City of Unalaska

Water System Master Plan

May 18, 2018

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Acronyms and Abbreviations

ADL	Alaska Division of Lands
AI	Aggressivity Index
AMI	Advanced Metering Infrastructure
AMR	Automatic Meter Reading
AWWA	American Water Works Association
bgs	below ground surface
$CaCO_3$	calcium carbonate
CBR	Captains Bay Road
CMMP	Capital and Major Maintenance Plan
CMMS	computerized maintenance management system
COPA	Cost of Power Adjustment
CT	concentration x time
cVOCs	carcinogenic volatile organic compounds
DBP	disinfection byproduct
DCCED	Alaska Department of Commerce and Community Economic Development
DEC	Alaska Department of Environmental Conservation
DOL	Alaska Department of Labor
DNR	Alaska Department of Natural Resources
EPA	U.S. Environmental Protection Agency
FPS	feet per second
FY	Fiscal Year
gal	gallon
GIS	geographic information system
gpcd	gallons per capita per day
gpm	gallons per minute
GWUISW	groundwater under the influence of surface water
HDPE	high-density polyethylene
kW	kilowatt
kWh	kilowatt-hour
LAS	Land Administration System
lb	pound
LT2ESWTR or LT2	Long Term 2 Enhanced Surface Water Treatment Rule
M	million
Max	maximum
MG	million gallons
MGD	million gallons per day
Min	minimum
MWh	megawatt-hour
NTU	nephelometric turbidity unit
O&M	operations and maintenance
OSI	Offshore Systems, Inc.
PLC	programmable logic controller
PRV	pressure reducing valve
PPP	public-private partnership
PSI	pounds per square inch
Rd	Road
RMP	risk management program
SCADA	supervisory control and data acquisition
SDR	sidewall to diameter ratio
TEG	thermoelectric generator
ug/L	micrograms per liter
UPCH	Unalaska Pump Control House
WTP	water treatment plant

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1 EXECUTIVE SUMMARY

The City of Unalaska (City) contracted HDR in 2017 to prepare this Water System Master Plan. The master plan effort included evaluating Unalaska's water system, projecting future demands and regulatory drivers, assessing utility operational and management functions, and identifying needed capital improvements.

The previous Unalaska water system master plan was written in 2004. A central theme in that master plan was the then-impending Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR or simply LT2). That new federal regulation drove major capital improvements for surface water systems to control *Cryptosporidium*. As of 2015 the City is in full compliance with LT2 with the completion and startup of the Pyramid Water Treatment Plant (WTP), which treats water from the Icy Creek/Lake watershed. The City can now turn its attention toward other needs.

This master plan identifies a large number of capital and operational improvements to meet current and future water system needs and to continually improve the reliability of water service to customers. Some of the needs and improvements are carried forward from the 2004 master plan and others are new. From a broader perspective there are five key goals on which the City should focus on achieving over the next twenty years:

1. Solve several major hydraulic limitations in the water transmission and distribution system by installing a water main along Captains Bay Road to North Pacific Fuel.

   The lack of this critical water main has required numerous workarounds for many years in order to maintain water service to North Pacific Fuel; has prevented the City from realizing the full potential of a number of other water system assets; has caused the City many years of inefficient water supply management; has delayed several other critical projects due to interdependencies; and accounts for the waste of almost 50 million gallons of water annually through existing pipe leaks.

   A water main along Captains Bay Road to North Pacific Fuel could have numerous positive ramifications for many of the other improvement projects considered in this master plan and could enhance water system operational flexibility. The project would also improve the feasibility of providing future water service to other potential customers further down Captains Bay Road. Solving this need is the single most important step forward that the City could take for its water system in the next 20 years.

2. Take advantage of hydroelectric power generation opportunities.

   There is the potential for hydroelectric power generation from water flowing through the Pyramid WTP. Based on the economic analysis in this master plan, the project could pay for itself in less than 7 years. The system could generate more than enough electricity to power the water treatment plant for almost 8 months of the year and at times there could be excess electricity to use for space heating in the water treatment plant.

3. Produce more water to meet projected future demand growth.

   Annual water demand is projected to increase by approximately 200 million gallons in 20 years. Based on seasonal demand patterns, that is roughly the equivalent of needing to produce an additional 1 million gallons per day during processing seasons. The City has been taking steps to develop additional groundwater supply, and additional surface water supply capacity is also recommended.

4. Develop more treated water storage, especially in the Town pressure zone.

   The water system needs more treated water storage capacity to meet industry standards for emergency storage and to improve operational efficiency. A new water storage tank should be located in the Town pressure zone (Pressure Zone 3) to provide hydraulic balance to the system and to improve resiliency.

5. Implement a proactive and routine pipe asset management program.

   Unalaska is fortunate to have a relatively new pipe system (in comparison to many other utilities around the nation). However, as Unalaska's pipes approach "middle age" based on the estimated lifespan of ductile iron pipe, it is time that the City begin taking proactive steps to electronically document pipe condition whenever accessible, record field information about pipe breaks, and employ innovative condition assessment tools when practical and cost effective. While there are few pipe condition problems currently, starting to collect this information now could be invaluable in making informed decisions about pipe replacement in the future.

1.1 Recommended Capital Projects

A list of all of the recommended capital projects is presented in Table 1 along with HDR's opinion of probable project cost for each. Projects are listed in order of prioritization score with the highest scoring project first. Prioritization scores are from the scoring matrix developed in Section 6.4.

Improvements are categorized in Table 1 as being driven by Regulatory requirements, the desire for better Efficiency, or conformance with Industry Standards. The Efficiency category includes projects that directly improve energy efficiency as well as projects that improve operational efficiency or reduce maintenance. Projects that improve the City's water supply or distribution system resiliency, reliability, or operational flexibility are categorized under Industry Standards. Projects that address a serious safety issue are also identified as such in the Improvement Category column of Table 1.

The opinion of probable cost shown in Table 1 represents total cost of each project including construction, engineering, permitting, land acquisition, construction management, and a construction contingency. Costs are in 2018 dollars. Costs for the City's project administration activities are not included.

The column in Table 1 with the heading "Goal Addressed" and the numbers in that column identify specific projects that help the City achieve the goals indicated above, and which goal in particular. Some projects do not pertain to any of the goals described above and those projects are marked "N/A" in the "Goal Addressed" column.

Table 1: Recommended Capital Improvement Projects

Project Name	Goal Addressed	Improvement Category	Prioritization Score	Opinion of Probable Cost
Pyramid WTP Micro-Hydroelectric Generation	2	Efficiency	4.5	$ 316,000
Captains Bay Road Water Main	1	Industry Standard	4.3	$ 3,150,000
Additional Solar Panels for Icy Lake Valve Station	3	Efficiency and Safety	4.0	$ 50,000
Backup Generators for Groundwater Wells	4	Industry Standard	4.0	$ 600,000
Icy Lake Hydrographic Survey	3	Industry Standard	3.8	$ 45,000
Increase Treated Water Storage Capacity	4	Industry Standard	3.8	$ 9,240,000
UPCH Automated Controls	N/A	Efficiency	3.8	$ 300,000
East Point Crossing	5	Industry Standard	3.6	$ 150,000
Meter Reading System	N/A	Efficiency	3.5	$ 262,000
Water Meter Installation	N/A	Industry Standard	3.5	$ 210,000
Icy Lake Capacity Increase & Snow Basin Diversion	3	Industry Standard	3.4	$ 3,310,000
General Hill Water Pressure	N/A	Regulatory	3.2	$ 222,000
Increase Groundwater Supply	3	Industry Standard	3.0	$ 1,600,000
Meter and Booster Pump at Agnes Beach PRV Station	N/A	Industry Standard	3.0	$ 300,000
Public Watering Points	N/A	Regulatory	2.7	$ 286,000
Sediment Traps Between Icy Lake and Icy Creek Reservoir	3	Industry Standard	2.6	$ 500,000
Raven Way Water Main Extension	N/A	Industry Standard	2.2	$ 308,000
Biorka Drive Cast Iron Waterline Replacement	N/A	Industry Standard	1.8	$ 354,000

1.2 Recommended Utility Management Actions

The master plan identifies the following recommended utility management actions and process improvements:

- Water Rights: After years of updating, correcting, and consolidating water rights applications with the Alaska Department of Natural Resources, the City is close to obtaining permanent water rights for its groundwater wells and the Icy Lake/Icy Creek system. Water rights are not finalized until the submittal of the Statements of Beneficial Use. A Statement of Beneficial Use for each water right is due within ten years of the date that the permit to appropriate water is issued. If the Statement of Beneficial Use for each water right is not submitted by the due date, then the water rights appropriation will have to be redone, losing decades of effort.
- Watershed Control Program Plan update: An update to the Icy Creek watershed control program plan is overdue. In order to be compliant with regulations and as a supplier of a critical resource to a world-class fish processing industry it is recommended that the City maintain a proactive watershed control program, update the watershed control plan regularly, execute the watershed improvements proposed in the plan, and meet the regulatory requirement for annual reporting. Further, it is recommended that updates to the watershed control program plan be formally adopted by City Council in order to add accountability and promote awareness of issues that could affect water quality and economic prosperity.
- Staffing: The Water Utility appears to be short staffed on operators. It is recommended that the City perform a staffing analysis to verify the need for additional operators, determine how many more operators are needed, and look for ways to increase efficiency.

