	10.8%									**650**			10.3%	2.02	3.56	72.8			33	0.05	4	0.01	37	0.05	1.0%	0.11	0.19	
Wyndam Hills	Resid	43.8	3.4%									761	2.31	2.98	10.3%	2.02	3.56	22.9	158		12	0.02	1	0.00	14	0.02	0.4%	0.04	0.07	
Subtotal		1289.3	100.0%															675.4	**1,769**	**1,776**	**468**	**0.67**	**54**	**0.08**	**522**	**0.75**	**13.7%**	**1.52**	**2.68**	**425**
4. Woodland Park (3)															10.3%	2.02	3.56		1,800		**100**	**0.14**	**11**	**0.02**	**111**	**0.16**	**2.9%**	**0.32**	**0.57**	
TOTAL (4)																			**26,572**	**26,579**	**3,416**	**4.91**	**386**	**0.55**	**3,802**	**5.46**	**99.9%**	**11.04**	**19.47**	
TOTAL (with Woodland Pk)																			**28,372**											**193**

Red numbers represent Planning Criteria. **Bold Blue** numbers represent numbers for which existing system values are not available. **Green Bold** numbers represent 2040 increased population served and 2040 increased service population target.

Shaded cells represent planning criteria changed for the particular Demand Scenario. (1) Resid = Residential, Comm = Commercial, Ind = Industrial. (2) Demand equals sales plus Unaccounted-for water.

(3) Woodland Park Residential water use estimated to be 80 gpcd. (4) 2040 Population excludes Woodland Park. (5) Includes Woodland Park demand and population.

Table A-3 Amendment 4 Scenario 1 Development Areas and Demands

DEVELOP-MENT AREA NO.	AREA ADJUSTMENT FACTOR	ADJUSTED AREAS & DEMANDS BY ZONE (ACRES)						AVE DAY GPD PER ACRE	FUTURE DEMANDS & DEMAND FACTORS				
		1	2	3	4	5	Total		Ave Day (gpm)	Ave Day (mgd)	MD/AD	Max Day (gpm)	Max Day (mgd)
Scenario 1 - West, North, & South Sides (Development Areas 1, 2E, 3), 16.0 mgd													
Subtotal Areas 1, 2E, 3									1,109	1.60		2,242	3.23
Total 2030 Comprehensive Plan plus Areas 1, 2E, 3										7.40			14.95
Total 2040 Comprehensive Plan plus Areas 1, 2E, 3										8.38			16.93
Adj Factor	**0.7125**												
Adjusted Areas		**Adjusted Area (Acres) by Zone**											
1		364	0	0	0	0	364						
2E		186	272	269	0	0	727						
3		0	185	160	0	0	345						
Adjusted Demands		**Adjusted Average Day Demand by Zone (gpm)**											
1		200	0	0	0	0	200	793					
2E		102	150	148	0	0	400	793					
3		0	102	88	0	0	190	793					
Total (gpm)		303	252	236	0	0	790						
Total (mgd)		0.436	0.363	0.340	0.000	0.000	1.138						
		Adjusted Maximum Day Demand by Zone (gpm)											
1		405	0	0	0	0	405				2.02		
2E		207	303	299	0	0	809				2.02		
3		0	206	178	0	0	384				2.02		
Total (gpm)		611	509	477	0	0	1,597						
Total (mgd)		0.881	0.733	0.687	0.000	0.000	**2.300**						
Total 2040 + Amendment 4 Areas (mgd)							**16.000**						

Table A-3 (Continued) Amendment 4 Scenario 2 Development Areas and Demands

DEVELOPMENT AREA NO.	AREA ADJUSTMENT FACTOR	ADJUSTED AREAS & DEMANDS BY ZONE (ACRES)						AVE DAY GPD PER ACRE	FUTURE DEMANDS & DEMAND FACTORS				
		1	2	3	4	5	Total		Ave Day (gpm)	Ave Day (mgd)	MD/AD	Max Day (gpm)	Max Day (mgd)
Scenario 2 - South & East Sides (Development Areas 1, 5, 6, 9), 15.8 mgd													
Subtotal Areas 1, 5 ,6, 9									761	1.10		1,537	2.21
Total 2030 Comprehensive Plan plus Areas 1, 5, 6, 9										6.90			13.93
Total 2040 Comprehensive Plan plus Areas 1, 5, 6, 9										7.88			15.91
Adj Factor	**1.0000**												
Areas		**Area (Acres) by Zone**											
1		510	0	0	0	0	510						
5		0	0	0	0	92	92						
6		0	0	0	0	254	254						
9		0	0	0	459	0	459						
Demands		**Average Day Demand by Zone (gpm)**											
1		281	0	0	0	0	281	793			2.02		
5		0	0	0	0	50	50	793			2.02		
6		0	0	0	0	140	140	793			2.02		
9		0	0	0	253	0	253	793			2.02		
Total (gpm)		281	0	0	253	190	724						
Total (mgd)		0.405	0.000	0.000	0.364	0.274	1.043						
		Maximum Day Demand by Zone (gpm)											
		568	0	0	0	0	568						
		0	0	0	0	102	102						
		0	0	0	0	283	283						
		0	0	0	511	0	511						
Total (gpm)		568	0	0	511	385	1,464						
Total (mgd)		0.818	0.000	0.000	0.736	0.554	**2.108**						
Total 2040 + Amendment 4 Areas (mgd)							**15.808**						

Table A-3 (Continued) Amendment 4 Scenario 3 Development Areas and Demands

DEVELOPMENT AREA NO.	AREA ADJUSTMENT FACTOR	ADJUSTED AREAS & DEMANDS BY ZONE (ACRES)						AVE DAY GPD PER ACRE	FUTURE DEMANDS & DEMAND FACTORS				
		1	2	3	4	5	Total		Ave Day (gpm)	Ave Day (mgd)	MD/AD	Max Day (gpm)	Max Day (mgd)
Scenario 3 - Balanced Adjusted (Development Areas 1, 2E, 3, 5, 6), 16.0 mgd													
Subtotal Areas 1, 2E, 3, 5, 6									1,300	1.87		2,627	3.78
Total 2030 Comprehensive Plan plus Areas 1, 2E, 3, 5, 6										7.67			15.50
Total 2040 Comprehensive Plan plus Areas 1, 2E, 3, 5, 6										8.65			17.48
Adj Fac	**0.6080**												
Adjusted Areas		**Adjusted Area (Acres) by Zone**											
1		310	0	0	0	0	310						
2E		159	232	229	0	0	620						
3		0	158	137	0	0	294						
5		0	0	0	0	56	56						
6		0	0	0	0	155	155						
Adjusted Demands		**Adjusted Average Day Demand (gpm)**											
1		171	0	0	0	0	171	793			2.02		
2E		87	128	126	0	0	342	793			2.02		
3		0	87	75	0	0	162	793			2.02		
5		0	0	0	0	31	31	793			2.02		
6		0	0	0	0	85	85	793			2.02		
Total (gpm)		258	215	201	0	116	790						
Total (mgd)		0.372	0.309	0.290	0.000	0.167	1.138						
		Adjusted Maximum Day Demand (gpm)											
1		345	0	0	0	0	345						
2E		177	259	255	0	0	690						
3		0	176	152	0	0	328						
5		0	0	0	0	62	62						
6		0	0	0	0	172	172						
Total (gpm)		522	434	407	0	234	1,597						
Total (mgd)		0.751	0.625	0.586	0.000	0.337	**2.300**						
Total 2040 + Amendment 4 Areas (mgd)							**16.000**						

Table A-3 (Continued) Amendment 4 Scenario 4 Development Areas and Demands

DEVELOPMENT AREA NO.	AREA ADJUSTMENT FACTOR	ADJUSTED AREAS & DEMANDS BY ZONE (ACRES)						AVE DAY GPD PER ACRE	FUTURE DEMANDS & DEMAND FACTORS				
		1	2	3	4	5	Total		Ave Day (gpm)	Ave Day (mgd)	MD/AD	Max Day (gpm)	Max Day (mgd)
Scenario 4 - Balanced (Development Areas 1, 2E, 3, 5, 6), 17.5 mgd													
Subtotal Areas 1, 2E, 3, 5, 6									1,300	1.87		2,627	3.78
Total 2030 Comprehensive Plan plus Areas 1, 2E, 3, 5, 6										7.67			15.50
Total 2040 Comprehensive Plan plus Areas 1, 2E, 3, 5, 6										8.65			17.48
Adj Fac	**1.0000**												
Areas		**Area (Acres) by Zone**											
1		510	0	0	0	0	510						
2E		261	382	377	0	0	1,020						
3		0	259	225	0	0	484						
5		0	0	0	0	92	92						
6		0	0	0	0	254	254						
Demands		**Average Day Demand (gpm)**											
1		281	0	0	0	0	281	793			2.02		
2E		144	211	208	0	0	562	793			2.02		
3		0	143	124	0	0	267	793			2.02		
5		0	0	0	0	50	50	793			2.02		
6		0	0	0	0	140	140	793			2.02		
Total (gpm)		425	353	331	0	190	1,300						
Total (mgd)		0.612	0.509	0.477	0.000	0.274	1.872						
		Maximum Day Demand (gpm)											
1		568	0	0	0	0	568						
3		290	425	420	0	0	1,135						
5		0	289	250	0	0	539						
6		0	0	0	0	102	102						
		0	0	0	0	283	283						
Total (gpm)		858	714	670	0	385	2,627						
Total (mgd)		1.236	1.028	0.964	0.000	0.554	**3.783**						
Total 2040 + Amendment 4 Areas (mgd)							**17.483**						

3.0 Existing Distribution System Facilities

Water is delivered to the City's distribution system through a complex system of pump stations, pipelines, and storage tanks/reservoirs. This section describes the major physical facilities that comprise the City's water transmission/distribution system.

The major pumping stations, storage facilities, pipes, and pressure zone boundaries that make up the transmission/distribution system and are represented in the hydraulic model are show Figure 3-1.

3.1 SUPPLY AND TREATMENT

West Well Field. The West Well Field (WWF) is located southeast of the West Water Treatment Plant (WWTP) and is the raw water source for the WWTP. The WWF includes seven (7) vertical wells (Well Nos. 6 through 12) and a horizontal collector well (Well No. 13). The wells extract water from an alluvial aquifer underlain by shale or limestone bedrock.

The WWF vertical Well Nos. 6 through 11were installed in the 1960s and 1970s. Well No. 12 was installed in 1991. The firm pumping capacities of the vertical well are approximately 560 to 980 gallons per minute (gpm). Well No. 13 was constructed in 2004 and has a capacity of approximately 3,000 gpm.

Layne completed a capacity modeling study for the WWF (Layne, 2021). The West Well Field will have a rated peak day pumping rate of 14.5 mgd and a sustainable yield of 7.8 to 9.6 mgd.. The Layne modeling study estimated the capacity of a future WWF Well No. 14 collector well to be approximately **2,600 gpm (3.7 mgd)** while pumping existing Well No. 13 at its design capacity of 3,000 gpm [assuming 100% efficiency at new Well No. 14].

East Well Field. The East Well Field (EWF) is the raw water source for the East Water Treatment Plant (EWTP). The EWF is located in close proximity to the EWTP and includes five wells, Well Nos. 1 through 5. EWF Well No. 2 is no longer used to supply water to the EWTP. The EWF capacity is rated at **3.7 mgd**.

West Water Treatment Plant. The WWTP is located at 300 South 49th Street and serves as the primary source of potable water for the City. The WWTP was constructed in 1975, with filter improvements completed in 2003.

WWTP treatment processes include aeration, reaction basins to precipitate and remove oxidized iron particles, chlorination, and rapid sand filtration. Chlorine is added after the reaction basin at approximately 1.8 to 2.1 mg/L to maintain a target chlorine residual of 1.1 to 1.15 mg/L. From the filters, treated water flows to a clearwell where it is pumped to a 2 million gallon (MG) above ground storage tank. The 2 MG storage tank serves as suction storage for the WWTP Pump Station, which delivers water to distribution system Zones 1 and 2.

The Nebraska Department of Environment & Energy (NDEE) rated the current WWTP capacity at **10.5 mgd**. WWTP improvements identified in the *City of Norfolk, NE, Task 452 – WTP Capacity Evaluation Technical Memorandum (Black & Veatch, July 19, 2021)* would increase the WWTP rated capacity to **14.5 mgd**.

(Blank Page)

Zone 3 Future
Zone 2 Future
Zone 1 Future
Zone 4 Elevated Tank
0.75 MG, O.F. Elev. 1,789 Ft.
Zone 4
Zone 2 Tank
1.1 MG, O.F. Elev. 1,789 Ft.
Zone 3
Zone 3 Future
Zone 2
Zone 3 Future
Zone 2 Future
Zone 1 (Dirt) Tank
0.75 MG, O.F. Elev. 1,701 Ft.
16th St. Pump Sta.
(Zone 2)
29th St. Pump Sta.
(Zone 2)
NE Industrial Pump Sta. (Zone 4)
Zone 4 Future
Zone 5 Future
Eastern Hts.
Pump Sta.
East Water Treatment Plant
0.79 MG, O.F. Elev. 1,517 Ft.
Zone 1 Pump Sta.
Zone 1
West Water Treatment Plant
2.2 MG Tank, O.F. Elev. 1,589 Ft.
Zone 1 & 2 Pump Sta.
Zone 1 Future
Zone 1 Future

Water Master Plan Update
City of Norfolk, Nebraska
Existing Distribution
System Facilities
Figure 3-1

LEGEND

12" Pipe & Diameter (in)

Storage Tank/Reservoir

PS Pump Station

Distribution System Pressure Zones

- Zone 1
- Zone 2
- Zone 3
- Zone 4
- Zone 1 (Future)
- Zone 2 (Future)
- Zone 3 (Future)
- Zone 4 (Future)
- Zone 5 (Future)

Norfolk NEBRASKA right at home.

BLACK & VEATCH Building a world of difference.

NORFOLK_INFOWATER_PRO40.aprx
January 26, 2023

(Blank Page)

East Water Treatment Plant. The EWTP is located at 111 South 1st Street and is suppled from the EWF. The EWTP was constructed in 1933, with filter improvements completed in 1956, chlorine scrubber improvements in 1998, and backwash improvements in 2009. The EWTP typically only operates during the peak demand season.

The Nebraska Department of Environment & Energy rated the EWTP capacity at **3.0 mgd**. The *City of Norfolk, NE, Task 452 – WTP Capacity Evaluation Technical Memorandum (Black & Veatch, July 19, 2021)* identified the filters as the primary capacity constraint at the EWTP.

3.2 PRESSURE ZONES

In order to provide adequate service to its customers at acceptable pressures Norfolk's distribution system is currently divided into three (3) pressure zones – Zones 1, 2, and 4. [While the service area for Zone 3 has been delineated, service to Zone 3 has not yet been established.] Pressure zone boundaries are based on storage facility overflow (or maximum water level) elevations, distribution system hydraulics, and ground elevations. The City's goal is to maintain a minimum distribution system pressure of 35 psi during peak demand conditions.

Pressure zone static hydraulic grade line (HGL) elevations, tank elevations and depths, and maximum and minimum elevations served within the pressure zones are given in Table 3-1 and shown on Figure 3-1. The static HGL elevation within each pressure zone is established by the overflow/high water elevation of the storage facility serving the pressure zone.

Table 3-1 Pressure Zones

PRESSURE ZONE	TANK				PRESSURE ZONE & TANK ELEVATIONS & HGLS (FT)						WOOD-LAND PARK MAX PRES-SURE AT ELEV 1652' (PSI) (3)
	Name	Vol-ume (MG)	Depth (Ft)	Elevat-ed Tank Height (Ft)	Floor/ Bottom of Bowl Eleva-tion	Ground Eleva-tion	Static HGL (Over-flow/ High Water Eleva-tion)	HGL at 50% Full	Maxi-mum Eleva-tion Served (Ft) (1)	Mini-mum Eleva-tion Served (Ft) (2)	
1	Dirt Tank	0.75	27.0	-	1,674	1,674.0	1,701	1,687.5	1,595	1,493	
2	Zone 2	1.00	24.0	-	1,765	1,765.0	1,789	1,777.0	1,684	1,581	
3	Zone 3	-	-	-	-	-	-	-	1,780	1,680	
4	Zone 4 Elevated Tank	0.75	40.0	136.5	1,749	1,652.5	1,789	1,769.0	1,676	1,581	
5 (Initial)	Woodland Park Standpipe	0.09	110.0	-	1,725	1,725.0	1,835	1,780.0	1,687	1,627	
5 (Expand-ed)	Future Zone 5 Elevated Tank	-	-	-	-	-	1,855	1,835.0	1,742	1,647	88

(1) Equivalent to 40 psi static pressure with tank 50% full.
(2) Equivalent to 90 psi static pressure with tank water level at overflow elevation.
(3) Pressure at elevation 1,652 feet (Woodland Park lowest elevation/customer served); future Zone 5 Elevated Tank 100% full.

Maximum and minimum customer ground elevations served and given in Table 3-1 are based on the following service criteria:

- Maintain a minimum pressure of 40 psi when the zone tank is 50% full.
- Maintain a maximum pressure of 90 psi with the zone tank is 100% full.

Pressure Zone 1, Static HGL 1,701 feet. Zone 1 is the largest zone in the system with a static HGL of 1,701 feet established by the overflow elevation of the Zone 1 "Dirt Tank". Zone 1 serves customer ground elevations from approximately 1,493 to 1,595 feet.

Pressure Zone 2, Static HGL 1,789 feet. Zone 2 is located in the northwestern part of the City and has a static HGL of 1,789 feet established by the overflow elevation of the Zone 2 ground storage tank. Zone 2 serves customer ground elevations from approximately 1,581 to 1,684 feet.