2 INTRODUCTION

The City of Unalaska contracted HDR in 2017 to perform a water system master plan. This project was assigned the City project / file number 43-467 and HDR project number 10057343. This master plan was prepared by HDR civil engineers Wescott Bott and Anson Moxness under the direction of Dan Billman.

The purpose of this master plan is to project future customer demands, identify deficiencies and improvement needs, and document operations and maintenance concerns, so that current and future operational and capital needs for the system are understood, substantiated, and incorporated into the Capital and Major Maintenance Plan (CMMP). This plan is necessary to allow the City to program and budget funding for required upgrades and replacements in a forward-looking manner. The master plan is based on a 20-year planning horizon for the system needs, population and water demand projections, and capital improvement implementation.

The scope of this master plan included the following general components:

- Gather and review existing documents and data about the water system.
- Identify and interview key stakeholders for input on the water system.
- Visit key water system facilities and discuss their use, limitations, and deficiencies with operations and maintenance staff.
- Document and evaluate existing conditions, deficiencies, and opportunities for system improvement.
- Analyze population, fish processing throughput, and water use data to develop trends and define base year planning criteria.
- Evaluate future growth and how the growth relates to water use.
- Define future planning criteria for water use.
- Evaluate pipe life expectancy.
- Develop and analyze alternatives for capital and operational improvements.
- Prepare a master plan document and associated list of prioritized capital improvements to implement the plan’s recommendations.

A map of Unalaska’s water system is provided in Figure 1.

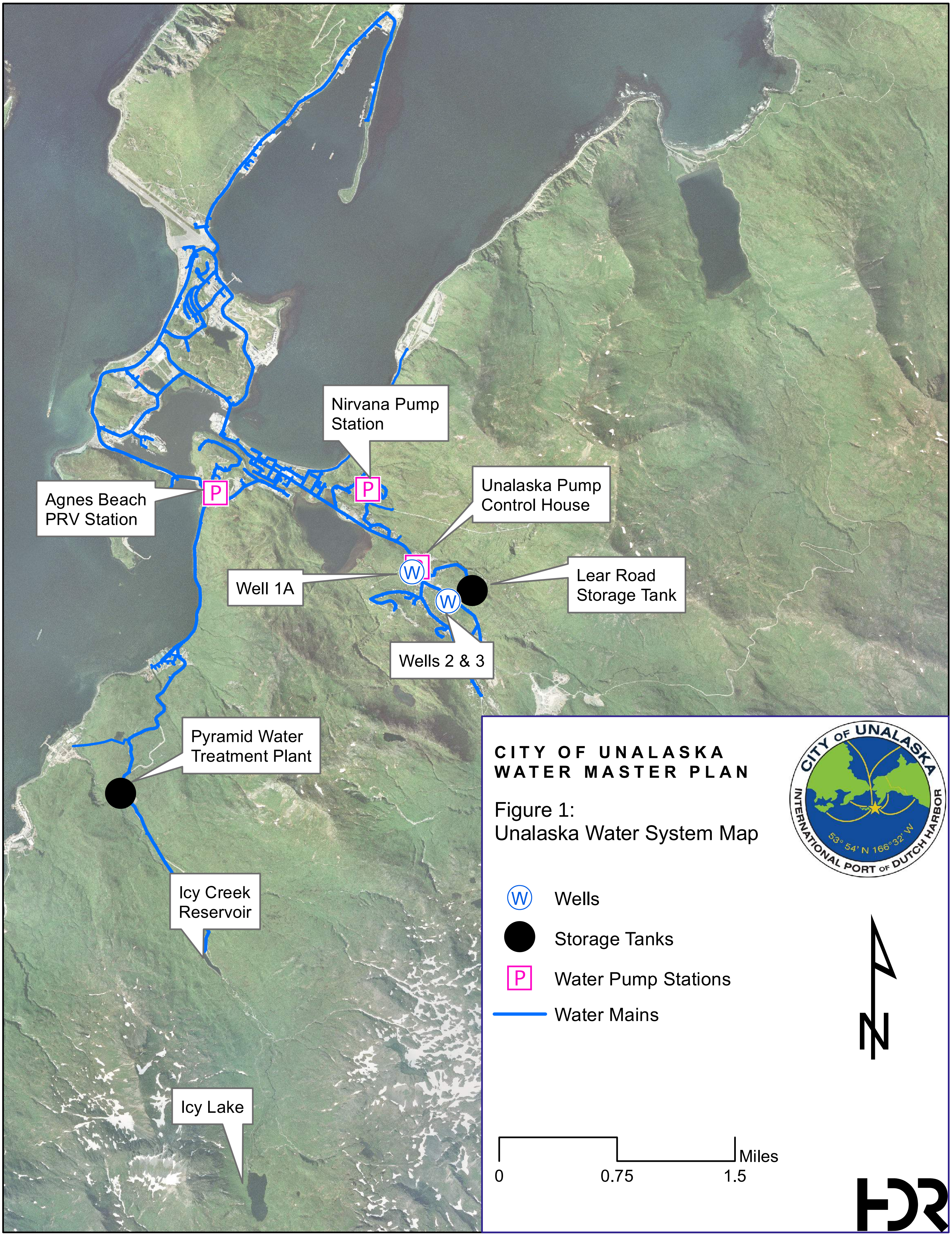


Figure 1:
Unalaska Water System Map

3 POPULATION AND WATER DEMAND

One of the goals of a water master plan is to determine the existing planning conditions in the community and then forecast the future conditions. These forecasted conditions help define the design criteria that govern the size and extent of future improvement recommendations. This section will review the planning parameters including: current and projected population, current and projected water demands, and existing and anticipated future storage requirements.

3.1 Current Population

The 2010 U.S. census reports that there are 4,376 residents for the City of Unalaska. The 2010 U.S. Census reports that 2,277 residents of the City of Unalaska live in households and 2,099 residents live in “group quarters”.

The Alaska Department of Labor (DOL) provides yearly population estimates. The DOL estimates that in 2016 there are 4,448 residents in the City of Unalaska.

The population for Unalaska varies throughout the different seasons as people move in and out for the commercial fishing industry. According to the City website 5,000 to 6,000 transient people can come to Unalaska during peak fishing seasons and processing times.

3.2 Current Water Production and Use

The City has identified water use for Unalaska as metered services (industrial, commercial, some single-family residential and multi-family units), unmetered services (single-family residential), miscellaneous water use for hydrants and water truck fills, and unaccounted (leakage or lost). Current water use data has been developed using monthly flow data from 2003 to 2016 and daily water production data from 2013-2017. Figure 2 shows the minimum, average, and maximum daily water production data from 2013- 2017.

Peak water use periods are influenced by fishing seasons and fish processor water use. Peak water use is during the "A" Season, which starts in mid- to late-January and extends through March. The secondary major use period is during the "B" Season, which commences approximately mid-June and extends through mid-September. These processing seasons can be seen in Figure 2 and they control the peak required water production. Peak processor use also corresponds with peak population periods due to the influx of transient workers. It is important to note that the Utility must plan major maintenance activities around peak processor seasons.

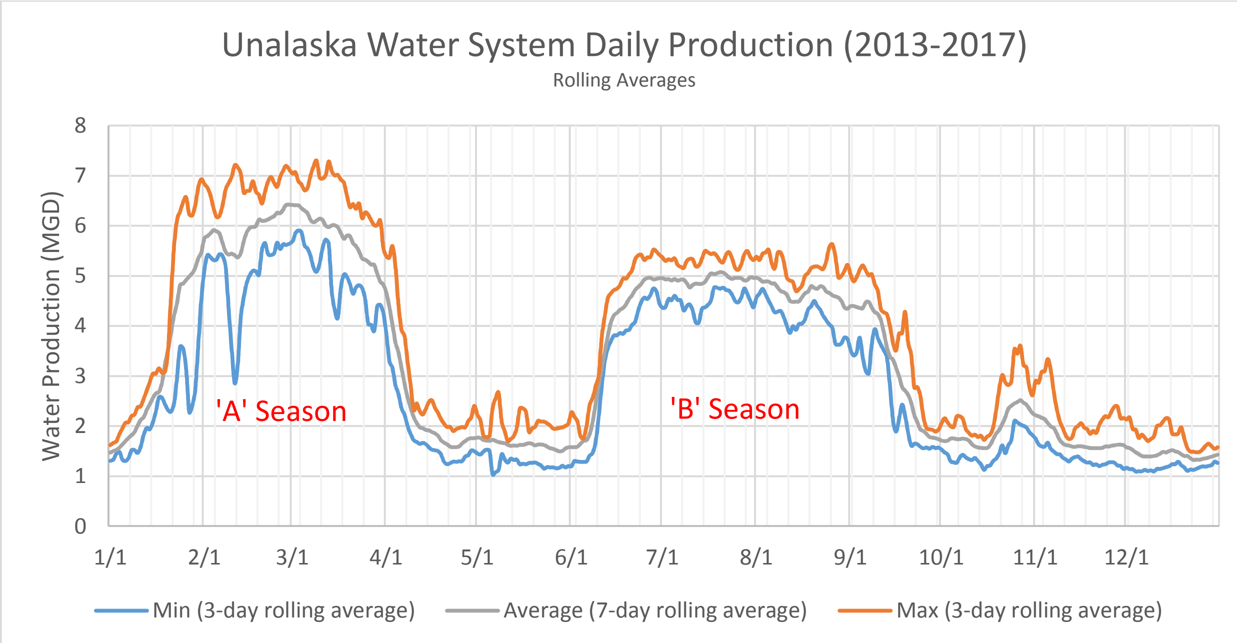


Figure 2: Average Daily Production Data (2013-2017)

3.2.1 Metered Users

Most water demand comes from metered commercial and industrial services. The largest component of this water demand comes from four seafood processing facilities (Unisea, Westward, Alyeska, and Icicle). Other metered structures include some single-family residential buildings, multi-family residential buildings, restaurants, retail stores, City facilities, and seafood processing support facilities.

3.2.2 Metered Water Use

The majority of water use in Unalaska is metered, largely because of the substantial demand from the seafood processors. Within the thirteen years of records collected (2003-2016) the metered water demand has remained relatively stable with an average total demand of 983 million gallons (MG) per year. In 2016, metered water use accounted for approximately 83% (1,052 MG) of the total water produced. Typically the highest demands on the system occur in February, March, August and September, which are also the highest seafood processing months.

Metered services include both the large, seasonal water demands of seafood processing facilities and smaller year-round water demands such as single- and multi-family residential, and city facilities. A base metered use was determined by calculating the average daily demands during May, between the A and B fish processing seasons, when there is no fish processing. The base metered use was subtracted from the metered data to determine estimated processor use during the fish processing seasons. The estimated annual processor use was compared to recorded annual fish landings as reported by NOAA Fisheries. Figure 3 below shows a comparison between annual fish landings, base use, and estimated annual processor use.

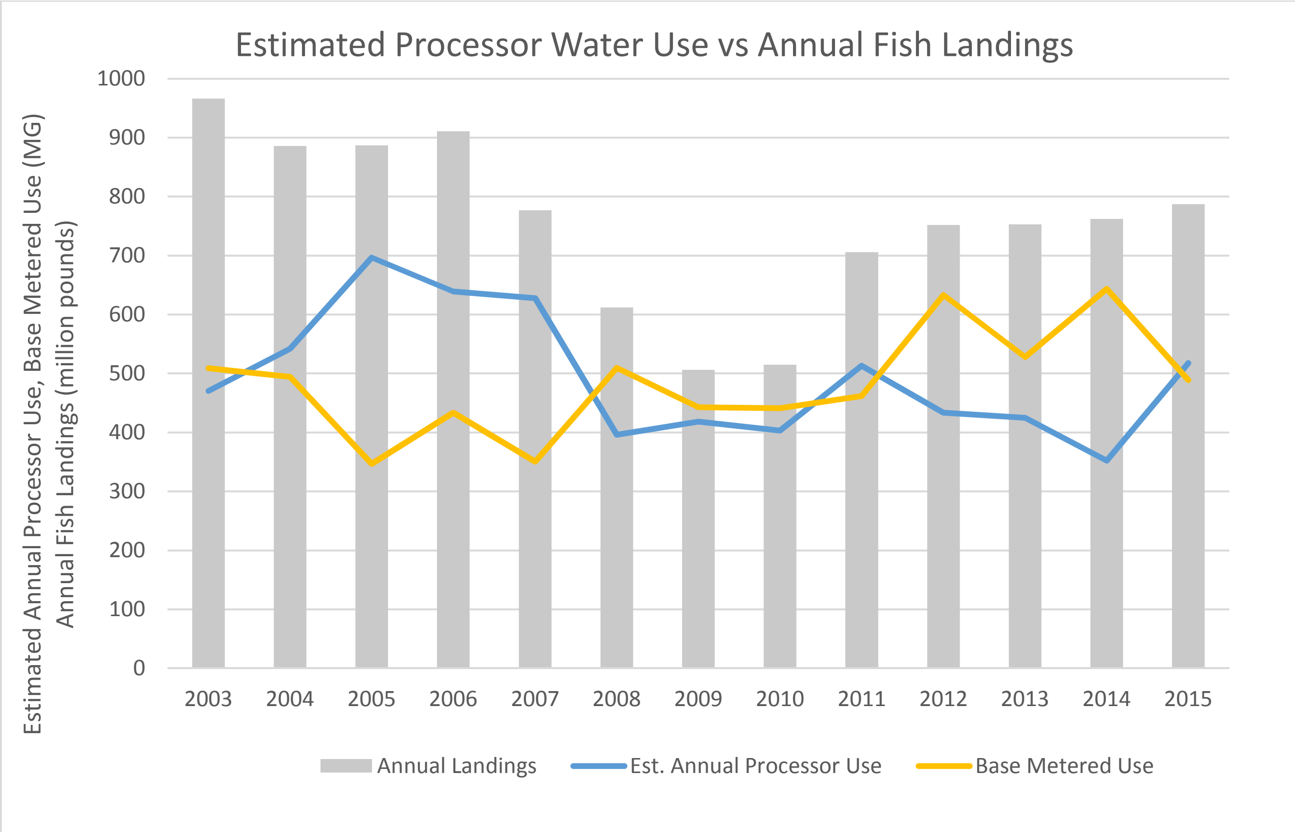


Figure 3: Estimated Base and Processor Water Use vs Annual Fish Landings in Dutch Harbor

3.2.3 Unmetered Users

Currently, most single-family and duplex residential units are not metered by the City but instead charged a flat fee for water service. The majority of residential properties in Unalaska are serviced by the public water system. According to the 2016 water records from the City, 371 homes were billed for unmetered water service. As of 2014, all new single-family and duplex residential unit water connections are metered.

3.2.4 Unmetered Water Use

According to 2016 records, unmetered water use accounts for 2.1% of the total water produced, totaling approximately 27 MG in 2016. The City calculates unmetered water use by multiplying the total number of dwelling units by a daily water demand of 200 gallons per dwelling unit. The water use rate assigned to each dwelling unit assumes an average of 4 people per dwelling unit and a consumption rate of 50 gallons per capita per day.

Unmetered water use *(gal/month)* = # of dwellings * 200 *gal/day/unit* * days/billing cycle

The unmetered water use for each month are then summed over the year to find an annual average number of unmetered water service connections. Figure 4 below shows the number of unmetered water services between 2004 and 2016.

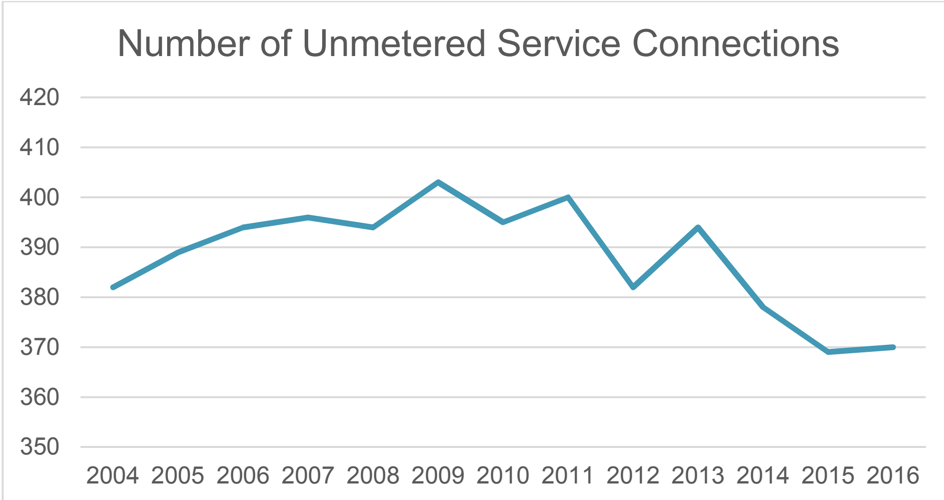


Figure 4: Number of Unmetered Service Connections 2004-2016

The number of unmetered water service connections has remained relatively constant over the past 12 years, with a slight drop starting in 2014 as some meters were installed on services that were previously unmetered. Starting in 2014, all new service connections to single-family and duplex residential units are metered. Over this 12-year period the number of single-family and duplex units have slightly increased. The new metered service connections are accounted for in the base metered use shown above in Figure 3. Over this period the average daily flow to unmetered service connections is calculated as 80,000 gallons per day.

3.2.5 Miscellaneous Water Use

The water reports from the City identify water used for hydrants and water truck fills as part of the total water records for the community, although this is a small component of system demands. Water for hydrant and truck fills was found to be 3.5 MG per year, only 0.3% of the total water produced in 2016.

3.2.6 Unaccounted Water Use

Unaccounted water includes any water use not included in the metered, unmetered, and miscellaneous categories. The City considers this water to be primarily leakage in the system. The City calculates unaccounted water by subtracting the recorded metered, calculated unmetered water use, and miscellaneous water use from the recorded total water produced.

Records indicate that unaccounted water is approximately 14% of the total water use, totaling about 182 MG for 2016. On average, the City loses 0.5 million gallons per day (MGD) to unaccounted water use. Figure 5 below shows the monthly unaccounted water use from 2007-2016. A linear trend line shows an approximately 1.2% annual growth in unaccounted water use over this period. It is important to note that some of the unaccounted water could be attributable to error in the estimated unmetered water use.