Pressure Zone 3 (Not yet in Service). Zone 3 is not yet in serve. Initial Zone 3 boundaries identified by the City and future Zone 3 boundaries to serve Amendment 4 development areas are shown on Figure 3-1 and will serve customer ground elevations from approximately 1,680 to 1,780 feet.

Pressure Zone 4, Static HGL 1,789 feet. Zone 4 is located in the northeastern part of the City and has a static HGL of 1,790 feet established by the overflow elevation of the Zone 4 Elevated Tank. Zone 4 serves customer ground elevations from approximately 1,581 to 1,676 feet. Zones 2 and 4 have the same static HGL (1,789 feet).

Pressure Zone 5 (Initial), Static HGL 1,835 feet (Not yet in Service). Zone 5 would initially be created by providing service to Woodland Park. The initial Zone 5 static HGL of 1,835 feet would be established by the overflow elevation of the Woodland Park Standpipe. The initial Zone 5 boundaries will serve customer ground elevations from approximately 1,627 to 1,687 feet.

Pressure Zone 5 (Future), Static HGL 1,855 feet (Not yet in Service). A future expanded Zone 5 would serve areas east of the initial Zone 5 boundary up to customer ground elevation 1,742 feet. The future expanded Zone 5 would be served by a future Zone 5 Elevated Tank with and overflow elevation of approximately 1,855 feet, approximately 20 feet higher than the Woodland Park Standpipe overflow elevation of 1,835 feet.

Eastern Heights Service Area. The Eastern Heights service area represents a small, localized area consisting of the Easter Heights subdivision. This area is supplied by the Eastern Heights Pump Station which boosts water from Zone 1 to Eastern Heights. No floating storage exists within the Eastern Heights service area.

3.3 PUMPING STATIONS

The distribution system includes six (6) high service pumping and booster pumping stations as shown on Figure 3-1. Pumping station total and firm capacities are given in Table 3-2.

The WWTP Pumping Station conveys water from the WWTP to Zones 1 and 2; the EWTP Pumping Station conveys water from the EWTP to Zone 1. The 16th Street, 29th Street, Northeast Industrial, and Eastern Heights Pumping Station convey water from Zone 1 to Zones 2 and 4 and the Eastern Heights service area.

Table 3-2 Pumping Station Total and Firm Pumping Capacities

PUMPING STATION	ZONE/ SERVICE AREA	DESIGN CAPACITY			
		Total (1)		Firm (2)	
		(gpm)	(mgd)	(gpm)	(mgd)
West WTP	1	13,000	18.72	9,500	13.68
	2	5,200	7.49	3,200	4.61
East WTP	1	4,775	6.88	3,275	4.72
16th Street	2	1,520	2.19	760	1.09
29th Street	2	2,400	3.46	1,600	2.30
Northeast Industrial	4	4,110	5.92	2,110	3.04
Eastern Heights	Eastern Heights	1,500	2.16	500	0.72
Zone 1 Total		17,775	25.60	12,775	18.40
Zone 2 Total		9,120	13.13	5,560	8.01

(1) Total design capacity based on sum of individual pump "nameplate" capacities.
(2) Largest pump out of service.

West Water Treatment Plant Pumping Station. The WWTP Pumping Station is located within the WWTP and includes four (4) Zone 1 pumps and two (2) Zone 2 pumps. The pumps take suction from the WWTP 2 MG above ground storage tank. The WWTP Pumping Station Zone 1 total and firm pumping capacities are **18.7 and 13.7 mgd**, respectively. The WWTP Pumping Station Zone 2 total and firm pumping capacities are **7.5 and 4.6 mgd**, respectively.

East Water Treatment Plant Pumping Station. The EWTP Pumping Station is located within the EWTP and includes four (4) Zone 1 pumps. EWTP Pump No. 3 is equipped with a natural gas engine. The pumps take suction from the EWTP clearwells. The EWTP Pumping Station total and firm pumping capacities are **6.9 and 4.7 mgd**, respectively.

16th Street and 29th Street Pumping Station. The 16th Street and 29th Street Pumping Stations are booster pump stations that convey water from Zone 1 to Zone 2.

Northeast (NE) Industrial Pumping Station. The NE Industrial Pumping Station is a booster pumping station that conveys water from Zone 1 to Zone 4. The NE Industrial Street Pumping Station has total and firm pumping capacities of **5.9 and 3.0 mgd**, respectively.

Eastern Heights Pumping Station. The Eastern Heights Pumping Station is a booster pump station that convey water from Zone 1 to the Eastern Heights subdivision.

Zone 1 and 2 Total and Firm Pumping Capacities. The total and firm pumping capacities of all pumping stations conveying water to Zone 1 are **25.6 and 18.4 mgd**, respectfully. The total and firm pumping capacities of all pumps conveying water to Zone 2 are **13.1 and 8.0 mgd**, respectfully.

Individual pump information is given in Table 3-3.

Table 3-3 Pump Design Flows and Heads

PUMP STATION	PUMP NO.	ZONE	DESIGN CAPACITY			DRIVE (1)
			Flow		Head	
			(gpm)	(mgd)	(ft)	
West WTP	2	1	3,500	5.04	180	CSD
	3		3,500	5.04	180	CSD
	4		2,500	3.60	150	VFD
	5		3,500	5.04	196	VFD
	1	2	1,600	2.30	245	CSD
	2		1,600	2.30	245	CSD
East WTP	1	1	975	1.40	240	CSD
	2		1,500	2.16	240	CSD
	3 (2)		800	1.15	240	CSD
	4		1,500	2.16	240	CSD
16th Street	1	2	760	1.09	100	CSD
	2		760	1.09	100	CSD
29th Street	1	2	800	1.15	95	CSD
	2		800	1.15	95	CSD
	3		800	1.15	96	CSD
Northeast Industrial	-	4	70	0.10	140	VFD
	-		70	0.10	140	VFD
	-		70	0.10	140	VFD
	1		400	0.58	113	VFD
	2		1,500	2.16	123	VFD
	4		2,000	2.88	130	VFD
Eastern Hts	1	Eastern Hts	100	0.14	100	VFD
	2		400	0.58	100	VFD
	3		400	0.58	100	VFD
	4		1,00	1.44	100	VFD

(1) CSD = Constant Speed Drive, VFD = Variable Speed Drive.
(2) Natural Gas Engine.

Pump Operations and Controls. Pump operations and controls are summarized below.

- ***WWTP Zone 1 Pump Nos. 4 and 5 (VFDs).*** Pump Nos. 4 and 5 are equipped with variable frequency drives (VFDs) and have a duty selection interlock with the SCADA controller. The interlock prevents Pump Nos. 4 and 5 from operating concurrently. The pumps are set to operate when water levels in the Zone 1 Dirt Tank reach 24.5 feet.
- ***Northeast Industrial Pump Station.*** The Northeast Industrial Pump Station currently includes automated pump controls/logic to operate one pump at a time and maintain a target discharge pressure of 80 psi. If Pump No. 1 (400 gpm) cannot maintain the discharge pressure it is turned off and Pump No. 2 (1,500 gpm) is turned on. When the pump discharge pressure is maintained above the set point and the discharge flow decreases the pumps shut down in the reverse order.

- ***Northeast Industrial Pump Station – Package (70 gpm Jockey) Pumps.*** The Northeast Industrial Pump Station package (70 gpm jockey) pumps step through operation of the three pumps to maintain the target discharge pressure. If the discharge pressure cannot be maintained by the 3 package pumps, then Northeast Industrial Pump Station Pump No. 1 (400 gpm) starts and the package pumps are off.
- ***Eastern Heights Pump Station.*** The Eastern Heights Pump Station includes automated pump controls/logic to operate one pump at a time and maintain a target discharge pressure of 80 psi. Pump No. 1 (100 gpm) is typically operated full-time. If Pump No. 1 cannot maintain the target discharge pressure, Pump Nos. 2 or 3 (400 gpm) are operated. SCADA controls switch operations between Pump Nos. 2 and 3 with only one pump running at a time.
- ***WWTP Zone 2 Pumps, EWTP Zone 1 Pumps, 16th Street Pump Station, 29th Street Pump Station.*** Pumps at these location are manually controlled by operations staff at the WWTP.

3.4 STORAGE FACILITIES (TANKS/RESERVOIRS)

The distribution system includes five (5) treated water storage tanks/reservoirs including the WWTP above ground storage tank and the EWTP clearwells. The WWTP 2 MG storage tank and EWTP clearwells provide suction storage to the WWTP and EWTP high service pumps. The Zone 1 "Dirt" Tank, Zone 2 Tank, and Zone 4 Elevated Tank provide "floating" storage in Zones 1, 2, and 4, respectively. The Zone 1 Tank, Zone 2 Tank, and Zone 4 Elevated Tank deliver water to their respective zones during peak demand periods and are replenished during off peak periods.

Information on the distribution system storage facilities is given in Table 3-4. The total suction storage at the WWTP and EWTP is 2.95 MG. The total floating storage in Zones 1, 2, and 4 is 2.6 MG. The total system storage including suction and floating storage is 5.5 MG.

Table 3-4 Storage Facilities (Tanks/Reservoirs)

TANK/RESERVOIR	ZONE	VOLUME (MG)	OVERFLOW/ MAXIMUM OPERATING ELEVATION (FT)	DEPTH (FT)
West Water Treatment Plant	-	2.16	1,589	45
East Water Treatment Plant	-	0.79	1,517	15
Zone 1 (Dirt Tank)	1	0.75	1,701	27
Zone 2	2	1.07	1,789	24
Zone 4	4	0.75	1,789	40
Total Suction Storage		2.95		
Total Floating Storage		2.57		
TOTAL		5.52		

3.5 DISTRIBUTION SYSTEM MAINS/PIPES

Pipe diameters and lengths were extracted from the City's GIS data. Pipe lengths and volumes for the various pipe diameters are given in Table 3-5 and shown on Figure 3-2. The distribution system includes approximately **181 miles** of pipe which is equivalent to a volume of **9.8 MG**. [Approximately 6,029 feet (1.1 mile) of pipe in the City's GIS is missing pipe diameter data.]

- 4-inch and 6-inch pipes account for **17.4%** and **35.3%** of the total pipe length, respectively.
- 8-inch and 12-inch pipes account for **15.7%** and **12.8%** of the total pipe length, respectively.
- 16-inch and 20-inch pipes account for **6.5%** and **2.5%** of the total pipe length, respectively.
- 24-inch pipes account for **4.0%** of the total pipe length.
- Pipes 8-inch and smaller account for **70%** of the total pipe length and **26%** of the total pipe volume.
- Pipes 12-inch and smaller account for **87%** of the total pipe length and **49%** of the total pipe volume.

Only 4% of the GIS pipe data included pipe installation information. Only 12% of the GIS pipe data included pipe material information. For this reason no breakdown of pipe installation or pipe material is given.

Table 3-5 Pipe Lengths and Volumes

PIPE DIAMETER (IN)	PIPE LENGTH (FT)	PERCENT OF TOTAL LENGTH	CUMULATIVE LENGTH (FT)	PERCENT OF CUMULATIVE LENGTH	PIPE VOLUME (GAL)	PERCENT OF TOTAL VOLUME	CUMULATIVE VOLUME (GAL)	PERCENT OF CUMULATIVE VOLUME
0.75	221	0.0%	221	0.0%	13	0.0%	13	0.0%
1	562	0.1%	783	0.1%	59	0.0%	72	0.0%
2	10,089	1.1%	10,872	1.1%	4,237	0.0%	4,309	0.0%
3	570	0.1%	11,442	1.2%	539	0.0%	4,848	0.0%
4	165,372	17.4%	176,814	18.6%	277,824	2.8%	282,672	2.9%
6	335,053	35.3%	511,868	53.9%	1,266,499	12.9%	1,549,171	15.8%
8	149,076	15.7%	660,943	69.6%	1,001,786	10.2%	2,550,957	26.0%
10	43,377	4.6%	704,320	74.1%	455,460	4.6%	3,006,417	30.6%
12	121,927	12.8%	826,247	87.0%	1,843,532	18.8%	4,849,949	49.4%
14	164	0.0%	826,411	87.0%	3,372	0.0%	4,853,321	49.4%
16	61,976	6.5%	888,388	93.5%	1,665,916	17.0%	6,519,237	66.4%
20	23,937	2.5%	912,325	96.0%	1,005,371	10.2%	7,524,608	76.6%
24	37,751	4.0%	950,076	100.0%	2,283,189	23.3%	9,807,797	99.9%
30	111	0.0%	950,188	100.0%	10,535	0.1%	9,818,332	100.0%
Total (Ft/Percent)	950,188	100.0%				100.0%		
Total (miles)	**180.0**							
Total (MG)					**9.82**			
0	6,029	0.6%						
Total Including Zero Diameter (Ft)	956,217							
Total Including Zero Diameter (mi)	**181.1**							

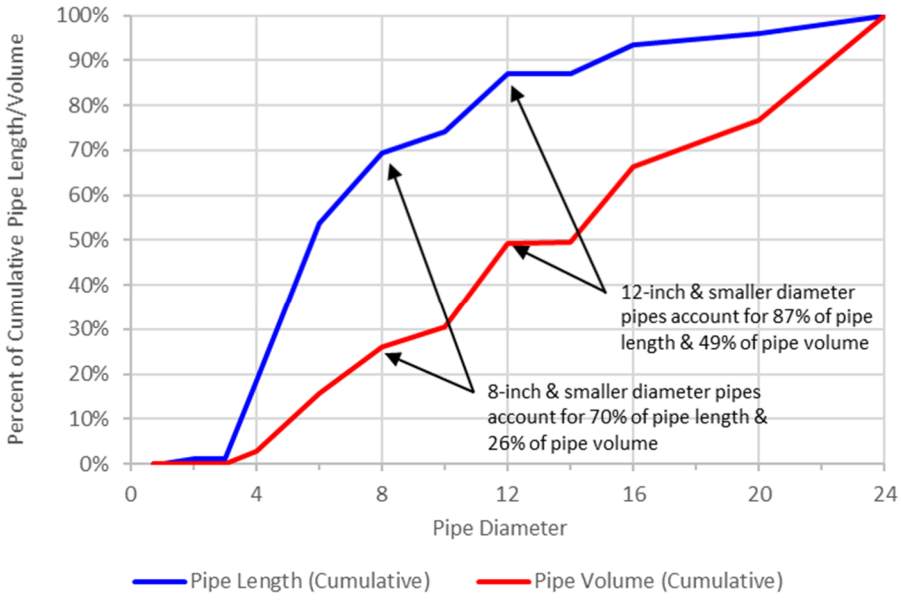


Figure 3-2, Pipe Cumulative Length and Volume as Percentage of Total Length and Volume

3.5.1 Electrical Power Generators

The distribution system includes a number of generators to provide electricity to facilities during power outages and maintain service to customers during emergency conditions. The electrical generators are described below.

- ***West Water Treatment Plant, 1,000 kW (1,490 Hp).*** Provides power to all treatment plant equipment.
- ***East Water Treatment Plant, 80 kW (128 Hp).*** Provides power to office lights and chlorine scrubber equipment.
- ***Northeast Industrial Pump Station, 300 kW (470 Hp).*** Provides power to all pump station equipment.
- ***Eastern Heights Pump Station, 100 kW (130 Hp).*** Provides power to all pump station equipment.
- ***Well Nos. 6 & 7, 125 kW (207 Hp).*** Portable generator provides power to Well Nos. 6 and 7 equipment.
- ***Well No. 12, 80 kW (135 Hp).*** Provides power to Well No. 12 equipment.
- ***Well No. 13, 200 kW (317 Hp).*** Provides power to Well No. 13 equipment.

4.0 Model Validation and Existing System Evaluation

The computer hydraulic model is an essential tool in analyzing water distribution systems and developing recommended improvements and a Capital Improvement Plan (CIP). The hydraulic model uses engineering equations and mathematical algorithms to determine flows, hydraulic grade line (HGL) elevations, and pressures that would occur in the distribution system under a specified set of demand and operating conditions.

The Innovyze INFOWATER PRO 4.0 computer program was used for the hydraulic analyses performed for this study. Tasks completed as part of the hydraulic model update and validation/calibration include the following.

- Pipes and facilities constructed since the 2008 Master Plan were reviewed and added to the model as required to assure the model reliably represents current facilities.
- The 2008 Master Plan model included **779** existing facilities pipes. The Water Master Plan 2022 Update model includes **947** existing facilities pipes. This represents **168** new pipes added to the model under this study. Additionally, the City's GIS data, which more accurately represents pipe locations, diameters, etc. compared to the old AutoCAD water basemap, was used to update a large number of model pipes.
- Year 2019 individual customer residential, commercial, and industrial average day metered sales data (water demands) was obtained, evaluated, and allocated to model junctions (pipe endpoints).
- 24 hours of operating data was obtained from SCADA for the July 27, 2021 maximum day demand condition.
- Demand pattens for July 27, 2021 (Table 2-6, Figure 2-8) were entered into the model and a 24-hour Extended Period Simulation (EPS) model validation/calibration analysis was performed.
- Hydraulic model validation/calibration was completed by comparing modeled tank levels and pump station flows during the 24-hour period to values recorded in SCADA.
- Results of the July 27, 2021 hydraulic model results were reviewed with regards to system pressures, pipe velocities and head loss, tank levels and storage utilization, etc. to evaluate existing system performance.

Detailed discussion of the model update, validation, and existing system evaluations is given in the following sections.

4.1 MODEL VALIDATION/CALIBRATION - JULY 27, 2021 MAXIMUM DAY

The July 27, 2021 model validation/calibration is discussed below.