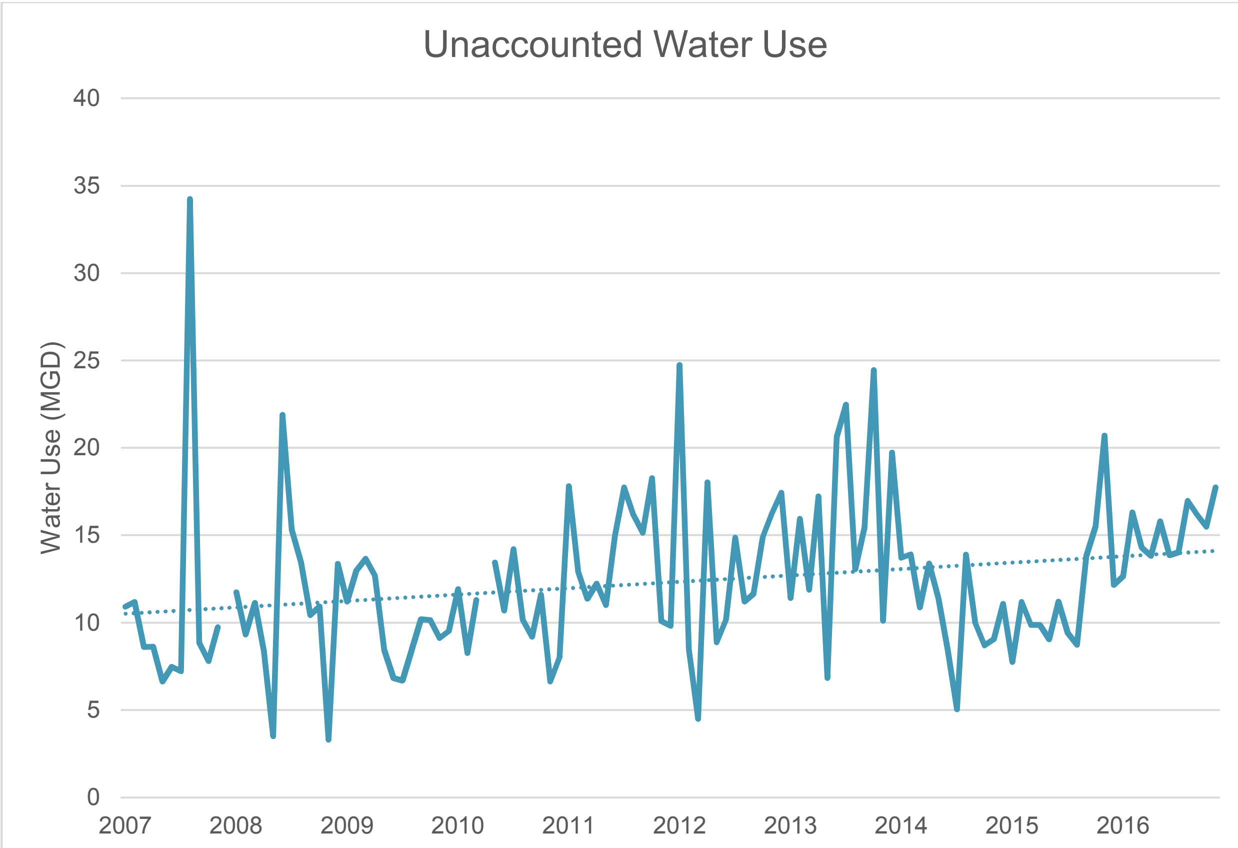


Figure 5: Unaccounted Water Use 2007-2016

3.3 Future Population

DOL and DCCED reports show irregular growth in the community throughout the recorded history. Based on census records and DOL estimates for the last 13 years, the growth rate ranges from -8.4% to 9.3%. It is often difficult to predict future populations in the Aleutian area due to the dependence on fisheries, which brings large transient numbers to the community. DOL projections found that Unalaska's permanent resident growth rates may range from no change to a 0.3% annual loss.

Based on these predictions, three scenarios were selected to project future population for water planning purposes: minimum population projection based on the DOL estimates of population loss in the Aleutians West Census area; zero growth population estimate; and a maximum population projection growth rate of 0.5% based on DOL statewide projections. Table 2 and Figure 6 show these population projections for Unalaska.

Table 2: Unalaska Population Projections

Year	2016	2021	2026	2031	2036
DOL Unalaska Population Projection	4,448	4,436	4,417	4,386	4,334
Zero Growth Population	4,448	4,448	4,448	4,448	4,448
DOL Alaska Growth Rate Projection	4,448	4,641	4,815	4,970	5,111

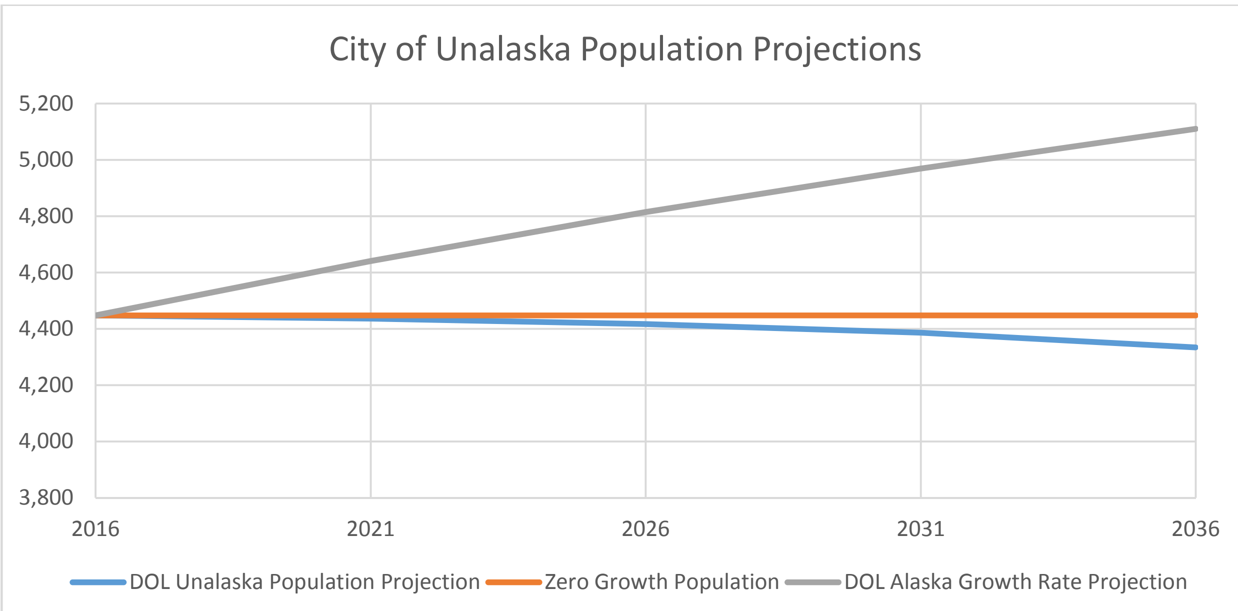


Figure 6: City of Unalaska Population Projections 2016-2036

These projections represent an average annual population of year-round permanent residents. The seasonal surges in population will increase demands on the community's utilities.

3.4 Future Water Production and Use

Evaluation of previous and current water use records have shown that Unalaska's industrial water use dwarfs domestic use. The local industry—fish processing—is water-intensive. As Dutch Harbor is one of the two largest fishing ports in the United States, large quantities of water are needed to process the volume of fish moved through this port. An examination of past landing records from NOAA Fisheries for Dutch Harbor establish a range of expected values from a high point of 966 million pounds in 2003 to 506 million pounds in 2009. An analysis of water demand compared to annual fish landings show a very close relationship as seen in Figure 3.

For planning and estimation purposes, water demands were split into five use categories: base metered, estimated processor, unmetered residential, miscellaneous, unaccounted water.

3.4.1 Planning Assumptions Used for Projected Water Use

Growth rates for the community's population, housing, and fishing industry trends were selected to assist in predicting future water use for the community. Table 3 summarizes the planning assumptions used for the community of Unalaska to determine estimated future water use. Discussion on how the growth rates were applied to each water use category follows the individual water use sections.

Table 3: Community Growth Rates

Category	Growth Rate
Metered Base Use	1.0%
Processor Fish Landings	0%
Population	0%
Miscellaneous water use	0%
Piping Infrastructure	1.0%

In addition to the assumed growth rates, water use rates were developed to estimate future water needs for two categories. Table 4 summarizes the water use rates assumed for the community of Unalaska to determine projected future water use. Discussion on how the rates were applied is in the individual category sections below.

Table 4: Water Use Rates

Type of Water Use	Water Use Rate	Units
Metered Water (industrial processing)	0.75	gal/pound of fish processed
Unmetered Water	200	gal/service connection/day

3.4.2 Projected Base Metered Water Use

The base metered water use represents a year-round water use rate of service connections attached to the system via water meters. This water use currently accounts for city-operated facilities, multi-family dwellings which are inhabited year-round, some single-family residences, restaurants, and other services. Some of these connections, such as restaurants, will use larger amounts of water during fish processing seasons, but this water is accounted for in the estimated fish processor use. Over the five year period from 2018-2023, it is assumed that all unmetered service connections will have meters installed.

The base metered water use is found by extrapolating the metered water use in May, an off-peak month, to the entire year, plus the additional metered water use from newly installed residential water meters.

To estimate future single-family residential water use, an annual 0% growth rate was applied to the current (2016) number of housing units. The 0% growth rate was selected to match the population growth rate of the community. While the DOL estimates the population of the Aleutians West Census Area to drop slightly over the planning period, a 0% growth rate for population was selected as the census area encompasses a larger area than just the City of Unalaska. Department of Labor population estimates generally show a decrease in census areas which are primarily rural, and a flat or slight increase in areas which are more urban. As the Aleutians West Census Area also contains some rural areas outside the City of Unalaska, it is assumed that the population loss is predominantly coming from those areas. The high level of industry may insulate the City from the projected population loss seen in other parts of the Aleutians.

Records from 2016 indicate that there were 370 unmetered customers. Current residential unmetered flows were estimated by multiplying the City's residential usage rate of 200 gallons per day per unit by the number of dwelling units. Using the City's usage rate, the 2016 unmetered water demand was calculated to be 27 MG per year. One fifth of the 27 MG per year of unmetered water demand (5.4 MG/year) was added to each year of estimated base metered water use from 2018 to 2023 to represent the additional meters installed on residential properties.

Figure 7 below shows the historic and projected base metered water use for the City over the planning period.

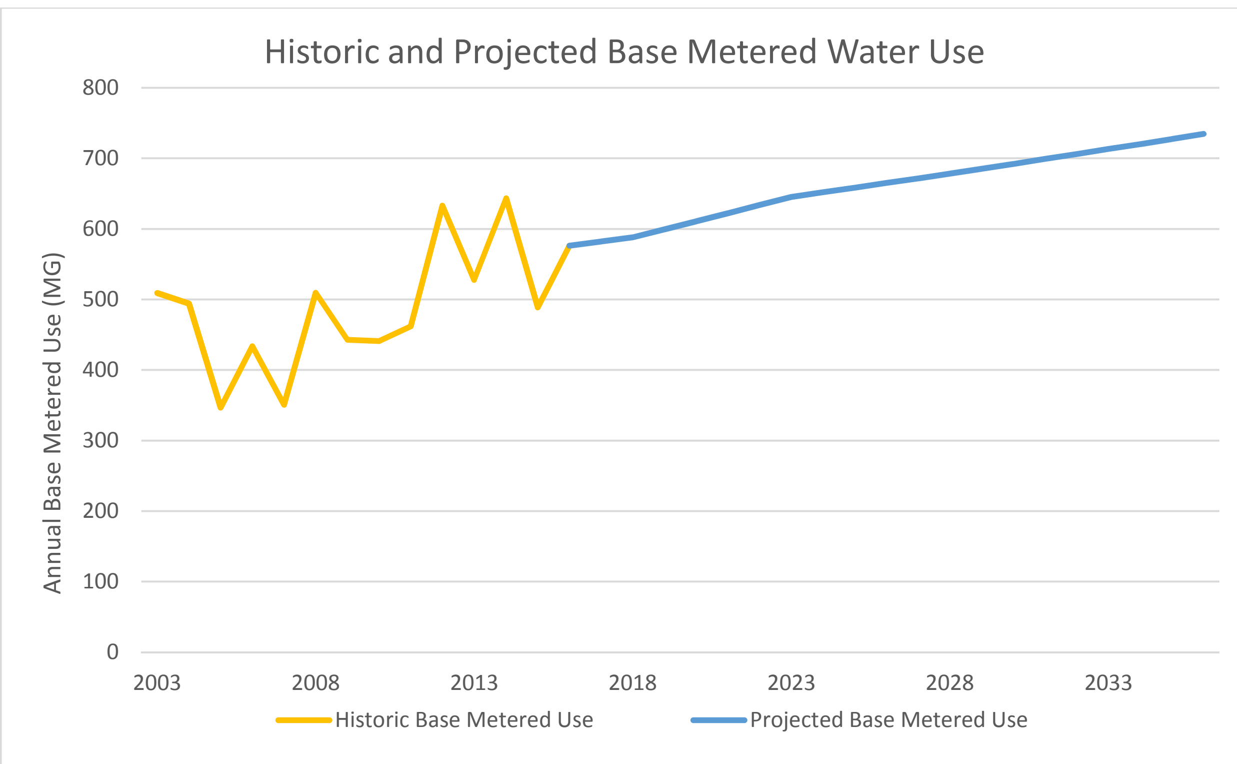


Figure 7: Historical and Projected Base Metered Water Use

3.4.3 Projected Fish Processing Metered Water Use

As seen in Figure 3, the estimated annual processor water use closely mirrors the total annual fish landings in Dutch Harbor. The projected annual fish landings as published by NOAA Fisheries can be used to estimate processor water use in the near future. It is difficult to predict the ebb and flow of fisheries in the Bering Sea and Gulf of Alaska for a 20-year planning period. To account for this, a range of possible fish landings, based on prior data, is used to estimate future processor water use.

In the prior 13 years, the highest amount of fish landings in Dutch Harbor occurred in 2003 when 966 million pounds of fish came through the port. This value will represent the maximum projected catch. After several years of landings at or near 900 million pounds, Dutch Harbor saw several years of only 500 million pounds of fish landing in 2009 and 2010. 500 million pounds will represent the minimum projected catch. From 2012 to 2015, the total fish landings have stabilized between 750 and 780 million pounds, which represents the projected annual landings.

The addition of an Icicle Seafoods processor ship, which formerly operated offshore, is expected to add approximately 0.3 MGD from one production line during the A processing season (Jan 15th through Apr 15th). This operation is estimated to add approximately 30 MG per year of demand at peak production. Icicle may choose to add an additional production line, which could add another approximately 30 MG per year of demand. No other large expansions in fish processing operations are expected during the planning period. The projected annual landings should be between 950 million pounds and 500 million pounds. The Projected Median Processor Use shows an increase of 30 MG per year over the course of 2 years to account for the new processing ship and additional processing line.

The City is contemplating a project that would bring piped water and sewer utilities to Offshore Systems, Inc. (OSI) at the end of Captains Bay Road. While OSI is not a fish processor, it does support the fishing industry with fuel, cargo, and logistics services as well as providing water for filling boats. OSI currently relies on a private water system and also hauls City water by tank truck. It is expected that connecting OSI with piped water could result in a small increase in water demand, but that any increase in demand would be offset by the elimination of a major pipe leak which that project would also address (see Section 6.3.1).

As seen in Figure 8, between 2003 and 2015, the water use per pound of fish processed has remained fairly level between 0.46 and 0.83 gallons. The average value over this period is 0.66 gallons per pound of fish. For the purpose of this analysis, a slightly more conservative value of 0.75 gallons per pound of fish processed was used to project estimated processor water use in the future. As shown in Figure 9 at the maximum projected landing of 950 million pounds the annual projected processor water use is 712 MG; at the minimum projected landing of 500 million pounds the annual projected processor water use is 375 MG; and the median annual projected processor water use is 536 MG.