4.1.1 Model Update

A major component of the model update included addition of the new Zone 4 piping and customers (*Norfolk, Nebraska, Northeast Loop (Zone 4) Hydraulic Analyses Technical Memorandum, Black & Veatch, January 19, 2019*). This includes the new Zone 4 main along Victory Road, John Doherty Drive, Northeast Industrial Highway, and Nucor Road. New Zone 4 customers include Norfolk Iron & Metal, Nucor, and a new customer located near Victory Road and Nucor Road.

4.1.2 July 27, 2021 Model Demands and Demand Factors

Year 2021 annual residential, commercial, and industrial customer metered sales data for 8,911 customers (see Section 2.4) was allocated to the hydraulic model using the INFOWATER Allocator tool. The Allocator "Nearest Pipe, Nearest Junction" option was used to allocate metered sales data to the model. Model demands were only allocated to pipe endpoints (model junctions) for pipes 16-inch and smaller.

The model was validated for the July 27, 2021 maximum demand and operating conditions. The July 27, 2021 maximum day and maximum hour demands are 9.85 and 15.4 mgd, respectively (Table 2-6, Figure 2-7). The maximum day hourly demands are computed in the model by multiplying the average day demands (average day metered sales) by the hourly demand factors in the pressure zones (Table 2-6, Figure 2-8).

4.1.3 July 27, 2021 Model Validation/Calibration Results (Scenario 27JULY2021)

The July 27, 2021 24-hour model validation/calibration analysis (Scenario 27JULY2021) was performed to confirm the INFOWATER PRO model accurately simulates actual performance in the City's water distribution system. Figures depicting hourly modeled tank levels and tank levels recorded by SCADA are shown on Figures 4-1, 4-2, and 4-3. Figures depicting hourly modeled pump station flows and flows recorded by SCADA for July 27, 2021 are shown on Figures 4-4 and 4-5.

The modeled Zone 1 and 2 tank water levels (Figures 4-1 and 4-2) reliably track the tank levels recorded by SCADA. This confirms that (1) the modeled hourly demands and demand patterns accurately simulate temporal demands in the system and (2) the modeled tanks, in response to hourly demands and pumping rates, correctly cycle through draft and replenishment modes.

The modeled WWTP, EWTP, and 29th Street pump station flows (Figures 4-4 and 4-5) reliably track the pump station flows recorded by SCADA. This confirms that the pump curves contained in the model accurately simulate the actual capacities of the pumps in the field.

In summary, the model update and July 27, 2021 maximum day 24-hour EPS validation analysis demonstrates that the City's INFOWATER PRO model reliably simulates actual distribution system performance and can be used to perform the existing system evaluation and future design year analyses in support of a Capital Improvement Plan (CIP).

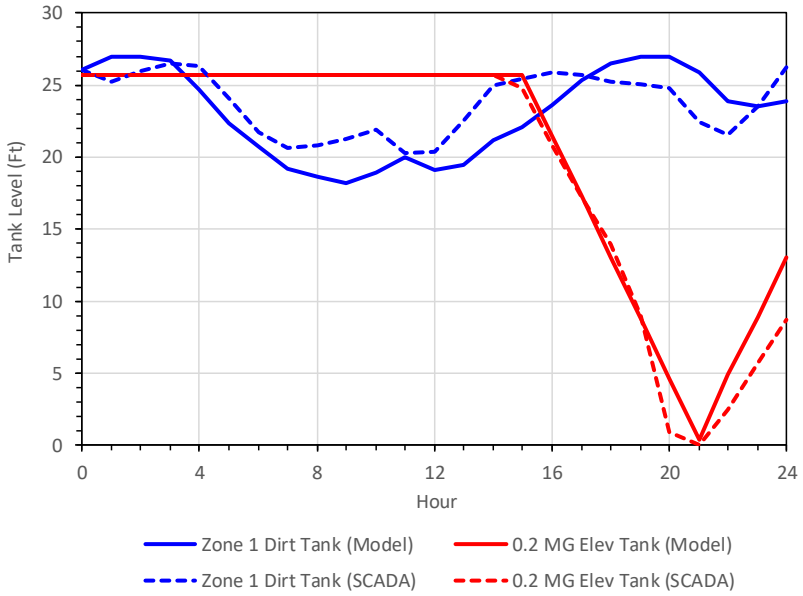


Figure 4-1, July 27, 2021 Maximum Day Zone 1 Tank Levels

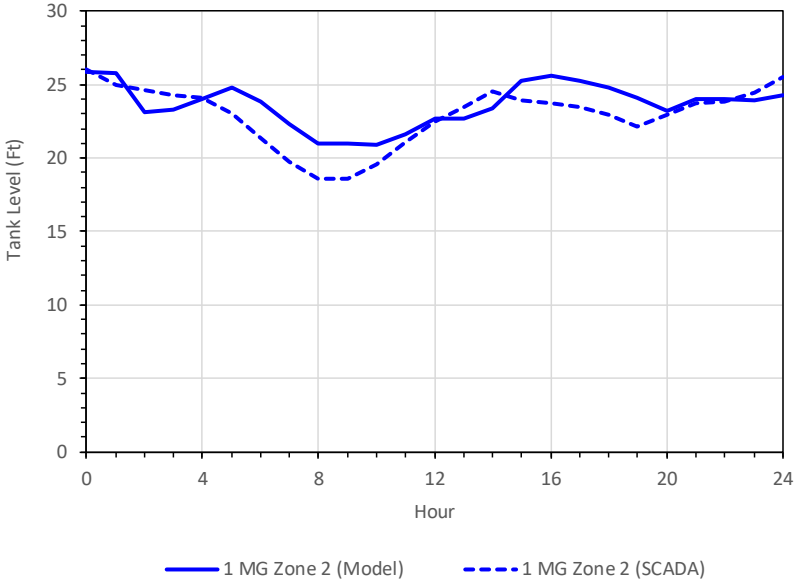


Figure 4-2, July 27, 201 Maximum Day Zone 2 Tank Levels

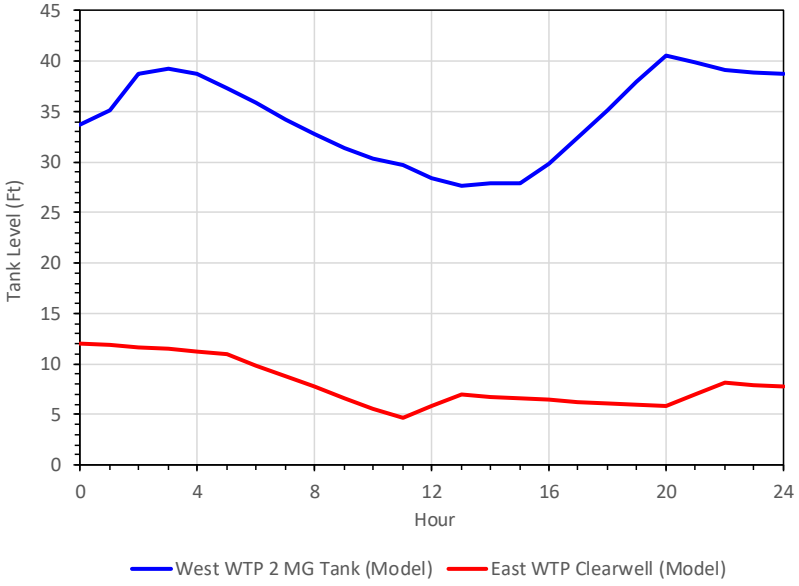


Figure 4-3, July 27, 2021 Maximum Day Treatment Plant Tank & Clearwell Levels

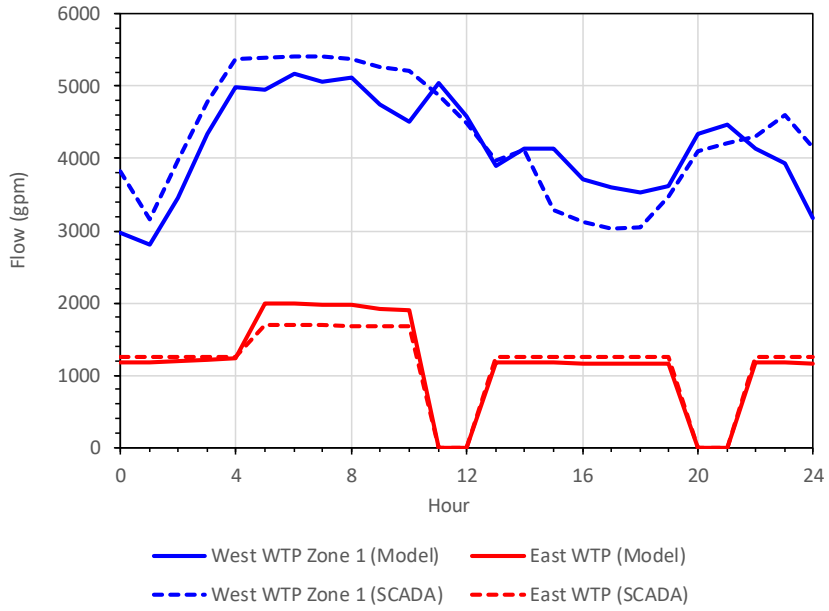


Figure 4-4, July 27, 2021 Maximum Day Zone 1 Pumping Station Flow Rates

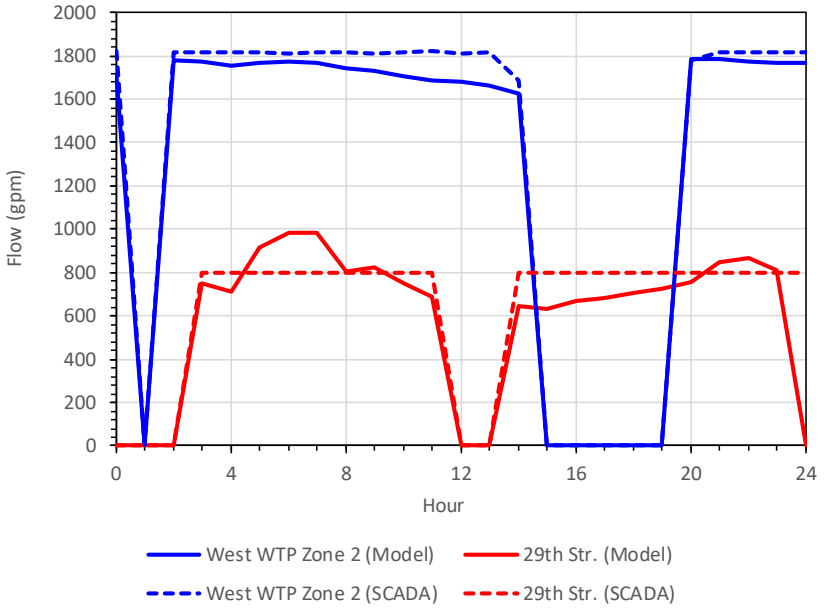


Figure 4-5, July 27, 2021 Maximum Day Zone 2 Pumping Station Flow Rates

4.2 EXISTING SYSTEM EVALUATION (SCENARIO 27JULY2021)

The July 27, 2021 maximum day demand hydraulic analysis (Scenario 27JULY2021) was used to evaluate the existing system hydraulic performance. Results of the July 27, 2021 maximum day model validation analysis at Hour 6 (6 a.m.) is shown on Figure 4-6. The following information and model results are shown on Figure 4-6.

- **Pipe diameter** at select pipes, with an emphasis on larger pipes (units inches).
- **Pipe flow** is shown for pipes at which pipe diameter is annotated (units gallons per minute [gpm]). [Pipe flows (**red numbers**) are typically shown above or to the right of the pipe.
- **Pipe velocity** is color coded for all pipes (units feet per second [fps]). High pipe velocities greater than 5 feet per second (fps) may be indicative of inadequate pipe hydraulic capacity and can lead to low pressures, increased pumping costs, fire flow deficiencies, etc.
- **Pipe flow direction (flow arrow)** is shown for most pipes. Flow direction is shown for pipe segments 1,000 feet in length or greater to avoid excessive detail/clutter.
- **System (dynamic) pressures** are colored coded at pipe end points/model junctions (units pounds per square inch [psi]). Junctions with pressures in the range of 40-90 psi (preferred operating range) are depicted by **green** symbols (circles).

Overall, there are very few existing system deficiencies for the July 27, 2021 demand and operating conditions.

- A small number of low pressures (less than 40 psi) were identified for the maximum hour demand condition (Hour 6, 6 a.m.). This includes the Zone 1 area near Highway 35 & Benjamin (39 psi) and the Zone 2 area near 37th Street and Golf View Drive (37 psi). However, pressures below 40 psi at these location are limited to hours during the morning peak demand period.
- With only a few exceptions, distribution system pipe velocities were less than 1 fps (**blue color**) or 1-2 fps (**green color**). A small number of Zone 2 small diameter pipes experienced maximum hour velocities in the 3-4 fps range (**orange color**). This included the Zone 2 8-inch main along Benjamin east of 37th Street and the Zone 2 10-inch main along Benjamin west of 25th Street.
- No pump station firm capacities were exceeded during the July 27, 2021 maximum day demand and operating conditions (Table 5-2). The July 27, 2021 WWTP Zone 1 and 2 average pumping rates were **45%** and **41%** of the station firm capacities. The EWTP Zone 1 and 29th Street Zone 2 average pumping rates were **36%** and **39%** of the station firm capacities.
- It is industry standard to reserve 50% of total storage volume for meeting peak hour demands. This storage volume is typically referred to as "equalization storage". All distribution system storage facilities (tanks/reservoirs) operated within acceptable water level ranges (Table 5-4). The WWTP 2 MG Tank, Zone 1 (Dirt) Tank, and Zone 2 Tank experienced maximum day utilization rates (maximum water volume minus minimum water volume) of **29%**, **32%**, and **19%**, respectively (expressed as a percentage of total tank storage volume). It is noted that the Zone 4 Elevated Tank was not in service on July 27, 2021.

In summary, no serious distribution system deficiencies were identified for the July 27, 2021 maximum day demand and operating conditions.

(Blank Page)

Water Master Plan Update
City of Norfolk, Nebraska
July 27, 2021 (9.8 mgd)
WWTP 8.2 mgd
EWTP 1.5 mgd
Results at Hr 6 (15.4 mgd)
Scenario 27JULY2021
Figure 4-6

LEGEND

Junction Pressure (psi)

- < 20
- 20 - 30
- 30 - 40
- 40 - 90
- 90 - 110
- > 110

174 / 12" — Pipe Flow (gpm), Direction & Diameter (in)

Pipe Velocity (fps)

- < 1
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

Norfolk NEBRASKA right at home.

BLACK & VEATCH Building a world of difference.

NORFOLK_INFOWATER_PRO40.aprx
February 2, 2023

(Blank Page)

4.3 MODEL MAINTENANCE

The City's water distribution system hydraulic model constructed for the City of Norfolk, Nebraska, Water Facilities Master Plan Update 2002 was constructed from the City's AutoCAD basemap. The City's distribution model has been updated for Water Master Plan 2008 Update and 2022 Update and other interim distribution planning studies.

The City has recently migrated from the AutoCAD water distribution system basemap to ESRI's ArcGIS software to maintain information on its water distribution system. This presents opportunities for the City to improve its water distribution hydraulic model and to reduce the time and effort to maintain its water distribution system model.

"All Pipes" INFOWATER PRO Model. Like the City, most utilities that maintain water distribution system models (1) build and maintain the hydraulic model from their GIS data and (2) represent "All Pipes" in the hydraulic model. These All Pipes models support (1) more accurate system-wide performance of hydraulic model, (2) more accurate customer demand allocation, (3) the ability to more reliably evaluate localized hydraulic conditions, and (4) more efficient maintenance of the hydraulic model.

Figure 4-7 shows a representative portion of the City's current INFOWATER PRO hydraulic model. Pipes included in the INFOWATER PRO model are show in **Blue**. GIS pipes are shown in **Red**. An updated Norfolk All Pipes model would include all GIS pipes.