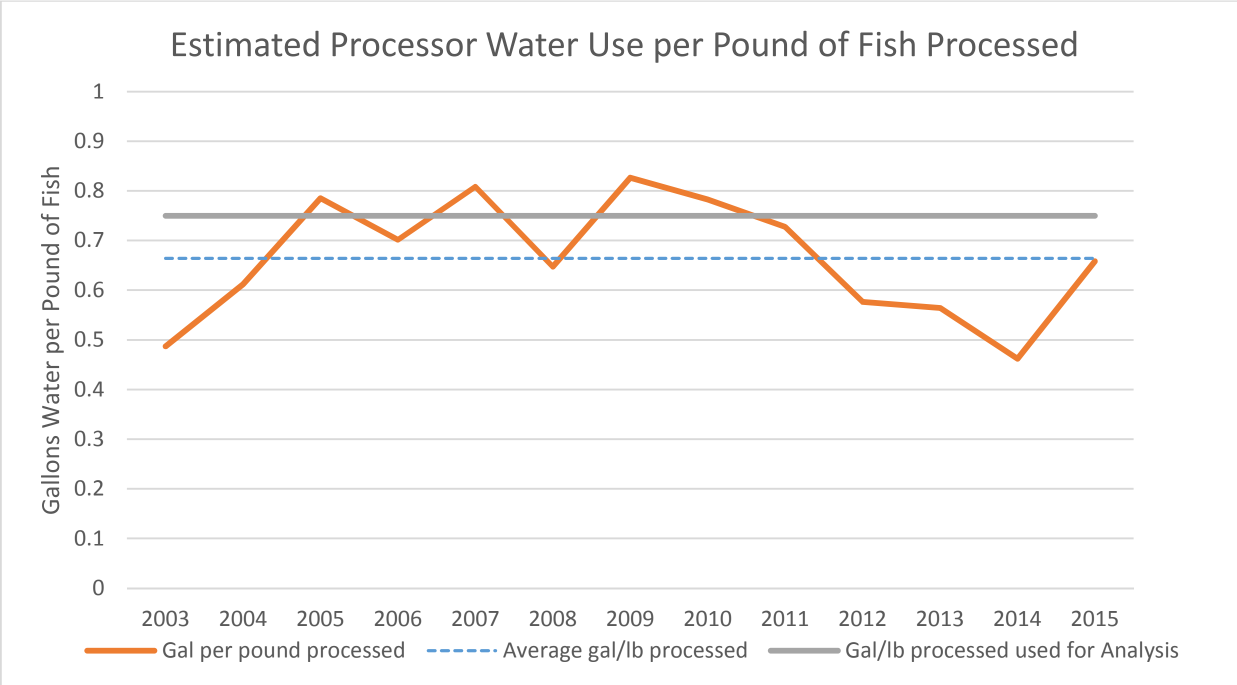


Figure 8: Estimated Processor Water Use per Pound of Fish Processed

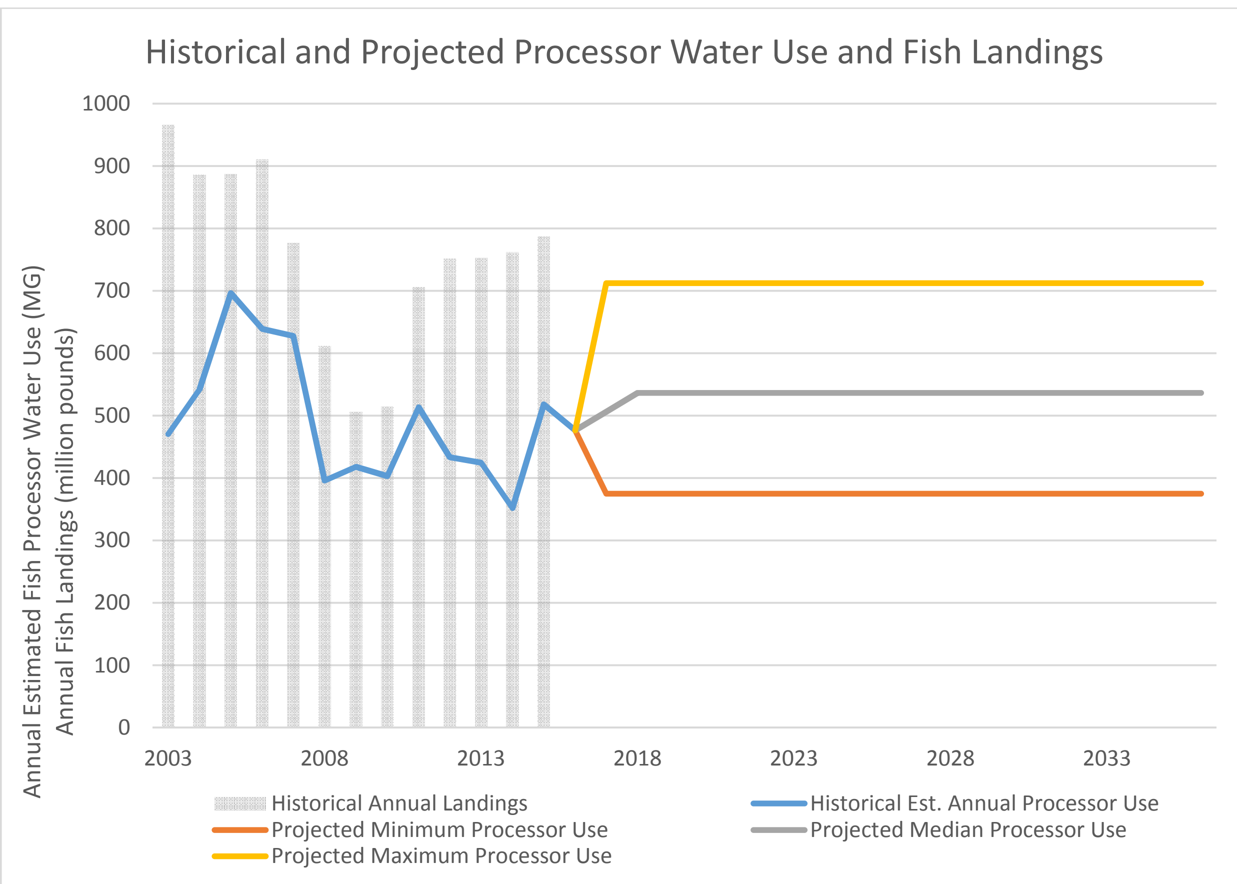


Figure 9: Historical and Projected Processor Water Use and Fish Landings

3.4.4 Projected Unmetered Water Use

City water records collected from 2003 through 2016 identified the number of unmetered service connections (see Figure 4). Over the next 5 years, the City intends to install meters on all unmetered service connections. The water which currently is classified as Unmetered Water, will change to Metered Water over this period. It is assumed that the installation of meters on unmetered service connections will occur evenly over the five year period from 2018 to 2023.

Figure 10 shows the recorded and projected unmetered water demands for the City through the planning period.

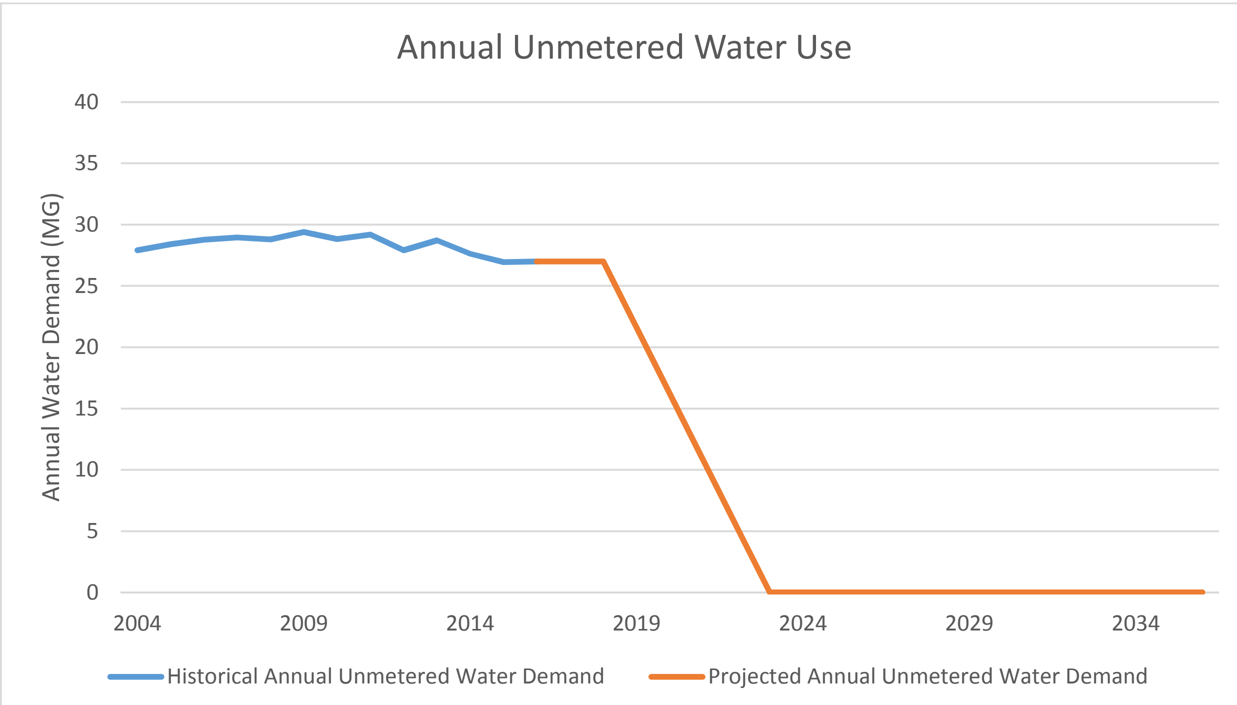


Figure 10: Historical and Projected Annual Unmetered Water Use

3.4.5 Projected Unaccounted Water Use

Unaccounted for water is defined as the remaining water not accounted for by metered or unmetered water, most of which is attributed to leakage and losses in the system. It is difficult to project future unaccounted water as the loss rates can change as piping systems ages and as leaks are detected and fixed. Based on past observations, the unaccounted water use was assumed to grow at a rate of 1.0% annually. This rate accounts for system expansion, aging of pipe, and other growth that may be seen in the system. 182 million gallons of water was unaccounted for in 2016.

Using a 1.0% annual increase in unaccounted water use, the estimated future unaccounted water use is 200 million gallons in 2025 and 222 million gallons in 2036. Figure 11 shows the projected unaccounted water over the planning period.