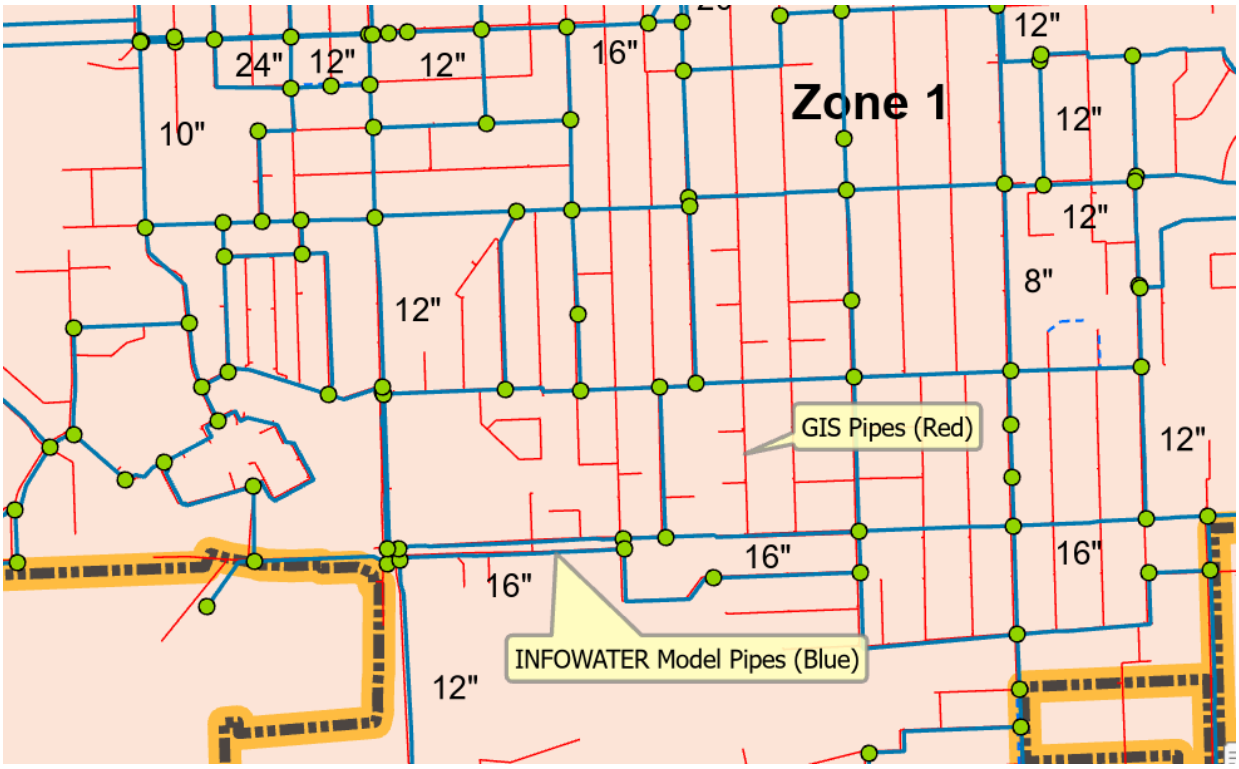


Figure 4-7, INFOWATER PRO Hydraulic Model and GIS Pipes

GIS Data Requirements to Support Model Update/Maintenance. While there are advantages to using GIS data to develop a new All Pipes model or to update/maintain the existing INFOWATER PRO model, there are GIS data requirements needed to effectively complete these tasks, including the following.

- GIS pipe segments/features need to be "snapped" other GIS pipe segments/features to eliminate pipe gaps, pipe "overshoots", connectivity errors, etc. Figure 4-8 shows common pipe gaps that exist in the City's GIS Data.

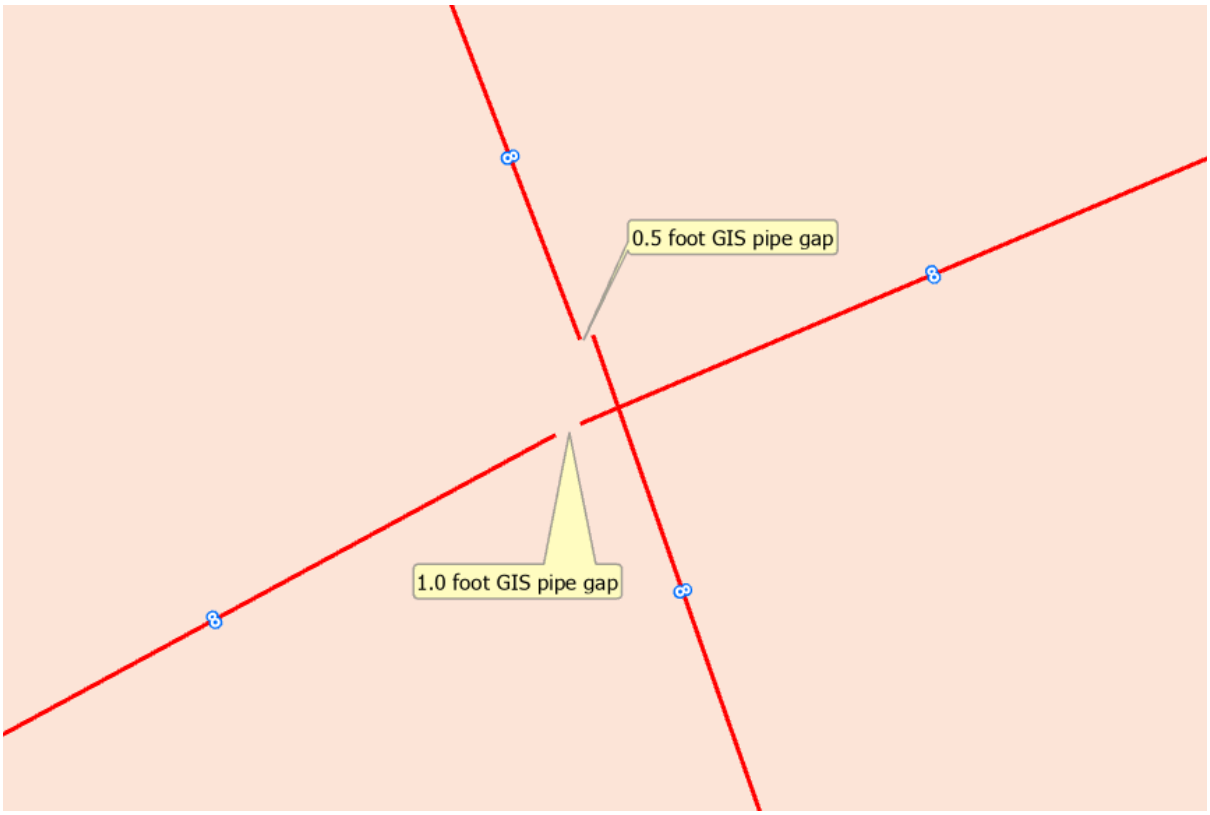


Figure 4-8, GIS Pipe Gaps (Connectivity Errors)

- Complete and reliable pipe installation dates and pipe material are required to compute hydraulic model pipe roughness coefficients (pipe "C" values). Only 4% of the current GIS pipe data includes pipe installation information. Only 12% of the GIS pipe data included pipe material information. Pipe installation date and material attribute data will need to be added to the City's GIS data to support model updates/maintenance from it GIS information.

Model Update/Maintenance from GIS. The INFOWATER PRO hydraulic modeling software includes tools to effectively and efficiently update and maintain INFOWATER PRO model from GIS data. It is recommended that the City review and edit its GIS data to (1) eliminate pipe gaps and overshoots, (2) add pipe installation/retire dates, and (30 add pipe material information. This will support future model updates/maintenance using INFOWATER PRO tools and GIS data.

The City should consider updating it INFOWATER PRO model to include all distribution system pipes (i.e., creating an All Pipes model).

5.0 Distribution System Evaluations, Recommended Improvements, and Capital Improvement Plan (CIP)

The primary responsibility of a domestic water utility is to provide its customers with an adequate supply of high quality water in a financially responsible manner. It is standard practice within the water industry that distribution system facilities should be designed and operated to provide an acceptable degree of reliability, maintain adequate pressures throughout the system while supplying peak demands, be capable of providing necessary fire protection, and comply with all water quality regulations.

This Water Master Plan 2022 Update included evaluations to address current and future operational and structural needs. Analyses were performed to identify recommended improvements in the following areas:

- Comprehensive Plan based Medium-term (2030) and long-term (2040) future demands.
- Amendment 4 development areas future demands.
- Transmission/distribution main hydraulic capacities.
- System pressures.
- Pump station and storage facility capacities.
- Water quality (age).

Recommended improvements for this study were broken down into the following categories:

- 2030 Replacement Pipes.
- 2030 Improvements (pipes, pumps, storage facilities).
- 2040 Replacement Pipes.
- 2040 Improvements (pipes, pumps, storage facilities).
- Amendment 4 Improvements (pipes, pumps, storage facilities).
- Amendment 4 Development Mains.

The evaluations and analyses performed to identify the recommended distribution system improvements and replacement mains are described in the following sections.

5.1 MODEL SCENARIOS/ANALYSES

A total of 38 distribution system hydraulic model scenarios/analyses were completed for the study as summarized below:

- July 27, 2021 Model Validation and existing facilities improvements: **1** Scenario
- 2030 Maximum Day: **5** Scenarios
- 2030 Maximum Day System Reliability: **2** Scenarios
- 2030 Winter Day Water Age: **2** Scenarios
- 2040 Maximum Day: **10** Scenarios
- 2040 Maximum Day Water Age: **3** Scenarios
- Amendment 4 Maximum Day: **15** Scenarios
- Total Number of Analyses/Scenarios: **38**

The 2040 analyses were performed first identify the most hydraulically efficient and cost effective long-term improvements. To facilitate report clarity, the 2030 analyses are presented first.

5.2 MAJOR IMPROVEMENTS

Five (5) major improvements were evaluated to meet the long-term (2040) demand conditions. The five major improvements are listed along with the pros and cons of each in Table 5-1. The selected major improvement is identified in Table 5-1 and discussed in later subsections.

Table 5-1 Major Improvements

MAJOR IMPROVEMENT	PROS	CONS	SELECTED
Zone 1 Transmission Main			
Northern Option (Madison, Phillip,1st, Benjamin)	- Shorter length - Lower cost	- No expanded service to southeast Norfolk	
Southern Option (Monroe/Victory Rd)	- Supports expanded service to Southeast Norfolk	- Greater length - Higher cost	X
Zone 1 Increased Storage Capacity			
Second "Dirt Tank" at 25th & Prospect	- Lower Cost - Simple standard operations	- Less effective in reducing low pressures in northeast Zone 1	X
Zone 1 Elevated Tank adjacent NE Industrial Pump Sta.	- Higher cost - Complex operations	- More effective in reducing low pressures in northeast Zone 1	
Zone 5 Pump Station			
Adjacent existing Zone 4 Elevated Tank	- Increased circulation in Zone 4 Elevated Tank	- Increased pipe length and cost to complete Northeast Loop	
Magnet Drive & Highway 35	- Adjacent to Zone 5 customers - Lower improvement main costs	- No increased circulation in Zone 4 Elevated Tank	X
Zone 3 Pump Station			
37th Street & Eisenhower Ave	- Lower Zone 3 improvement main costs	- Reduced Zone 2 pressures	
49th Street & Eisenhower Ave	- Less impact on Zone 2 pressures	- Higher Zone 3 improvement main costs	X
Zone 4 Northeast Loop Alignment			
From Eisenhower & Hwy 35 north along Hwy 35 to NE Industrial Hwy; west to existing 20-inch main	- Potential larger Zone 4 service area	- Longer length, higher cost	
North from future Zone 5 Pump Sta. to Eisenhower; east 400 feet, north to NE Industrial Hwy	- Shorter length, lower cost - Provides more economical service to Zone 4 Amendment 4 Development Area 9	- No service at intersection of Hwy 35 & NE Industrial Hwy	X

5.3 MEDIUM-TERM (2030) AND LONG-TERM (2040) HYDRAULIC ANALYSES

Maximum day 24-hour Extended Period Simulation (EPS) hydraulic analyses were performed for the medium-term (2030, 11.7 mgd) and long-term (2040, 13.7 mgd) demand conditions. Amendment 4 hydraulic analyses were performed for maximum day demands ranging from 15.8 to 17.5 mgd, depending on the Amendment 4 development areas included in the analyses.

Pump station total and firm capacities, pump station total flows and percent of station firm capacity for the 2030, 2040, and Amendment 4 final hydraulic analyses are summarized in Table 5-2.

Individual pump operations for the final hydraulic analyses are summarized in Table 5-3. Tank/reservoir total storage volumes, maximum and minimum volumes (expressed as percent of total tank volume), and tank storage volume utilization (maximum minus minimum percent full and volume[MG]) during the 24-hour maximum day hydraulic analyses are summarized in Table 5-4.

The medium-term (2030), long-term (2040), and Amendment 4 Capital Improvement Plan (CIP) improvement projects are shown on Figure 5-1 and discussed in later subsections. Improvements are divided categories:

- Pipes: "**R**" prefix represents Replacement Pipe, "**I**" prefix represents Improvement Pipe, "**D**" prefix represents Development Pipe.
- Pumps and Pump Stations: "**P**" prefix.
- Storage Facilities (Tanks/Reservoirs): "**T**" prefix.

In addition, improvements are staged according to their recommended construction year.

- Medium-term 2030 Improvements color **Red**.
- Long-term 2040 Improvements color **Blue**.
- Amendment 4 Improvements color **Green**.

Table 5-2 Existing and Future Pump Station Total and Firm Capacities, Modeled Flows and Modeled Flows Percent of Firm Capacity

PUMP STATION	ZONE	DESIGN CAPACITY				HYDRAULIC ANALYSIS RESULTS FOR FINAL MODELED SCENARIOS							
		Total (1,2)		Firm (3)		2021 Maximum Day (27JULY2021)		2030 Maximum Day (2030MD4)		2040 Maximum Day (2040MD10)		Amendment 4 Maximum Day (AMEND4_ALT4-4)	
		(gpm)	(mgd)	(gpm)	(mgd)	Total Average Flow (gpm)	Percent Of Firm Capacity	Total Average Flow (gpm)	Percent Of Firm Capacity	Total Average Flow (gpm)	Percent Of Firm Capacity	Total Average Flow (gpm)	Percent Of Firm Capacity
West WTP	1	13,000	18.72	9,500	13.68	4,227	44.5%	5,899	62.1%	7,147	75.2%	8,384	88.3%
	2	5,200	7.49	3,200	4.61	1,302	40.7%	1,272	39.8%	1,374	42.0%	1,753	54.8%
East WTP	1	4,775	6.88	3,275	4.72	1,183	36.1%	1,020	31.1%	1,029	31.4%	974	29.7%
16th Street	2	1,520	2.19	760	1.09	0	0.0%	0	0.0%	0	0.0%	0	0.0%
29th Street	2	2,400	3.46	1,600	2.30	615	38.5%	758	47.4%	747	46.7%	749	46.8%
Northeast Industrial	4	4,110	5.92	2,110	3.04	130	6.2%	1,023	48.5%	1,686	79.9%	2,033	96.3%
Eastern Hts	Eastern Hts	900	1.30	500	0.72	66	13.2%	62	12.4%	62	12.4%	62	12.4%
Zone 3 (Future)	3	2,470	3.56	970	1.40	-	-	0	-	0	-	680	70.1%
Zone 5 (Future)	4	2,020	2.91	520	0.75	-	-	214	41.1%	216	41.5%	581	111.8%

(1) Total design capacity based on sum of individual pump “nameplate” capacities.
(2) Includes future pump improvements (see Table 5-3).
(3) Largest pump out of service.

Table 5-3 Existing and Future Pump Capacities and Modeled Flows and Heads

PUMP STATION	PUMP NO.	ZONE	DESIGN CAPACITY			DRIVE (1)	HYDRAULIC ANALYSIS RESULTS FOR FINAL MODELED SCENARIOS											
			Flow		Head		2021 Maximum Day (27JULY2021)			2030 Maximum Day (2030MD4)			2040 Maximum Day (2040MD10)			Amendment 4 Maximum Day (AMEND4_ALT4-4)		
			(gpm)	(mgd)	(ft)		Average Flow (gpm)	Average Head (ft)	Hours On per 24 Hours	Average Flow (gpm)	Average Head (ft)	Hours On per 24 Hours	Average Flow (gpm)	Average Head (ft)	Hours On per 24 Hours	Average Flow (gpm)	Average Head (ft)	Hours On per 24 Hours
West WTP	2	1	3,500	5.04	180	CSD	0	0	0	4,347	132	24	4,378	129	24	4,289	137	24
	3		3,500	5.04	180	CSD	0	0	0	0	0	0	0	0	0	0	0	0
	4		2,500	3.60	150	VFD	0	0	0	1,553	127	24	2,769	126	24	0	0	0
	5		3,500	5.04	196	VFD	4,227	132	24	0	0	0	0	0	0	4,096	137	24
	1	2	1,600	2.30	245	CSD	1,302	170	18	1,272	157	17	1,374	164	18	1,753	225	24
	2		1,600	2.30	245	CSD	0	0	0	0	0	0	0	0	0	0	0	0
	3 (future)		2,000	2.88	245	VFD	-	-	-	-	-	-	-	-	-	-	-	-
East WTP	1	1	975	1.40	240	CSD	691	117	14	1,020	161	20	1,029	159	20	974	152	19
	2		1,500	2.16	240	CSD	492	51	6	0	0	0	0	0	0	0	0	0
	3 (2)		800	1.15	240	CSD	0	0	0	0	0	0	0	0	0	0	0	0
	4		1,500	2.16	240	CSD	0	0	0	0	0	0	0	0	0	0	0	0
16th Street	1	2	760	1.09	100	CSD	0	0	0	0	0	0	0	0	0	0	0	0
	2		760	1.09	100	CSD	0	0	0	0	0	0	0	0	0	0	0	0
29th Street	1	2	800	1.15	95	CSD	0	0	0	0	0	0	0	0	0	0	0	0
	2		800	1.15	95	CSD	0	0	0	0	0	0	0	0	0	0	0	0
	3		800	1.15	96	CSD	615	74	19	758	95	24	747	96	24	749	96	24
Northeast Industrial	-	4	70	0.10	140	VFD	65	141	24	0	0	0	0	0	0	0	0	0
	-		70	0.10	140	VFD	65	141	24	0	0	0	0	0	0	0	0	0
	-		70	0.10	140	VFD	0	0	0	0	0	0	0	0	0	0	0	0
	1		400	0.58	113	VFD	0	0	0	0	0	0	0	0	0	444	93	24
	2		1,500	2.16	123	VFD	0	0	0	1,023	91	24	1,686	98	24	1,589	94	24
	4		2,000	2.88	130	VFD	0	0	0	0	0	0	0	0	0	0	0	0

Table 5-3 Existing and Future Pump Capacities and Modeled Flows and Heads (Continued)

PUMP STATION	PUMP NO.	ZONE	DESIGN CAPACITY			DRIVE (1)	HYDRAULIC ANALYSIS RESULTS FOR FINAL MODELED SCENARIOS											
			Flow		Head		2021 Maximum Day (27JULY2021)			2030 Maximum Day (2030MD4)			2040 Maximum Day (2040MD10)			Amendment 4 Maximum Day (AMEND4_ALT4-4)		
			(gpm)	(mgd)	(ft)		Average Flow (gpm)	Average Head (ft)	Hours On per 24 Hours	Average Flow (gpm)	Average Head (ft)	Hours On per 24 Hours	Average Flow (gpm)	Average Head (ft)	Hours On per 24 Hours	Average Flow (gpm)	Average Head (ft)	Hours On per 24 Hours
Eastern Hts	1	Eastern Hts	100	0.14	114	VFD	0	0	0	0	0	0	0	0	0	0	0	0
	2		400	0.58	104	VFD	66	137	24	62	137	24	62	137	24	62	137	24
	3		400	0.58	104	VFD	0	0	0	0	0	0	0	0	0	0	0	0
Zone 3 (Future)	1	3	70	0.10	110	VFD	-	-	-	-	-	-	-	-	-	58	96	24
	2		300	0.43	110	VFD	-	-	-	-	-	-	-	-	-	147	96	24
	3		600	0.86	110	VFD	-	-	-	-	-	-	-	-	-	475	96	24
	4 (3)		1,500	2.16	-	VFD	-	-	-	-	-	-	-	-	-	0	0	0
Zone 5 (Future)	1	5	70	0.10	66	VFD	-	-	-	0	0	0	0	0	0	105	37	24
	2		150	0.22	66	VFD	-	-	-	214	36	24	216	35	24	225	38	24
	3		300	0.43	66	VFD	-	-	-	0	0	0	0	0	0	251	24	15
	4 (3)		1,500	2.16	-	VFD	-	-	-	-	-	-	-	-	-	-	-	-

(1) CSD = Constant Speed Drive, VFD = Variable Speed Drive.
(2) Natural Gas Engine.
(3) Fire flow pump.