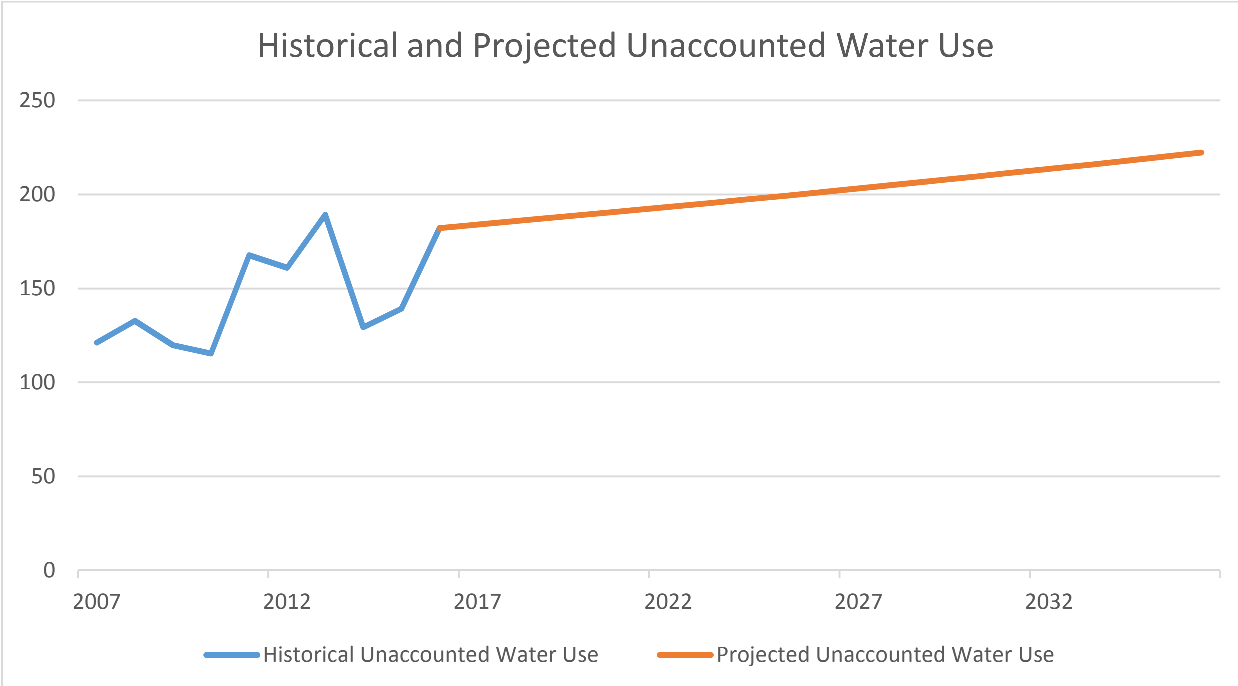


Figure 11: Historical and Projected Unaccounted Water Use

3.4.6 Projected Miscellaneous Water Use

To account for hydrant use and truck fills, an estimated future value was found by averaging the recorded data from the past 7 years (2009-2016) excluding the months during startup of the new water treatment plant and any large water use that was noted as belonging in another category. The average value was found to be 6.0 MG per year. With the exception of one large outlier of 18 MG in 2013, the recorded values for hydrant and water truck had little variation over the seven year data period. Future hydrant and water truck use is assumed to remain constant at 6.0 MG per year over the planning period.

3.5 Summary of Water Use

Figure 12 and Table 5 show a summary of the current and projected future water use for the City.

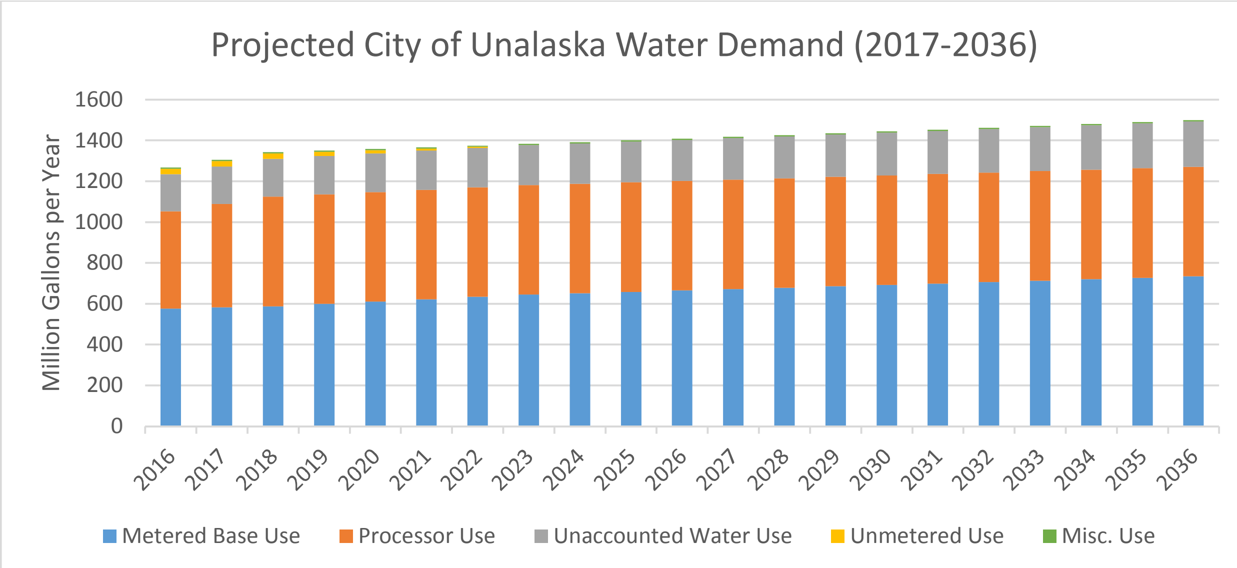


Figure 12: Projected City of Unalaska Water Demand 2016-2036

Table 5: Summary of Current and Projected Water Use

Type of Use	Current Water Use (2016)	Projected Water Use (2024)	Projected Water Use (2036)
Base Use	576,320,000	651,900,000	734,700,000
Processor Use	476,310,000	536,250,000	536,250,000
Unmetered	26,990,000	0	0
Unaccounted	182,110,000	197,200,000	222,200,000
Misc.	5,980,000	6,000,000	6,000,000
Total	**1,267,710,000**	**1,391,350,000**	**1,499,150,000**

The Unalaska water system provides service for residential users (unmetered flow), commercial and industrial users (metered flow), and miscellaneous City uses (hydrants and water truck fills). In addition to the services, a component of total water produced is lost in the system to leakage. The City refers to this as unaccounted water. The Unalaska water system is unique in that the four seafood processing facilities create the majority of water demand on the system (nearly 90%). Because of the large need for water to serve the industrial users, the City must forecast accordingly by evaluating the trends of the fishing industry in addition to the typical population forecasts for the community.

To understand the potential population growth for the community, research was completed using census and DOL statistics. Research found that over the planning period, a constant population should be used to estimate future population, housing, and water piping infrastructure growth in the community.

Based on the large industrial water demand, research was also completed on the potential growth for the fishing industry in Unalaska. This research indicates that the catch rates and processing should remain relatively stable over the planning horizon for this water master plan. It was also assumed that no new processing facilities would come into Unalaska, except for one offshore processing ship moving to onshore operations. Water use for the processors is directly tied to the amount of fish (pounds) landed. To estimate future industrial water use, the current amount of fish landings was projected to increase slightly with the new processing ship and then remain constant. The base water use is expected to follow current trends and increase an annual rate of 1% growth.

Using the growth criteria selected for the population and fishing industry the total water use is projected to be 1.4 billion gallons per year in 2024 and 1.5 billion gallons per year in 2036.

4 SYSTEM CONDITION AND PLANNING CRITERIA

In order to accurately identify appropriate future needs and improvements a key task in master planning is to review and document the information pertaining to the current condition of the water system and to set the planning criteria that will be used in gauging the performance of existing infrastructure. This information is then used to identify water system improvement needs.

For this effort HDR acquired and reviewed a variety of information including:

- 2004 Unalaska Water System Master Plan and other recent studies
- Water production records
- Water sample data
- Water system maintenance records
- Water rights records
- Capital Improvement Plan information
- Water system tour, May 10-11, 2017
- Interviews of utility staff by email, telephone, and in person

4.1 Water Sources and Water Rights

Unalaska uses surface water and groundwater sources.

Unalaska's surface water source is the Icy Creek watershed. This source includes Icy Lake and Icy Creek Reservoir. Unalaska also uses groundwater wells for water supply.

4.1.1 Icy Lake

Icy Lake is a surface water source located upstream of the Icy Creek Reservoir near the top of the Icy Creek watershed. Icy Lake provides impounded water storage for Unalaska and is used during periods of low water or during significant demand. The lake is impounded behind a sheet pile dam at its outlet. Water from the lake is released with a remote controlled valve at the sheet-pile dam when needed to fill the Icy Creek Reservoir.

The valve is motor actuated with remote control capability provided by wireless communications and electricity provided by solar panels and a propane thermoelectric generator. Two small wind turbine were originally installed for electricity, but the turbines were destroyed in a wind storm. Utility staff report that the existing solar panels are marginally adequate to provide the electrical power for the equipment at the Icy Lake valve station.

Based on volume data at various elevations provided to the City by Golder Associates, Inc. and extrapolated in-house by Utility staff, the estimated volume at the spillway elevation is 57 MG. As far back as the original 1994 Icy Lake Feasibility Study by Golder Associates, Inc., the City has contemplated raising the north dam approximately 5 more feet in order to increase the storage capacity of the lake by approximately 35 MG. Raising the lake level would also require construction of an approximately 6-foot tall dam at the south end of the lake where a saddle in the valley creates a drainage divide between Icy Lake and a steep downward slope to Uniktali Bay.

4.1.2 Icy Creek Reservoir

A sheet pile dam along Icy Creek impounds the Icy Creek Reservoir. The dam was originally constructed in 1976 with a 10-foot raise and other upgrades performed in 1994 and 2007 (Golder, 2014). The reservoir is estimated to hold 9.62 million gallons (HDR, 2004), although the actual capacity is reduced by steady accumulation of rock and sediment at the inlet end of the reservoir from high discharge events in the creek. Water from the reservoir travels through a 24-inch ductile iron pipe to the Pyramid WTP.