Table 5-4 Existing and Future Tank/Reservoir Volumes and Modeled Maximum and Minimum Percent Full and Utilization

TANK/ RESERVOIR	ZONE	VOLUME (MG)	OVERFLOW/ MAXIMUM OPERATING ELEVATION (FT)	DEPTH (FT)	HYDRAULIC ANALYSIS/SCENARIO															
					2021 Maximum Day (27JULY2021)				2030 Maximum Day (2030MD4)				2040 Maximum Day (2040MD10)				Amendment 4 Maximum Day (AMEND4_ALT4-4)			
					Percent Full		Utilization		Percent Full		Utilization		Percent Full		Utilization		Percent Full		Utilization	
					Maxi-mum (%)	Mini-mum (%)	Per-cent (1)	MG (2)	Maxi-mum (%)	Mini-mum (%)	Per-cent (1)	MG (2)	Maxi-mum (%)	Mini-mum (%)	Per-cent (1)	MG (2)	Maxi-mum	Mini-mum	Per-cent (1)	MG (2)
West Water Treatment Plant	-	2.16	1,589	45	90.2	61.4	28.7%	0.62	88.0	74.4	13.7%	0.55	89.3	77.0	12.4%	0.49	96.8	72.5	24.3%	0.97
West Water Treatment Plant (Future)	-	2.00	1,589	45	-	-	-	-												
East Water Treatment Plant	-	0.79	1,517	15	80.0	30.2	49.8%	0.39	96.0	64.8	31.2%	0.25	94.9	63.7	31.2%	0.25	97.7	65.8	31.9%	0.25
Zone 1 (Dirt Tank)	1	0.75	1,701	27	100.0	68.3	31.7%	0.24	90.9	53.0	37.9%	0.66	94.9	30.8	64.1%	1.12	95.1	52.4	42.7%	0.75
Zone 1 (Future)	1	1.00	1,701	27	-	-	-	-												
Zone 2	2	1.07	1,789	24	99.6	80.3	19.3%	0.21	100.0	63.2	36.8%	0.39	93.8	52.1	41.3%	0.44	96.9	36.6	60.3%	0.65
Zone 4	4	0.75	1,789	40	-	-	-	-	87.3	52.5	34.8%	0.26	94.5	59.6	35.0%	0.26	99.4	41.8	57.6%	0.43
Woodland Park Standpipe	5	0.09	1,835	110	-	-	-	-	93.7	57.8	35.9%	0.003	96.5	60.3	36.1%	0.003	97.9	59.9	38.0%	0.003

(1) Tank storage utilization percentage equal to maximum percent full minus minimum percent full.
(2) Tank storage utilization in million gallons (MG) equal to storage utilization percentage times total tank volume.

Water Master Plan Update
City of Norfolk, Nebraska
Capital Improvement Plan (CIP)
Figure 5-1

LEGEND

- Existing City Limits
- Extraterritorial Jurisdiction Area (ETJ)

Future Growth Areas

- Blackberry (SF Residential)
- Channel Rd (MF Residential)
- Commercial/Public
- East Side Area (SF Resid)
- Industrial
- Legacy Bend (SF) Residential)
- Northwest Area (SF Resid)
- Nor-Park (MF Residential)
- Parks/Recreation
- Wyndam Hills (SF Resid)

Amendment 4 Development Areas, Number, & Evaluation Type

- 2E — Detailed (Hydraulic Model)
- 2S — Qualitative
- 12" — Existing Pipe & Diameter (in)

Replacement, Improvement, & Development Mains. IDs & Diameters

- R1 (20") — 2030 Replacement
- R4 (16") — 2040 Replacement
- I1 (16") — 2030 Improvement
- I15 (20") — 2040 Improvement
- I18 (16") — Amendment 4 Impr
- Development Main
- Zone Boundary Valve

Norfolk NEBRASKA right at home.

BLACK & VEATCH Building a world of difference.

NORFOLK_INFOWATER_PRO40.aprx
February 14, 2023

(Blank Page)

5.3.1 Medium-Term (2030, 11.7 mgd) Hydraulic Analyses and Improvements

The medium-term, design year 2030, final hydraulic analysis (**Scenario 2030MD4**) was performed for a maximum day demand of 11.7 mgd and a maximum hour demand of 20.7 mgd. Hydraulic results for hydraulic Scenario 2030MD4 are shown on Figure 5-2. Model results shown on Figure 5-2 include the following:

- Water velocity in pipes color coded [units in feet per second (fps)].
- Flow direction in pipes depicted by "flow arrows".
- Flow magnitude is annotated for select pipes [units in gallons per minute (gpm)].
- Pressures at pipe endpoints (model junctions) are color coded [units in pounds per square inch (psi)].

The medium-term (2030) improvements include the following:

- ***Replacement Main R1***, 20-inch along Phillip Avenue, 7th to 13th Streets. This main replaces the existing 12/16-inch main installed in 1959. Based on the condition and maintenance history of this pipe, the City may consider deferring its replacement to a later date.
- ***Replacement Main R2***, 20-inch along Madison Avenue, 7th to 1st Streets, then 240 feet north on 1st Street. This main replaces the existing 6-inch main installed in 1915. A new 12-inch main was constructed in this location in 2016. Based on the condition and maintenance history of the 6-inch main, the City may consider deferring its replacement to a later date. Replacement Mains **R1** and **R2** (20-inch) provide increased interim hydraulic capacity from the WWTP to the eastern part of the distribution system and will help supply increased Zone 4 demands until the long-term (2040) Zone 1 transmission mains (**I15** and **I16**) along Monroe Avenue and Victory Road are constructed.
- **Replacement Main R3**, 16-inch from the existing Zone 1 "Dirt" Tank to Prospect Avenue. This main replaces the existing 16-inch main installed in 1945 which is nearing the end of its service life and located in close proximity to high cost residential structures.
- ***Improvement Main I1***, 16-inch, will connect a Zone 1 16-inch dead-end main on Omaha Avenue with a 12-inch dead-end main on Victory Road.
- ***Improvement Mains I2 through I5*** will improve service and pressures in Zone 2.
- ***Improvement Mains I6 through I7*** will provide service to the future Zone 5 Pump Station and service to Zone 4 future service areas.
- ***Improvement Mains I8 though I13*** will provide service to Woodland Park and Amendment 4 future development areas.
- ***Improvement Main I14*** will provide service to the Zone 1 East Side Residential development.
- West Water Treatment Plant Zone 2, Pump #3 (***Improvement Pump P1***). This improvement pump will provide increased pumping capacity to Zone 2. The variable frequency drive (VFD) will improvement operational flexibility to Zone 2.
- West Water Treatment Plant High Service Pumps 2.0 MG Suction Storage (***Reservoir/Tank Improvement T1***). This improvement will supplement the existing 2.0 MG storage tank and improve West Water Treatment Plant operational flexibility including filter backwash.
- A second Zone 1 storage tank (1.0 MG) at the "Dirt Tank" site (***Reservoir/Tank Improvement T2***) will provide increased equalization storage for meeting peak hour demands in Zone 1.

- Zone 5 Pump Station (***Pump Improvement P2***). The Zone 5 Pump Station will provide future service to Woodland Park and future Amendment 4 development areas.

Water Master Plan Update
City of Norfolk, Nebraska
2030 Max Day (11.7 mgd)
WWTP 10.2 mgd
EWTP 1.5 mgd
Results at Hr 6 (20.7 mgd)
Scenario 2030MD4
Figure 5-2

LEGEND

Junction Pressure (psi)

- < 20
- 20 - 30
- 30 - 40
- 40 - 90
- 90 - 110
- > 110

174 / 12" — Pipe Flow (gpm), Direction & Diameter (in)

Pipe Velocity (fps)

- < 1
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

R1 (20") — 2030 Replacement Pipe & ID & Diameter

I1 (16") — 2030 Improvement Pipe & ID & Diameter

Norfolk NEBRASKA right at home.

BLACK & VEATCH Building a world of difference.

NORFOLK_INFOWATER_PRO40.aprx
February 7, 2023

(Blank Page)

Results of the medium-term (2030) final hydraulic analysis (Scenario 2030MD4) are summarized below:

- All pump station pumping rates were within the stations' firm pumping capacity (pumping capacity with the largest pump out of service). For example, the WWTP Zone 1 and Northeast Industrial Pump Stations operated at 62% and 49% of firm capacity, respectively.
- Reservoirs/tanks operated within their existing and proposed future storage capacities. For example, the existing Zone 1 "Dirt Tank" and the proposed second Zone 1 Dirt Tank operated between 91% and 53% full, equivalent to a utilization rate of 38% of total storage volume. [It is common operating practice to allocate 50% of total storage volume to meeting peak hour demands while reserving the remaining 50% of storage to emergencies and firefighting.]
- System pressures during the morning hour (6 a.m.) maximum hour demand (20.7 mgd) were generally maintained above 40 psi. Small, localized areas in Zone 2 near the Blackberry development and in Zone 1 near Highway 35 and Benjamin experienced maximum hour pressures in the mid-30s (psi).

5.3.2 Long-term (2040, 13.7 mgd) Hydraulic Analyses and Improvements

The long-term, design year 2040, final hydraulic analysis (**Scenario 2040MD10**) was performed for a maximum day demand of 13.7 mgd and a maximum hour demand of 24.2 mgd. Hydraulic results for hydraulic Scenario 2040MD10 are shown on Figure 5-3.

The long-term (2040) improvements include the following:

- ***Replacement Main R4***, 16-inch main located along Prospect Avenue, from end of 2030 Replacement Main R3, to 16th Street. This main replaces the existing 16-inch main installed in 1945 which is nearing the end of its service life.
- ***Improvement Mains I15 and I16.*** Improvement Main I15 (20-inch along Monroe Avenue, 13th Street to Victory Road) and Improvement Main I16 (20-inch along Victory Road, Monroe Avenue to Benjamin) represent one of the largest improvements evaluated in this study. Improvement Mains I15 and I16, also referred to as the Zone 1 "southern" transmission main alternative was evaluated and selected versus the Zone 1 "northern" transmission main alternative (20-inch along Phillip Ave., Madison Ave., 1st Street, Benjamin). Selection of the southern transmission main alternative was based on the comparable hydraulic performance of the Zone 1 southern and northern transmission main alternatives and the southern transmission main's potential to provide increased service to the southern, southeastern, and eastern parts of the City.
- ***Improvement Main I17***, 16-inch main from the Zone 1 Dirt Tank along 25th Street to the existing Zone 1 24-inch main at 25th Street & Phillip Ave. This improvement main provides a second (redundant) Zone 1 draft/fill main to the Zone 1 Dirt Tanks. Expansion of the Zone 1 storage volume to 2.0 MG in 2040 places increased reliance on storage at this location and the transmission mains serving this storage location.
- The existing Zone 1 0.75 MG "Dirt Tank" located at 25th and Prospect was constructed in the mid 1940's, has undergone repairs and upgrades, and is generally considered to be in sound structural condition. ***Reservoir/Tank Improvement T3*** represents replacement of the existing Zone 1 Dirt Tank with a new 1.0 MG storage tank at the same location. Based on the condition and structural integrity of the existing Zone 1 0.75 MG Dirt Tank, the City may consider deferring its replacement to a later date.

(Blank Page)

Water Master Plan Update
City of Norfolk, Nebraska
2040 Max Day (13.7 mgd)
WWTP 12.2 mgd
EWTP 1.5 mgd
Results at Hr 6 (24.2 mgd)
Scenario 2040MD10
Figure 5-3

LEGEND

Junction Pressure (psi)

- < 20
- 20 - 30
- 30 - 40
- 40 - 90
- 90 - 110
- > 110

174 / 12" — Pipe Flow (gpm), Direction & Diameter (in)

Pipe Velocity (fps)

- < 1
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

R1 (20") — 2030 Replacement Pipe & ID & Diameter

I1 (16") — 2030 Improvement Pipe & ID & Diameter

R4 (16") — 2040 Replacement Pipe & ID & Diameter

I15 (20") — 2040 Improvement Pipe & ID & Diameter

Norfolk NEBRASKA right at home.

BLACK & VEATCH Building a world of difference.

NORFOLK_INFOWATER_PRO40.aprx
February 7, 2023

(Blank Page)

Results of the long-term (2040) final hydraulic analysis (Scenario 2050MD10) are summarized below:

- All pump station pumping rates were within the stations' firm capacity. The WWTP Zone 1 and Northeast Industrial Pump Stations operated at 75% and 80% of firm capacity, respectively.
- Reservoirs/tanks operated within their existing and proposed future storage capacities. The existing Zone 1 "Dirt Tank" and the new second 1.0 MG Zone 1 Dirt Tank (***Improvement T2***), combined with the new Dirt Tank draft/fill pipe (***Improvement I17***), resulted in the Dirt Tanks operating between 95% and 31% full, equivalent to a utilization rate of 64% of total storage volume. While this is slightly above the 50% storage utilization target, the Zone 1 tanks strong utilization rate demonstrates the effectiveness of the second Dirt Tank (***Improvement T2***) and a second/redundant Dirt Tank draft/fill pipe (***Improvement I17***).
- System pressures during the morning hour (6 a.m.) maximum hour demand (24.2 mgd) were generally maintained above 40 psi. Small, localized areas in Zone 2 near the Blackberry development experienced pressures below 40 psi. Zone 1 pressures near Highway 35 and Benjamin experienced maximum hour pressures slightly below 30 psi (29 psi). Discussions with City staff indicated these maximum hour system pressures were acceptable.
- Pressures below 30 psi in the Woodland Park development near the Woodland Park Standpipe are predicted despite maintaining water levels in the Woodland Park Standpipe in the range of 97% to 60% full. Increasing Woodland Park Standpipe minimum operating levels will increase minimum pressures in this area but reduce water circulation/turnover in the Woodland Park Standpipe.

5.3.3 Amendment 4 Detailed Hydraulic Analyses and Improvements (15.8 – 17.5 mgd)

Amendment 4 to the Water Master Plan 2022 Update includes ten (10) "development areas" not included in the 2040 service area (see Figure 12-9). "Qualitative" (conceptual) evaluations and "detailed" hydraulic modeling analyses were performed for the 10 development areas to identify the infrastructure needed to extend water service to the development areas.

Five (5) Amendment 4 detailed hydraulic scenarios were developed by combining the individual development areas (see Table 2-10). Amendment 4 detailed hydraulic analysis/scenario numbers 1 through 3 have an overall target maximum day demand equal to approximately 16 mgd. The WWTP and EWTP modeled operating rates were 14.5 and 1.5 mgd, respectively. Detailed hydraulic analyses/scenarios 4 and 5 were simulated for maximum day demands of 17.5 and 13.8 mgd, respectively.

Results of the Amendment 4 detailed hydraulic analyses are presented below.

Amendment 4 Detailed Hydraulic Analysis/Scenario #1, Development Areas 1, 2E, 3 (Scenario 16MGD-1). Detailed Analysis #1 evaluated future supply to Development Areas 1, 2E, and 3 on the west, north, and south sides of the City. The analysis was performed for a maximum day demand of 16.0 mgd.

Major improvements included under Detailed Analysis #1 include the following:

- Amendment 4 Development Areas 2E and 3 will require water service in future pressure Zone 3 and construction of the future Zone 3 Pump Station (***Improvement P3***). Preliminary analyses evaluated future Zone 3 Pump Station sites at 37th & Eisenhower and 49th & Eisenhower. The

49th & Eisenhower location was selected for the future Zone 3 Pump Station to minimize potential low pressures in the far northwest corner of Zone 2.

- Future improvement mains will be required in Zones 2 and 3 to supply the future Zone 3 Pump Station and Development Area 2E and 3 growth.
- Future improvement mains will be required in Zone 1 to extend service south to Development Area 1.

Amendment 4 Detailed Hydraulic Analysis/Scenario #2, South/East – Development Areas 1, 5, 6, 9 (Scenario 16MGD-4). Detailed Analysis #2 evaluated future supply to Development Areas 1, 5, 6, and 9 on the south and east sides of the City. The analysis was performed for a maximum day demand of 15.8 mgd.

Major improvements included under Detailed Analysis #2 include the following:

- Detailed Analysis #2 included significant growth on the east side of the City and was therefore a good test of the hydraulic performance of expanded Zone 1 storage at the existing Zone 1 Dirt Tanks site and at a Zone 1 elevated tank site adjacent to the Northeast Industrial Pump Station. Based on Zone 1 storage utilization and superior operational flexibility, the Zone 1 Dirt Tank site at 25th & Prospect Ave. was selected for future Zone 1 storage (***Improvement T2***).
- Development Area 9 will require expanded service in Zone 4 and completion of the "Northeast Loop" transmission main. Alternative alignments for completion of the Northeast Loop were evaluated with ***Improvement Mains I34 and I35 (16-inch)*** selected.
- ***Improvement Mains I36 and 137 (12-inch)*** will be required to supply Development Area 6 in Zone 5.

Amendment 4 Detailed Hydraulic Analysis/Scenario #3, Development Areas 1, 2E, 3, 5, 6 (Scenario 16MGD-4). Detailed Analysis #3 evaluated future supply to Development Areas 1, 2E, 3, 5, and 6 at the periphery of all sides of City. The analysis was performed for a maximum day demand of 16 mgd.

Major improvements included under Detailed Analysis #3 include the following:

- Amendment 4 Detailed Hydraulic Analysis/Scenario #3 led to the inclusion of Zone 2 ***Improvement Main I24 (16-inch)*** to improve maximum hour pressures in the Zone 2 Wyndam Hills and Blackberry development areas.

FINAL - Amendment 4 Detailed Hydraulic Analysis/Scenario #4, Balanced (North/South/East/West) – Development Areas 1, 2E, 3, 5, 6 (Scenario AMEND4_ALT4-4). Amendment 4 Detailed Analysis #4 is the same as Analysis/Scenario #3 with the exception that the analysis was performed for a maximum day demand of **17.5 mgd**. No adjustments were made to the future demands projections in Development Areas 1, 2E, 3, 5, and 6 (100% of the demand projections in these development areas was simulated).

Amendment 4 Analysis/Scenario #4 was simulated for a WWTP operating rate of 16 mgd – its proposed maximum expanded capacity. Analysis/Scenario #4 therefore represents infrastructure required to convey flow from the WWTP at its maximum operating rate.

Amendment 4 Analysis/Scenario #4 simulates the highest system-wide maximum day demand (17.5 mgd), places the greatest hydraulic stress on the distribution system infrastructure, and is considered the most representative of future required infrastructure improvements.

Results of the Amendment 4 Analysis/Scenario #4 hydraulic analysis are shown on Figure 5-4 and described below:

- Pipeline (main), pump station, and storage facility improvements identified in Amendment 4 Analyses/Scenarios #1, #2, and #3 were shown to be adequate to supply the Analysis/Scenario #4 demand of 17.5 mgd at acceptable system pressures, tank levels, and pump station flows.
- No maximum hour pressures below 30 psi were observed. Maximum hour pressures in the low to mid 30's were observed in far northern parts of Zone 2 in the Wyndam Hills and Blackberry developments and in the far eastern part of Amendment 4 Development Area 5 (Zone 5).
- All existing and future pump stations operated within their firm pumping capacity (Table 5-2).
- The Zone 2 Tank and Zone 4 Elevated Tank utilized 60% and 58% of their total storage capacity, respectively, to supply demands during the peak demand period (Table 5-4). The higher Zone 2 tank utilization (60%) reflects the need for increased Zone 3 pumping to meet Zone 3 peak demands (no floating storage is proposed in Zone 3). Similarly the higher Zone 4 Elevated Tank utilization (58%) represents the impact the potential Amendment 4 Development Area 9 demand will have on Zone 4 operations.

(Blank Page)

Water Master Plan Update
City of Norfolk, Nebraska
Amendment 4
Maximum Day (17.5 mgd)
WWTP 16.0 mgd, EWTP 1.5 mgd
Results at Hr 6 (30.9 mgd)
Scenario AMEND4_ALT4-4
Figure 5-4

LEGEND

Junction Pressure (psi)

- < 20
- 20 - 30
- 30 - 40
- 40 - 90
- 90 - 110
- > 110

174 — 12" Pipe Flow (gpm), Direction & Diameter (in)

Pipe Velocity (fps)

- < 1
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

R1 (20") 2030 Replacement Pipe & ID & Diameter

I1 (16") 2030 Improvement Pipe & ID & Diameter

R4 (16") 2040 Replacement Pipe & ID & Diameter

I15 (20") 2040 Improvement Pipe & ID & Diameter

I18 (16") Amendment 4 Impr Pipe & ID & Diameter

Amendment 4 Development Main

Norfolk NEBRASKA right at home.

BLACK & VEATCH Building a world of difference.

NORFOLK_INFOWATER_PRO40.aprx
February 7, 2023

(Blank Page)

Amendment 4 Detailed Hydraulic Analysis/Scenario #5, Service to the Town of Hadar – Development Area 4 (Scenarios AMEND4_HADAR1 and AMEND4_HADAR_FF1). Amendment 4 Analysis/Scenario #5 evaluated future service to the Town of Hadar (Development Area 4). Because the Town of Hadar represents a small increase in system-wide demand, the Scenario #5 maximum day demand of **13.8 mgd** is only 0.1 mgd above the Comprehensive Plan based 2040 maximum day demand of 13.7 mgd.

Results of the Amendment 4 Analysis/Scenario #5 hydraulic analyses and improvements are described below:

- Approximately 16,400 feet (3.1 miles) of 12-inch pipe was simulated from the end of the existing Zone 1 16-inch main along Old Hadar Road to the town of Hadar.
- The maximum hour demand at the Town of Hadar was 50 psi (approximate elevation 1,558 feet).
- A maximum day 750 gpm fire flow was simulated at the Town of Hadar and yielded a residual pressure of about 32 psi. Fire protection to Hadar in excess of about 750 gpm will require a dedicated Zone 1/Hadar (fire flow) Pump Station.

5.3.4 Amendment 4 Qualitative Evaluations

Amendment 4 Development Areas 2W, 2S, and 8 were selected to perform qualitative, "high level", evaluations regarding future service requirements. The qualitative service requirement evaluations are given below.

Development Area 2W. Development Area 2W is located west of 49th Street and bounded by Norfolk Avenue on the south and Eisenhower Avenue on the north (Figure 2-12). Development Area 2W has a gross area equal to 1,034 acres and average day and maximum day demand estimates of 0.7 and 1.3 mgd, respectively.

- Service to Development Area 2W will require new infrastructure in 3 pressure zones – Zones 1, 2, and 3.
- Zone 1 can be served by a new main extending west along Norfolk Avenue (U.S. Highway 275) from the existing Zone 1 24-inch main along Norfolk Avenue.
- Zone 2 will be served by the 20-inch main along 49th Avenue.
- Zone 3 will be served by the future Zone 3 Pump Station to be located at 49th Street and Eisenhower Avenue and the future Zone 3 12-inch main along 49th Street.

Development Area 2S. Development Area 2S is bounded by Norfolk Avenue on the north, Omaha Avenue on the south, and approximately 37th Street on the east. Development Area 2S has a gross area equal to 1,141 acres and average day and maximum day demand estimates of 0.7 and 1.5 mgd, respectively.

- Development Area 2S will be supplied entirely through Zone 1. The eastern portion of Development Area 2S can be served by the Zone 1 24-inch main extending southeast from the WWTP. The western portion of Development Area 2S may be supplied by connections to the Zone 1 24-inch main leaving the WWTP and/or the Zone 1 24-inch main along 49th Street.

Development Area 8. Development Area 8 represents a band of future commercial development along Eisenhower Avenue, Johnny Carson Boulevard, and the Northeast Industrial Highway

between 25th Street and Victory Road. Because of the specialized nature of development in this area, no future demand projections are provided.

- Development Area 8 is located primarily in Zone 1 but has small sections located in Zone 2 along the west and Zone 4 along the east.
- There are a number of potential configurations for providing service to Development Area 8. The Zone 1 portion may be served from the terminus of the existing Zone 1 16-inch main along Old Hadar Road.
- The Zone 2 portion may be served from future Improvement Main I26 (12-inch) located along Eisenhower Avenue.
- The Zone 4 portion may be served from a new tee installed at the existing Zone 4 12-inch main along Victory Road, near the intersection of Northeast Industrial Road and Victory Road.
- Isolation (closed zone boundary) valves or pressure reducing valves (PRVs) will need to be installed at the Zone 1/Zone 2 and Zone 1/Zone 4 boundaries of Development Area 8.

5.3.5 2030 Winter Day Water Age/Quality Analyses

Transmission/distribution system water age cannot be directly measured in the field. No regulatory rules exist for water age. However, water age can be used as a surrogate for general transmission/distribution system water quality in lieu of more complex water quality constituent modeling (e.g., chlorine, disinfection byproducts, etc.).

For this planning study, 2030 winter day water age analyses were performed to compare predicted water age/quality for the two Zone 1 storage facility options and to evaluate system-wide water age/quality:

- ***Scenario 2030WD1.*** A second Zone 1 storage tank (1 MG) at the existing Dirt Tank site.
- ***Scenario 2030WD2.*** Zone 1 Elevated Tank (1 MG) adjacent the Northeast Industrial Pump Station.
- The two 2030 winter day analyses/scenarios include a second WWTP tank (2 MG) on the suction side of the Zone1/Zone 2 pumps.

Water age correlations with chlorine, disinfection byproducts, and other transmission/distribution system regulated constituents varies for individual water systems based on source water quality, treatment processes, season and water temperature, pipe materials and age, etc. However general water age categories/classifications can be used to provide qualitative assessments of transmission/distribution system water quality. Typical water age categories/classifications are given below.

- ***Water Age Less Than 7 Days.*** Water age less than 7 days typically characterizes very good water quality and very limited potential for water quality complaints or regulatory violations.
- ***Water Age 7-10 Days.*** Water age in the range of 7-10 days typically characterizes good water quality and limited potential for water quality complaints or regulatory violations.
- ***Water Age 10-14 Days.*** Water age in the range of 10-14 day typically characterizes acceptable water quality and only minor potential for water quality complaints or regulatory violations.

- ***Water Age Greater Than 14 Days.*** Water age greater than 14 days may represent areas within the transmission/distribution system where structural and/or operational improvements may be warranted to maintain good water quality and avoid regulatory violations.

Tank/reservoir water age for 2030 winter day Scenarios 2030WD1 (second Zone 1 Dirt Tank; 1.0 MG) and 2030WD2 (Zone 1 Elevated Tank, 1.0 MG) are given in Table 5-5 and discussed below.

Table 5-5 Tank/Reservoir 2030 Winter Day Water Age

TANK/RESERVOIR	VOLUME (MG)		WATER AGE (DAYS)	
	Scenario		Scenario	
	2030WD1 (1)	2030WD2 (2)	2030WD1 (1)	2030WD2 (2)
West Water Treatment Plant	4.00		**0.8**	**0.8**
Zone 1 Dirt Tank (25th & Prospect Ave.)	1.75	1.00	**3.2**	**3.0**
Zone 1 Elevated Tank (near NE Industrial Pump Sta.)	-	1.00	-	**3.3**
Zone 2	1.07		**3.6**	**3.6**
Zone 4 Elevated Tank	0.75		**9.0**	**9.9**
Woodland Park Standpipe	0.09		**10.3**	**11.2**

(1) **Scenario 2030WD1** includes Second Zone 1 Dirt Tank [1 MG], second WWTP Tank [2 MG].
(2) **Scenario 2030WD2** includes Zone 1 Elevated Tank [1 MG], second WWTP Tank [2 MG].

- The WWTP, Zone Dirt Tank, and Zone 2 Tank experience water age less than 4 days for the two 2030 winter day water age analyses.
- Water age in the potential Zone 1 Elevated Tank near the Northeast Industrial Pump Station (Scenario 2030WD2) was 3.3 days, approximately equal to water age in the Dirt Tank under Scenario 2030WD1 (3.2 days).
- Water age in the Zone 4 Elevated Tank increased by about 0.9 days to 9.9 days under Scenario 2030WD2 (Zone 1 Elevated Tank option) versus Scenario 2030WD1 (Zone 1 second Dirt Tank; 9.0 days).
- Water age in the Woodland Park Standpipe increased by about 0.9 days to 11.2 days under Scenario 2030WD2 (Zone 1 Elevated Tank option) versus Scenario 2030WD1 (Zone 1 second Dirt Tank; 10.3 days).
- Pump controls (pump On/Off) for the future Zone 5 pump supplying Woodland Park were set to maintain the Woodland Park Standpipe water level between 105 and 80 feet (maximum water level 110 feet). The minimum operating level of 80 feet maintains a minimum pressure of 35 psi for customers located near the standpipe. It may be possible to reduce water age in the Woodland Park Standpipe by operating the standpipe at a lower operating level. However, this will result in lower pressures (below 35 psi) for Woodland Park customers near the standpipe.

The above findings and the slightly lower water age in the Zone 4 Elevated Tank and Woodland Park Standpipe contributed to selection of expanded Zone 1 storage at the Zone 1 Dirt Tank site.

System-wide 2030 winter day water age for the selected Zone 1 Dirt Tank storage expansion option (Scenario 2030WD1) is shown on Figure 5-5 and described below.

Water Master Plan Update
City of Norfolk, Nebraska
2030 Winter Day (4.5 mgd)
WWTP 4.5 mgd; EWTP 0.0 mgd
Maximum Water Age
Flow Direction/Arrows at
Day 27, Hr 8 (8 A.M.)
Scenario 2030WD1_AGE
Figure 5-5

LEGEND

Pipe Flow Direction & Diameter (in)

12"

Pipe Maximum Water Age (Days)

- < 3
- 3 - 5
- 5 - 7
- 7 - 10
- 10 - 14
- > 14

R1 (20") 2030 Replacement Pipe & ID & Diameter

I1 (16") 2030 Improvement Pipe & ID & Diameter

Norfolk NEBRASKA right at home.

BLACK & VEATCH Building a world of difference.

NORFOLK_INFOWATER_PRO40.aprx
February 7, 2023

(Blank Page)

- Overall the majority of the system experiences water age less than 5 days.
- Water age in Zone 4 is in the range of 7-10 days.
- Water age in Woodland Park ranges from 5-7 days on the west side to 10-14 days in areas closest to the Woodland Park Standpipe.
- With the exception of dead-end mains, no areas experienced water age greater than 14 days.

5.3.6 2030 Maximum Day System Reliability/Redundancy Hydraulic Analyses

The City identified potential major infrastructure unplanned/emergency outages that might impact service to customers. These included (1) the Zone 1 24-inch main along Norfolk Avenue east of 49th Street and (2) the Zone 1 Dirt Tank draft/fill pipe along Prospect Avenue. Year 2030 maximum day (11.7 mgd) hydraulic analyses were performed to evaluate the impact of these outages and are presented below.

Zone 1 24-inch main along Norfolk Avenue east of 49th Street (Scenario 2030MD1_OUTAGE1). The results of the Scenario 2030MD1_OUTAGE1 hydraulic analysis is shown on Figure 5-6 and discussed below:

- The Zone 1 24-inch transmission main extending southeast from the WWTP conveys the entire flow delivered from the WWTP to Zone 1. The maximum day Hour 6 (6 a.m.) flow conveyed through this main was 6,402 gpm (9.2 mgd) and the velocity was 4.5 fps (Figure 5-6). While this would be considered a high transmission main velocity under normal operating conditions, it is considered acceptable during this unplanned/emergency operating event.
- The Zone 1 12-inch main along 13th Street north of Monroe Avenue conveyed 2,298 gpm (3.3 mgd) and the velocity was 6.5 fps (Figure 5-6). Although this is a high operating velocity it did not result in Zone 1 low pressures.
- The high velocity in the 13th Street 12-inch main was a factor in selecting the Zone 1 "southern" Monroe Avenue/Victory Road transmission mains improvement option. The future Zone 1 Monroe Avenue/Victory Road improvement mains (***I15 and I16***) will support increased unplanned/emergency flows to the eastern part of Zone 1 and reduce flows and velocities in the Zone 1 13th Street 12-inch main.
- No significant reductions in Zone 1 pressures and customer service are predicted for this outage.

(Blank Page)

Water Master Plan Update
City of Norfolk, Nebraska
2030 Max Day (11.7 mgd)
WWTP 10.2 mgd
EWTP 1.5 mgd
Results at Hr 6 (20.7 mgd)
OUTAGE - Zone 1 24-inch along Norfolk Avenue East of 49th
Scenario 2030MD1_OUTAGE1
Figure 5-6

LEGEND

Junction Pressure (psi)

- < 20
- 20 - 30
- 30 - 40
- 40 - 90
- 90 - 110
- > 110

174 / 12" — Pipe Flow (gpm), Direction & Diameter (in)

Pipe Velocity (fps)

- < 1
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

R1 (20") — 2030 Replacement Pipe & ID & Diameter

I1 (16") — 2030 Improvement Pipe & ID & Diameter

Norfolk NEBRASKA right at home.

BLACK & VEATCH Building a world of difference.

NORFOLK_INFOWATER_PRO40.aprx
February 7, 2023

(Blank Page)

Zone 1 16-inch Dirt Tank Draft/Fill Pipe along Prospect Avenue (Scenario 2030MD1_OUTAGE2). This analysis evaluated an outage of the Zone 1 Dirt Tank 16-inch draft/fill pipe along Prospect Avenue. This outage reduces the hydraulic capacity to/from the Zone 1 Dirt Tank to the 10-inch main which extends west from the Dirt Tank along Prospect Avenue and then south along 25th Street. The results of the Scenario 2030MD1_OUTAGE2 hydraulic analysis is shown on Figure 5-8 and discussed below:

- The Zone 1 Dirt Tank continued to operate effectively during the Zone 1 Dirt Tank 16-inch draft/fill main outage. The Zone 1 Dirt Tank water levels ranged from approximately 85% to 61% full. This is equivalent to a **24%** utilization rate (maximum minus minimum percent full).
- No significant reductions in Zone 1 pressures and customer service are predicted for this outage.
- The final 2030 maximum day hydraulic analysis (Scenario 2030MD4) yielded a combined Zone 1 existing and future Dirt Tanks utilization rate of **38%**. This is significantly higher than the combined Zone 1 existing and future Dirt Tanks utilization rate of **24%** under the 16-inch draft/fill main outage. While there were no significant hydraulic or customer deficiencies observed as a result of the Zone 1 Dirt Tanks 16-inch draft/fill main outage, a second/redundant Zone 1 Dirt Tanks 16-inch draft/fill main (***I17***) is recommended to support optimal utilization of the Zone Dirt Tanks storage volume.

(Blank Page)

Water Master Plan Update
City of Norfolk, Nebraska
2030 Max Day (11.7 mgd)
WWTP 10.2 mgd
EWTP 1.5 mgd
Results at Hr 6 (20.7 mgd)
OUTAGE - Zone 1 16-inch Dirt Tank Fill/Draft Pipe along Prospect Avenue
Scenario 2030MD1_OUTAGE2
Figure 5-7

LEGEND

Junction Pressure (psi)

- < 20
- 20 - 30
- 30 - 40
- 40 - 90
- 90 - 110
- > 110

174 / 12" — Pipe Flow (gpm), Direction & Diameter (in)

Pipe Velocity (fps)

- < 1
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

R1 (20") — 2030 Replacement Pipe & ID & Diameter

I1 (16") — 2030 Improvement Pipe & ID & Diameter

Norfolk NEBRASKA right at home.

BLACK & VEATCH Building a world of difference.

NORFOLK_INFOWATER_PRO40.aprx
February 7, 2023

(Blank Page)

5.4 CAPITAL IMPROVEMENT PLAN (CIP)

Infrastructure improvements to the Norfolk water transmission/distribution system and the Capital Improvement Plan (CIP) are presented below. The medium-term (2030), long-term (2040), and Amendment 4 based recommended improvements are shown on Figure 5-1.

5.4.1 Construction and Project Costs

Pipeline/main, pump and pump station, and storage facility construction unit costs are based on recent construction project costs, bid tabs, etc. Historical project bid tabs and construction costs were adjusted to an October 2022 Construction Cost Index of 13,175.

Total project costs include construction costs plus permitting, legal and contract administration, engineering/design/binding, construction/commissioning services, and contingency costs as summarized in Table 5-6. Additional non-construction and contingency project costs are **28.5%** and **30%**, respectively. Total project costs markups are equal to **58.5%** of construction costs.

Table 5-6 Project Costs as a Percentage of Construction Cost

ITEM	PROJECT COSTS AS A PERCENTAGE OF CONSTRUCTION COSTS
Non-Construction Costs	
Permitting	1.0%
Legal & Contract Administration	0.5%
Engineering Design & Bidding	15.0%
Construction & Commissioning Services	12.0%
Subtotal	**28.5%**
Contingencies	
Estimating	30.0%
Subtotal	**30.0%**
TOTAL	**58.5%**

5.4.2 Pipeline/Main Recommended Improvements and Costs

Three (3) types of pipeline/main improvement projects were identified for this project:

- ***Replacement Mains*** represent pipes which will replace pipes that are near or at the end of their normal service life.
- ***Improvement Mains*** represent pipes which are needed to provide acceptable service under future demand conditions.
- ***Development Mains*** represent localized piping in the Amendment 4 development areas. Layout and sizing of development mains was for the purpose of allocating future Amendment 4 demands to the hydraulic model, determination of system pressures in the Amendment 4 development areas, etc. Actual development plan pipe locations and sizes will supersede the Amendment 4 development mains included in this master plan.

Aerial photographs were reviewed to determine whether pipeline/main improvement projects will be located outside of street alignments and not require street pavement replacement. Two (2) sets of pipeline/main unit costs were developed as described below and given in Table 5-7.

- ***Pipeline unit costs in congested areas with street pavement replacement.*** Pipeline unit construction costs in congested areas were increased 15% versus construction cost in non-congested areas. Street pavement/surface restoration was estimated to equal approximately $107/foot.
- ***Pipeline unit costs in non-congested areas without street pavement replacement.*** No markups for congested area construction or street pavement replacement are included for these pipes.

Table 5-7 Pipeline/Main Unit Construction Costs

PIPE DIAMETER (IN)	UNIT CONSTRUCTION COSTS ($/FOOT)	
	Congested Area with Pavement Replace-ment	Non-congested Area without Pavement Replace-ment
8	203	84
12	266	138
16	396	251
20	441	291

Year 2030, 2040, and Amendment 4 replacement, improvement, and development mains construction and project costs are summarized in Table 5-8 and discussed below.

Table 5-8 2030, 2040, & Amendment 4 Replacement, Improvement, & Development Mains

CIP ID	DESCRIPTION	ZONE	CIP YEAR/ PERIOD	CIP TYPE	AMEND-MENT 4 DEVELOP-MENT AREA	DIA-METER (IN)	LENGTH (FT)	IMPROVE-MENT TYPE_YEAR	PAVEMENT REPLACE-MENT LENGTH (FT)	NO PAVEMENT REPLACE-MENT LENGTH (FT)	COST PER LINEAR FOOT ($/FT)		COST ($)	
											With Pavement Replace-ment	Without Pavement Replace-ment	Construction	Project
Replacement Mains														
R1	Phillip St, 7th to 13th	1	2030	Replacement		20	2,218	Repl_2030	2,218		441		978,300	1,550,600
R2	Madison Ave, 7th to 1st, then north 240'	1	2030	Replacement		20	2,909	Repl_2030	2,909		441		1,283,000	2,033,600
R3	Dirt Tank to Prospect Ave	1	2030	Replacement		16	242	Repl_2030	242		396		96,000	152,200
R4	Prospect Ave. end R3 to 16th	1	2040	Replacement		16	3,570	Repl_2040	3,570		396		1,413,800	2,240,900
Subtotal 2030 Replacement Mains													2,357,300	3,736,400
Subtotal 2040 Replacement Mains													1,413,800	2,240,900
Subtotal 2030 & 2040 Replacement Mains													**3,771,100**	**5,977,300**

Table 5-8 2030, 2040, & Amendment 4 Replacement, Improvement, & Development Mains (Continued)

CIP ID	DESCRIPTION	ZONE	CIP YEAR/ PERIOD	CIP TYPE	AMEND-MENT 4 DEVELOP-MENT AREA	DIA-METER (IN)	LENGTH (FT)	IMPROVE-MENT TYPE_YEAR	PAVEMENT REPLACE-MENT LENGTH (FT)	NO PAVEMENT REPLACE-MENT LENGTH (FT)	COST PER LINEAR FOOT ($/FT)		COST ($)	
											With Pavement Replace-ment	Without Pavement Replace-ment	Construction	Project
Improvement Mains														
I1	Omaha/Victory	1	2030	Improvement		16	1,152	Impr_2030		1,152		251	289,300	458,500
I2	Prospect, 49th to 37th	2	2030	Improvement		12	5,123	Impr_2030		5,123		138	707,000	1,120,600
I3	37th, Prospect to Benjamin	2	2030	Improvement		12	3,994	Impr_2030		3,994		138	551,200	873,700
I4	Prospect, 34th east to existing 16"	2	2030	Improvement		8	1,886	Impr_2030		1,886		84	158,400	251,100
I5	Sheridan Dr, 37th to Westview Dr	2	2030	Improvement		16	4,143	Impr_2030		4,143		251	1,039,800	1,648,100
I6	Magnet Dr, N Victory Rd to Hwy 35	4	2030	Improvement		20	7,397	Impr_2030		7,397		291	2,152,600	3,411,900
I7	Zone 5 PS Suction	4	2030	Improvement		16	150	Impr_2030		150		251	37,600	59,600
I8	Z5 Pump Sta Discharge to Highway 35 Crossing	5	2030	Improvement		16	506	Impr_2030	506		396		200,300	317,500
I9	Hwy 35 North, I8 Improvement to E. Eisenhower	5	2030	Improvement		12	4,090	Impr_2030		4,090		138	564,400	894,600
I10	Hwy 35 Crossing to Woodland Pk	5	2030	Improvement		12	261	Impr_2030	261		266		69,400	110,000
I11	Z5 Hwy 35 South, I8 Improvement to E. Benjamin	5	2030	Improvement		16	3,441	Impr_2030		3,441		251	863,700	1,369,000
I12	Zone 5 Woodland Pk/Area 5 E/W	5	2030	Improvement		12	4,983	Impr_2030		4,983		138	687,700	1,090,000
I13	Zone 5 Woodland Pk/Area 5 N/S	5	2030	Improvement		12	1,786	Impr_2030		1,786		138	246,500	390,700
I14	Norfolk Ave (Part), Hwy 35 to E. Norfolk Ave	1	2030	Improvement		12	1,950	Impr_2030		1,950		138	269,100	426,500
I15	Monroe Ave, 13th St to S. Victory Rd	1	2040	Improvement		20	10,713	Impr_2040	3,264	7,448	441	291	3,607,000	5,717,100
I16	Victory Rd, Monroe Ave to E. Benjamin	1	2040	Improvement		20	13,611	Impr_2040		13,611		291	3,960,900	6,278,000
I17	25th St, 24" Main at 25th to Dirt Tank	1	2040	Improvement		16	2,761	Impr_2040	2,761		396		1,093,200	1,732,700
I18	Zone 3 Pump Sta Suction	2	TBD	Improvement		16	170	Impr_Amend4		170		251	42,700	67,700
I19	Zone 3 Pump Sta Discharge	3	TBD	Improvement		16	102	Impr_Amend4		102		251	25,600	40,600
I20	Eisenhower Ave, 49th St to 37th St	3	TBD	Improvement		12	5,339	Impr_Amend4		5,339		138	736,800	1,167,800
I21	49th St, Eisenhower South to I23 Improvement	3	TBD	Improvement		12	2,356	Impr_Amend4		2,356		138	325,100	515,300
I22	37th St, Eisenhower South I23 Improvement	3	TBD	Improvement		12	2,440	Impr_Amend4		2,440		138	336,700	533,700
I23	49th to 37th	3	TBD	Improvement		12	5,331	Impr_Amend4		5,331		138	735,700	1,166,100
I24	49th to 37th	2	TBD	Improvement		16	5,296	Impr_Amend4		5,296		251	1,329,300	2,106,900
I25	Eisenhower South to Sheridan	2	TBD	Improvement		12	980	Impr_Amend4		980		138	135,200	214,300
I26	Eisenhower, I25 Improvement to 25th St	2	TBD	Improvement		12	2,920	Impr_Amend4		2,920		138	403,000	638,800
I27	West of 25th St, Eisenhower to Sheridan	2	TBD	Improvement		8	620	Impr_Amend4		620		84	52,100	82,600
I28	Eisenhower, to Zone 1/2 Boundary Valve	2	TBD	Improvement		12	3,467	Impr_Amend4		3,467		138	478,400	758,300
I29	Eisenhower, Zone 1/2 Boundary to 16" Hadar Rd	1	TBD	Improvement		12	1,612	Impr_Amend4		1,612		138	222,500	352,700
I30	16" to Industrial Hwy, east to Zone 1/4 Boundary	1	TBD	Improvement		12	11,377	Impr_Amend4		11,377		138	1,570,000	2,488,500
I31	NE Industrial Hwy, Zone 1/4 Boundary to Victory Rd	4	TBD	Improvement		12	1,533	Impr_Amend4		1,533		138	211,500	335,200
I32	1st St, South 1st St to E. Monroe Ave	1	TBD	Improvement		12	3,616	Impr_Amend4		3,616		138	499,000	790,900
I33	Sherwood Rd, 13th St to 1st St	1	TBD	Improvement		12	5,228	Impr_Amend4		5,228		138	721,400	1,143,400
I34	Z5 PS Suction to Eisenhower, east on Eisenhower	4	TBD	Improvement		16	3,573	Impr_Amend4		3,573		251	896,900	1,421,600
I35	Eisenhower to Nucor Rd	4	TBD	Improvement		16	2,698	Impr_Amend4		2,698		251	677,100	1,073,200
I36	Hwy 35 & Benjamin to Norfolk Ave	5	TBD	Improvement		12	5,310	Impr_Amend4		5,310		138	732,800	1,161,500
I37	To Development Area #6	5	TBD	Improvement		12	5,499	Impr_Amend4		5,499		138	758,900	1,202,900
Subtotal 2030 Improvement Mains													**7,837,000**	**12,421,800**
Subtotal 2040 Improvement Mains													**8,661,100**	**13,727,800**
Subtotal Amendment 4 Improvement Main													**10,890,700**	**17,262,000**
Total Improvement Mains													**27,388,800**	**43,411,200**
Total 2030 & 2040 Replacement & Improvement Mains													**20,269,200**	**32,126,900**
Total 2030, 2040, Amendment 4 Repl. & Improvement Mains													**31,159,900**	**49,388,500**

Table 5-8 2030, 2040, & Amendment 4 Replacement, Improvement, & Development Mains (Continued)

CIP ID	DESCRIPTION	ZONE	CIP YEAR/ PERIOD (1)	CIP TYPE	AMEND-MENT 4 DEVELOP-MENT AREA	DIA-METER (IN)	LENGTH (FT)	IMPROVE-MENT TYPE_YEAR	PAVEMENT REPLACE-MENT LENGTH (FT)	NO PAVEMENT REPLACE-MENT LENGTH (FT)	COST PER LINEAR FOOT ($/FT)		COST ($)	
											With Pavement Replace-ment	Without Pavement Replace-ment	Construction	Project
Amendment 4 Development Mains														
		1	TBD		1	8	154	Development		154		84	12,900	20,400
		1	TBD		1	12	728	Development		728		138	100,500	159,300
		1	TBD		1	8	1,441	Development		1,441		84	121,000	191,800
		1	TBD		1	12	1,474	Development		1,474		138	203,500	322,500
		1	TBD		1	12	1,826	Development		1,826		138	252,000	399,400
		1	TBD		1	12	2,602	Development		2,602		138	359,100	569,200
		1	TBD		1	8	2,610	Development		2,610		84	219,200	347,400
		1	TBD		1	12	2,735	Development		2,735		138	377,500	598,300
		1	TBD		1	12	2,772	Development		2,772		138	382,600	606,400
		1	TBD		1	8	2,773	Development		2,773		84	232,900	369,100
		1	TBD		1	12	3,728	Development		3,728		138	514,400	815,300
		1	TBD		1	8	3,771	Development		3,771		84	316,800	502,100
		1	TBD		2E	8	1,042	Development		1,042		84	87,500	138,700
		1	TBD		2E	8	1,422	Development		1,422		84	119,400	189,200
		1	TBD		2E	8	2,035	Development		2,035		84	171,000	271,000
		2	TBD		2E	8	526	Development		526		84	44,100	69,900
		2	TBD		2E	8	798	Development		798		84	67,000	106,200
		2	TBD		2E	8	1,105	Development		1,105		84	92,800	147,100
		2	TBD		2E	8	1,573	Development		1,573		84	132,100	209,400
		2	TBD		2E	8	1,935	Development		1,935		84	162,600	257,700
		2	TBD		2E	8	1,948	Development		1,948		84	163,600	259,300
		3	TBD		2E	8	1,002	Development		1,002		84	84,200	133,500
		3	TBD		2E	8	1,024	Development		1,024		84	86,000	136,300
		3	TBD		2E	8	1,419	Development		1,419		84	119,200	188,900
		3	TBD		2E	8	1,694	Development		1,694		84	142,300	225,500
		3	TBD		2E	8	2,689	Development		2,689		84	225,900	358,100
		3	TBD		2E	8	3,087	Development		3,087		84	259,300	411,000
		3	TBD		2E	8	3,091	Development		3,091		84	259,600	411,500
		2	TBD		3	8	2,015	Development		2,015		84	169,200	268,200
		2	TBD		3	8	2,026	Development		2,026		84	170,200	269,800
		2	TBD		3	8	3,221	Development		3,221		84	270,500	428,700
		2	TBD		3	8	5,233	Development		5,233		84	439,600	696,800
		3	TBD		3	8	845	Development		845		84	71,000	112,500
		3	TBD		3	8	873	Development		873		84	73,300	116,200
		3	TBD		3	8	1,217	Development		1,217		84	102,200	162,000
		3	TBD		3	8	2,436	Development		2,436		84	204,600	324,300
		3	TBD		3	8	5,323	Development		5,323		84	447,100	708,700
		3	TBD		3	8	5,617	Development		5,617		84	471,900	748,000

Table 5-8 2030, 2040, & Amendment 4 Replacement, Improvement, & Development Mains (Continued)

CIP ID	DESCRIPTION	ZONE	CIP YEAR/ PERIOD (1)	CIP TYPE	AMEND-MENT 4 DEVELOP-MENT AREA	DIA-METER (IN)	LENGTH (FT)	IMPROVE-MENT TYPE_YEAR	PAVEMENT REPLACE-MENT LENGTH (FT)	NO PAVEMENT REPLACE-MENT LENGTH (FT)	COST PER LINEAR FOOT ($/FT)		COST ($)	
											With Pavement Replace-ment	Without Pavement Replace-ment	Construction	Project
Amendment 4 Development Mains														
		1	TBD		4	12	16,448	Development		16,448		138	2,269,800	3,597,600
		5	TBD		5	8	698	Development		698		84	58,600	92,900
		5	TBD		5	8	1,678	Development		1,678		84	140,900	223,300
		5	TBD		5	8	2,639	Development		2,639		84	221,600	351,200
		5	TBD		5	8	2,639	Development		2,639		84	221,700	351,400
		5	TBD		5	8	2,639	Development		2,639		84	221,700	351,400
		5	TBD		6	8	2,435	Development		2,435		84	204,500	324,100
		5	TBD		6	8	2,435	Development		2,435		84	204,500	324,100
		5	TBD		6	8	2,435	Development		2,435		84	204,500	324,100
		5	TBD		6	8	2,486	Development		2,486		84	208,800	330,900
		5	TBD		6	8	2,486	Development		2,486		84	208,800	330,900
		5	TBD		6	8	4,972	Development		4,972		84	417,600	661,900
		5	TBD		6	8	4,972	Development		4,972		84	417,600	661,900
		4	TBD		9	12	2,040	Development		2,040		138	281,500	446,200
		4	TBD		9	12	2,129	Development		2,129		138	293,900	465,800
		4	TBD		9	12	2,542	Development		2,542		138	350,900	556,200
		4	TBD		9	12	2,595	Development		2,595		138	358,100	567,600
		4	TBD		9	12	2,882	Development		2,882		138	397,600	630,200
Area 1 Development Mains													3,092,400	4,901,500
Area 2E Development Mains													2,216,600	3,513,300
Area 3 Development Mains													2,419,600	3,835,100
Area 4 Development Mains													2,269,800	3,597,600
Area 5 Development Mains													864,500	1,370,200
Area 6 Development Mains													1,866,300	2,958,100
Area 9 Development Mains													1,682,000	2,666,000
Subtotal Amendment 4 Development Mains													**14,411,200**	**22,841,800**
TOTAL Replacement, Improvement, & Amendment 4 Development Mains													**45,571,100**	**72,230,200**

(1) TBD = To Be Determined

- 2030 and 2040 replacement main project costs are **$3,736,400** and **$2,240,900**, respectively. Total replacement main project costs are **$5,977,300**.
- 2030, 2040, and Amendment 4 improvement main project costs are **$12,421,800**, **$13,727,800**, and **$17,262,000**, respectively. Total improvement main projects costs are **$43,411,200**.
- Total 2030 and 2040 replacement and improvement main projects costs are **$32,126,900**.
- Total 2030, 2040, and Amendment 4 replacement and improvement main project costs are **$49,388,500**.
- Total Amendment 4 development main project costs are **$22,841,800**.
- Total 2030, 2040, and Amendment 4 replacement, improvement, and development Main project costs are **$72,230,300**.

2030 Service to Woodland Park and Amendment 4 Development Area #5. The 2030 improvement mains total project costs in Zones 4 and 5 (Improvement Mains I6 through I14) are equal to **$7,643,000**. This is equivalent to approximately **61.5%** of the 2030 improvement mains total project cost (**$12,421,800**). The 2030 Zones 4 and 5 improvement mains will provide service to Woodland Park and Amendment 4 Development Area #5. If service to Woodland Park and Amendment 4 Development Area #5 do not occur by 2030, the 2030 improvement mains total project cost will drop to **$4,778,500**.

2040 Zone 1 "Southern" (Monroe Avenue/Victory Road) Transmission Mains. The 2040 Zone 1 "Southern" (Monroe Avenue/Victory Road) transmission mains (***Improvement Mains I15 and I16***) will play a major role meeting future demands in the eastern portions of the distribution system. Improvement Mains I15 and I16 have a 2040 project cost of **$11,995,100**, which represents **87.4%** of the 2040 improvement mains total project cost (**$13,727,800**). Because of the high cost of these improvement mains, care will need to be exercised to monitor future development and demands in the easter part of the distribution system regarding when to initiate design and construction of these mains.

5.4.3 Pump and Pump Station Improvements and Costs

Pump and pump station improvements and costs are given in Table 5-9 and discussed below.

- ***Individual Pump Unit Construction Cost (per MGD basis).*** The individual pump unit cost used for this study is based the on the Northeast Industrial Pump Station Pump #6 construction cost (2020) adjusted to October 2022 costs (CCI 13175). The individual pump unit construction cost is **$152,000 per mgd**.
- ***Pump Station Unit Construction Cost (per MGD basis).*** The pump station unit cost used for this study is based the on the Northeast Industrial Pump Station construction cost (2010) adjusted to October 2022 costs. The pump station unit construction cost is **$738,000 per mgd**.

Table 5-9 Pump and Pump Station Improvements

CIP ID	PUMP STATION	PUMP NUMBER	CONSTRUC-TION YEAR OR AMEND-MENT 4	ZONE	DESIGN				UNIT COST ($/MGD)	COST ($)	
					Flow		Head (ft)	Variable Frequency Drive		Construction (1)	Project (2)
					(gpm)	(mgd)					
P1	West Water Treatment Plant	3	2030	2	**2,200**	**3.17**	245	Yes	**$152,000**	**$482,000**	**$764,000**
P2	Future Zone 5	1	2030	5	70		66	Yes			
		2			150		66	Yes			
		3			300		66	Yes			
		4			1,500		66	Yes			
					2,020	**2.91**			**$738,000**	**$2,147,000**	**$3,403,000**
P3	Future Zone 3	1	Amend-ment 4 (TBD)	3	70		110	Yes			
		2			300		110	Yes			
		3			600		110	Yes			
		4			1,500		110	Yes			
					2,470	**3.56**			**$738,000**	**$2,625,000**	**$4,161,000**
TOTAL										**$5,254,000**	**$8,328,000**
Individual Pump Construction Cost per MGD (1)										$152,000	
Pump Station Construction Cost per MGD (2)										$738,000	

(1) Based on Northeast Pump Station Pump No. 6 construction cost (2020) adjusted to October 2022 CCI (13175).
(2) Based on Northeast Pump Station construction cost (2010) adjusted to October 2022 CCI.

- ***WWTP Zone 2 Pump #3, Pump Improvement (2030).*** WWTP Zone 2 Pump #3, ***Pump Improvement P1*** (2000 gpm at 245 feet), will provide increased pumping capacity to Zone 2 and improved operational flexibility.
- ***Future Zone 5 Pump Station (2030).*** Future Zone 5 Pump Station, ***Pump Improvement P2***, will provide service to Woodland Park and Amendment 4 Development Areas #5 and #6. The Zone 5 Pump Station will be located along Magnet Drive west of Highway 35.

  It is proposed that the Zone 5 Pump Station include four (4) pumps with a total pumping capacity of **2,020 gpm (2.9 mgd)**. It is recommended that the pumps have rated heads of approximately **66 feet**. This will support a future Zone 5 hydraulic grade line elevation (HGL) of approximately **1,855 feet**. This is approximately 20 feet higher than the existing Woodland Park Standpipe maximum water operating level (overflow) of **1,835 feet** (see ***Improvement T4*** discussion below).
- ***Future Zone 3 Pump Station (Construction based on development within Amendment 4 Development Areas 2E, 2W, and 3).*** Construction of the Zone 3 Pump Station will be based on development within Amendment 4 Development Areas 2E, 2W, and 3. The Zone 3 Pump Station

pumps are sized to delivery Zone 3 maximum hour demands. No "floating" storage in Zone 3 is recommended at this time.

5.4.4 Tank/Reservoir Improvements and Costs

Storage facility (tank/reservoir) improvements and costs are given in Table 5-10 and discussed below.

Table 5-10 Storage Facility (Tank/Reservoir) Improvements

CIP ID	LOCATION/ DESCRIPTION	YEAR/ AMEND-MENT 4	ZONE	DESIGN					COST ($)		NOTES
				Type	Elevation (ft)		Depth (ft)	Vol-ume (MG)	Diam-eter (ft)	Construction	Project	
					Floor	Over-flow						
T1	West Water Treatment Plant	2030	Pump Station Suction Storage	Ground	1,544	1,589	45.0	2.0	87.0	$2,897,000	$4,592,000	Exposed steel tank. above grade, circular.
T2	Zone 1, Second Dirt Tank	2030	1	Ground	1,674	1,701	27.0	1.0	79.4	$2,210,000	$3,503,000	Below ground tank. concrete construction.
T3	Zone 1, Existing Dirt Tank Replacement	2040	1	Ground	1,674	1,701	27.0	1.0	79.4	$2,210,000	$3,503,000	Below ground tank. concrete construction.
T4	Zone 5	Amend-ment 4 (TBD)	5	Elevated	TBD	1,855 (1)	28	0.2	-	$1,450,000	$2,298,000	Elevated Tank. Approx. Height approx. 120 feet.
TOTAL										**$8,767,000**	**$13,896,000**	

TBD = To Be Determined
(1) Proposed future Zone 5 HGL equal to 1,755 feet, approximately 20 feet higher than Woodland Park Standpipe high water level (overflow).

- ***West Water Treatment Plant Pump Station Suction Storage (2030).*** An existing 2.0 MG ground storage tank currently supplies suction storage to the WWTP Zone 1 and 2 pumps. A second 2.0 MG ground storage tank (***Improvement T1***) is recommended to improve operational flexibility, filter backwashing, etc. at the WWTP.
- ***Zone 1 Second Dirt Tank (2030).*** A second Zone 1 below ground storage tank (1.0 MG, ***Improvement T2***) is recommended at the existing Zone 1 Dirt Tank site.
- ***Zone 1 Existing Dirt Tank (2040).*** The existing Zone 1 Dirt Tank was constructed in the mid 1940's, has undergone repairs and upgrades, and is generally considered to be in sound structural condition. ***Reservoir/Tank Improvement T3*** represents replacement of the existing Zone 1 Dirt Tank with a new 1.0 MG storage tank at the same location. Based on the condition and structural integrity of the existing Zone 1 0.75 MG Dirt Tank, the City may consider deferring its replacement to a later date while performing needed maintenance/rehabilitation of the existing tank.

- ***Zone 5 Elevated Tank (Construction Year To Be Determined).*** It is proposed that initial service to Woodland Park and Amendment 4 Development Area 5 be supported by the existing Woodland Park Standpipe. However, due to the small storage volume available in the Woodland Park Standpipe (90,000 gallons), the existing Woodland Park maximum operating level HGL (1,835 feet), and potential low pressures at Zone 5 high ground elevations, consideration should be given to replacing the Woodland Park Standpipe with a Zone 5 Elevated Tank (***Improvement T4***). It is recommended that the future Zone 5 Elevated Tank have a maximum operating level (overflow) HGL of **1,855 feet**, 20 feet higher than the Woodland Park Standpipe. This will support Zone 5 development up to a maximum ground elevation of approximately **1,740 feet** and increase Zone 5 system pressures during peak demand conditions.

Storage Capacity Comparison with other Utilities. It is noted that the distribution system current storage volume, including floating storage and water treatment plant high service pumps suction storage is equal to **5.5 MG** (Table 3-4). The 2021 maximum day demand was equal to **9.6 mgd** (Table 2-2). These figures indicate that the distribution system has approximately **57%** of the maximum day demand available in system storage.

For comparison, the Aurora Water (Colorado), City of Boulder (Colorado), and City of Pueblo (Colorado) water distribution systems contain the equivalent of 80%, 108%, and 120% of maximum day demand in storage. The City's existing distribution system storage volume, expressed as a percentage of maximum day demand, is considerably below the storage volumes maintained by the above Front Range Colorado utilities. The City may consider "fast tracking" construction of the tank/reservoir improvements included in the CIP to increase operational flexibility and system reliability and assure high quality customer service.

5.4.5 Valve Improvements

Two (2) isolation valves (***Improvements V1 and V2***; see Figure 5-1) will be required to separate Zones 1, 2, and 4 and support service to Amendment 4 Development Area 8. These will likely be closed gate or butterfly valves, but may be pressure reducing valves with low pressure setting that cause the valves to only become operational during firefighting and/or emergency conditions.

5.4.6 Capital Improvement Plan (CIP) Cost Summary

Capital Improvement Plan (CIP) construction and project costs are summarized in Table 5-11 and discussed below.

Table 5-11 Construction and Project Costs Summary (CIP)

ITEM	COST ($)		PROJECT COST PERCENT OF TOTAL (%)
	Construction	Project	
Pipelines/Mains			
2030 Replacement Mains	2,357,300	3,736,400	4.0%
2040 Replacement Mains	1,413,800	2,240,900	2.4%
2030 Improvement Mains	7,837,000	12,421,800	13.2%
2040 Improvement Mains	8,661,100	13,727,800	14.5%
Amendment 4 Improvement Mains	10,890,700	17,262,000	18.3%
Amendment 4 Development Mains	14,411,200	22,841,800	24.2%
Subtotal 2030 Mains	10,194,300	16,158,200	17.1%
Subtotal 2040 Mains	10,074,900	15,968,700	16.9%
Subtotal Amendment 4 Mains	25,301,900	40,103,800	42.5%
Subtotal Replacement, Improvement, & Development Mains	**45,571,100**	**72,230,700**	**76.5%**
Pumps & Pump Stations			
2030 Pumps & Pump Stations	2,629,000	4,167,000	4.4%
2040 Pumps & Pump Stations	0	0	0.0%
Amendment 4 Pumps & Pump Stations	2,625,000	4,161,000	4.4%
Subtotal Pumps & Pump Stations	**5,254,000**	**8,328,000**	**8.8%**
Tanks/Reservoirs			
2030 Tanks/Reservoirs	5,107,000	8,095,000	8.6%
2040 Tanks/Reservoirs	2,210,000	3,503,000	3.7%
Amendment 4 Tanks/Reservoirs	1,450,000	2,298,000	2.4%
Subtotal Tanks/Reservoirs	**8,767,000**	**13,896,000**	**14.7%**
Mains, Pumps, Tanks			
Subtotal 2030	17,930,300	28,420,200	30.1%
Subtotal 2040	12,284,900	19,471,700	20.6%
Subtotal Amendment 4	29,376,900	46,562,800	49.3%
TOTAL	**59,592,100**	**94,454,700**	**100.0%**

- Year 2030, 2040, and Amendment 4 total construction and project costs for pipelines/mains, pumps/pump stations, and tanks/reservoirs are **$59,592,100** and **$94,454,700**, respectively.
- Year 2030, 2040, and Amendment 4 Replacement, Improvement, and Development mains total construction and project costs are **$45,571,100** and **$72,230,200**. The pipeline/main total project cost represents **76.5%** or the total mains/pumps/tanks cost. However it is noted that a

major portion of this cost, approximately **42.5%**, is located in the Amendment 4 development areas.

- Year 2030 pipeline/main, pump and pump station, and tank improvement construction and project costs are **$17,930,300** and **$28,420,200**. Year 2030 total project costs account for **30.1%** of 2030, 2040, and Amendment 4 total project costs.
- Year 2040 pipeline/main, pump and pump station, and tank improvement construction and project costs are **$12,284,900** and **$19,471,700**. Year 2040 total project costs account for **20.6%** of 2030, 2040, and Amendment 4 total project costs.

5.4.7 Improvement Selection and Staging – Special Considerations.

While the main, pump, and tank improvements are generally grouped within the medium-term (2030), long-term (2040), and Amendment 4 planning periods, localized growth patterns and Norfolk's transmission/distribution system operations and performance can play a major role in selecting the timing of future improvement design and construction.

Improvements with immediate, large benefits. Certain improvements will have immediate, large benefits justifying prompt design and construction.

- ***Improvement Main I1*** will close a gap between 16-inch and 12-inch mains along Omaha Avenue and Victory and increase hydraulic capacity to the east side of the City.
- ***Tank/Reservoir Improvements T1 and T2.*** Tank improvements T1 and T2 will increase the total distribution system storage volume by about 3 MG. This will increase the total distribution system volume to approximately **8.5 MG**, which represents approximately 88% of the 2021 maximum day demand (9.6 mgd). This would result in the City's distribution system storage volume, expressed as a percentage of maximum day demand, being comparable to other well operated water utilities.
- ***Replacement Main R3*** will replace a short section of potentially vulnerable 16-inch draft/fill pipe near the Zone 1 Dirt Tank in close proximity to high end residential property. Examination of the pipe that is replaced and its condition will also provide direction regarding the staging/construction of ***Replacement Mains R1, R2, and R4***.

Localized growth based improvements. Certain improvements will be linked directly to service areas that "trigger" the need for their design and construction.

- The future Zone 5 Pump Station, ***Improvement P2***, will be dependent on future service to Woodland Park and/or Amendment 4 Development Area #5. Service to Woodland Park only would require ***Improvement Mains 16 through I10***; ***Improvement Mains I11 through I13*** may be deferred until development of Amendment 4 Development Area #5 occurs.
- The future Zone 3 Pump Station, ***Improvement P3***, and ***Zone 3 Improvement Mains*** will be dependent on future service to development in future Zone 3 and Amendment 4 Development Areas 2E, 2W, and/or 3.

System-wide demand based improvements. Certain improvements will be driven by system-wide demand growth.

- The "Southern" Zone 1 transmission mains, long-term (2040) ***Improvement Mains I15 and I16*** (20-inch) are projected to be required when system-wide maximum day demands reach approximately **13.7 mgd**. System-wide maximum day demands and potential growth trends

should be closely monitored to allow adequate time and budgeting for the major improvement project.