The Pyramid WTP operates under the filtration-avoidance criteria of LT2 and treats water through dual disinfection using ultraviolet light followed by gas chlorination. After the Pyramid WTP, flow breaks head in a 2.6 MG steel tank for chlorine contact before flowing by gravity to the community.

4.1.3 Groundwater Wells

The second water source for Unalaska is a well field in the Iliuliuk Valley. Wells 1 and 1A are located near the Public Works Building and Wells 2, 2A, and 3 are located approximately 1,500 feet up the valley. Wells 2 and 3 are plumbed through a common wellhouse. The well field is capable of producing a combined total of 2,800 gallons per minute (gpm) or 4 million gallons per day (MGD); however, a safe sustained yield has not been established for the Iliuliuk Valley aquifer. Wells 1 and 2 are World War II vintage, but were upgraded in 1976. Well 1 is not currently in operation due to damage to the well casing and should be properly decommissioned and plugged to prevent aquifer contamination. Well 2 can produce 340 gpm. Two additional wells, 1A and 2A were installed in 1991 and 1992, respectively. Well 1A can deliver approximately 886 gpm (Lund, 2013). Well 2A is no longer in operation as it was determined to be Ground Water Under the Influence of Surface Water (GWUISW). Well 3 was drilled in 2000 to replace Well 2A, and following testing and analysis ADEC determined that Well 3 is a groundwater source (Kirchhofer, 2017). Well 3 is capable of producing a maximum of 1,350 gpm. The wells were inspected and rehabilitated in 2013. The wells are currently instrumented with pressure transducers and the City is using the specific capacity to track when well production has declined and rehabilitation is required.

Well 1A is capable of being controlled automatically based on preset pressure or flow control. Pressure control does not work well because the system pressures fluctuate too much. Operators must be especially vigilant in monitoring system pressure when a well feeds directly into the water distribution system to prevent pressures from becoming too high and causing damage to the system and in-home plumbing. Wells 2 and 3 are capable of being operated manually in "Hand mode" from the well house control panel or automatically controlled based on tank level. The only way to manually start Wells 2 and 3 remotely is to change the tank level set points.

Problems or deficiencies at the well field that were found or mentioned include:

- Limited ability for remote or automatic control of wells
- The wells have no back-up power source to operate during a power outage or emergency situation

- No backup well in the event of a well or pump failure
- No known safe aquifer yield of Iliuliuk Valley aquifer

Groundwater is an important component of the Unalaska water system, as it supplies the community's water needs if the primary source (Icy Creek) is not in service or the reservoir has low water when demand is high. There are several situations where the Icy Creek is taken out of service including: the reservoir water becomes excessively turbid (above 3 NTU) requiring shut down; maintenance which requires shut down of the Icy Creek Reservoir, the chlorine contact tank or the transmission main delivering water; or a break in the transmission line which would interrupt service from the Icy Creek source. In these scenarios the wells become essential for delivering water to the community.

The City has discussed developing a safe yield of the Iliuliuk Valley aquifer and then proceeding with drilling a new Well 4. The City is also monitoring climatic conditions in Iliuliuk Valley and collecting water level data in the stream, two piezometers, and the wells. This data would be used to develop a model that shows the surface and groundwater interaction as well as developing an estimate of aquifer safe yield.

A geophysical survey was conducted in Shaishnikoff Valley to evaluate the valley for the potential for an aquifer. The survey results indicate that subsurface conditions in the Shaishnikoff Valley are likely similar to the Iliuliuk Valley. In general, bedrock was encountered at depths around 40 feet below ground surface. However, one of the geophysical lines encountered an area where the depth to bedrock appeared to be on the order of 100 feet below ground surface. This could be an area of weathered or sheared bedrock that may be able to produce significant quantities of groundwater if the feature extends across the valley. Any groundwater wells installed in the Shaishnikoff Valley have a potential to capture surface water and should be evaluated for GWUISW as well as the potential for saltwater intrusion.

4.1.4 Water Rights

The City has obtained or applied for a number of different water rights beginning in 1970. Unalaska water rights have evolved over the years as old water sources were abandoned, as new water sources were established, and as appropriations have been amended, corrected, updated, and consolidated. The final adjudication and issuance has been decades in the makings for some of the City's water rights. Some of the City's water rights applications are still pending. Recent efforts by the City to organize water rights documentation and coordination with the Alaska Department of Natural Resources (DNR) has gotten the City close to having all water rights in place. The water rights information in Table 2 is a synthesis of records from the DNR water rights database and documentation provided by the City.

Water rights are not finalized until the submittal of the Statements of Beneficial Use. A Statement of Beneficial Use for each water right is due within ten years of the date that the permit to appropriate water is issued. DNR wanted the City to delay submitting Statements of Beneficial Use for a few years in order to collect data to verify that the requested volume of water is still acceptable. However, if the Statement of Beneficial Use for each water right is not submitted by the due date, then the water rights appropriation will have to be redone, losing decades of effort.

Table 6: Summary of Current Unalaska Water Rights Status

	ADL / LAS Number	Priority Date	Amount	Status / Comments
Icy Lake	LAS 19542	24 Mar 1995	10 MGD	Permit to appropriate water issued 22 Jun 2017. Final water rights pending City submittal of Statement of Beneficial Use to DNR.
Icy Creek Reservoir	LAS 13684	14 Apr 1992	3,731.34 Ac-ft per year	Permit to appropriate water issued 22 Jun 2017. Final water rights pending City submittal of Statement of Beneficial Use to DNR.
Wells 1 & 1A	LAS 13451	23 Jul 1991	1.7 MGD	Permit to appropriate water issued 9 Sep 2015. Final water rights pending City submittal of Statement of Beneficial Use to DNR.
Wells 2 & 3	LAS 13450	23 Jul 1991	2.6 MGD	Permit to appropriate water issued 9 Sep 2015. Final water rights pending City submittal of Statement of Beneficial Use to DNR.

4.2 Hydraulic Planning Criteria

4.2.1 Pressure and Velocity Criteria

The following water system pressure criteria are recommended as general guidelines (AWWA M32, 2005):

- The minimum residual pressure at fire hydrants must be at least 20 pounds per square inch (PSI) during a fire event
- The minimum residual pressure at fire hydrants should be 50 PSI during normal flow operations and 40 PSI during peak hour demand
- The maximum pressure in the distribution system should not exceed 100 PSI. Note that the Uniform Plumbing Code requires that a pressure reducing valve be installed on building service lines where delivery pressures are above 80 PSI.

The following water system pipe velocity criteria are recommended as general guidelines (AWWA M32, 2005):

- Distribution pipe velocity should not exceed 5 feet per second (FPS) during normal flow operations
- Distribution pipe velocity should not exceed 7.5 FPS at maximum day demand plus fire flow
- Transmission mains should avoid velocities above 5 FPS.

Planning and design of new pipes should meet these criteria. The fact that the existing pipes might exceed these criteria, however, should not be viewed as grounds for replacement unless there are other pressure or velocity-related issues such as low downstream pressure or heightened risk of pipe failure due to scour or surge. In some cases, infrequent and short duration events of high velocity may be acceptable as long as the rate of change in velocity is controlled.

Existing pipes with velocities in the range of 7.5 to 10 FPS should be considered for replacement only if other circumstances indicate elevated risk. Existing pipes with velocities exceeding 10 FPS should be identified for replacement. A prudent first step prior to replacement is to perform condition assessment and mitigate potential sources of surge or improve looping of the pipe network.

4.2.2 Water Storage Criteria

The functions of storage in a water system are to:

- provide a buffer to meet peak hour demands
- supply fire-protection water
- provide operational flexibility
- provide pressure equalization
- enhance system reliability

The amount of storage needed in a water system is determined by review of fire flow requirements, operational storage requirements, and emergency storage requirements. The objective is to provide the greater of the sum of fire protection storage plus operational storage, or emergency storage equivalent to 3 days of average demand. The greatest demand volume required within each pressure zone controls the storage volume needed there.

There are six pressure zones located in Unalaska.

- Pressure Zone 1 runs from the Icy Creek Reservoir to the chlorine contact tank.
- Pressure Zone 2 (also called “Captains Bay Road” and formerly called “Crowley”) encompasses the Captains Bay area south of the Agnes Beach Plant (a combined pressure reducing and pump station). This pressure zone includes both the North Pacific Fuel complex, Westward Seafoods, and the Haystack Hill residential area (when served from the Icy Creek water system).
- Pressure Zone 3 (also called “Town”) encompasses the Amaknak Island/Dutch Harbor area and the Unalaska town area. This pressure zone serves residential buildings, commercial buildings, the remaining three processor facilities, the school, and the airport. Well 1A pumps into Pressure Zone 3.
- Pressure Zone 4 (also called “Lear Road”) encompasses Unalaska Valley south of the Unalaska Pump Control House. Wells 2 and 3 pump into Pressure Zone 4.
- Pressure Zone 5 (also called “Nirvana”) is a higher elevation residential area on the hillside to the north of Unalaska Lake. A hydropneumatic packaged pump station along Dutton Road serves approximately 15 residential service lines or 21 residential structures along Nirvana Drive and the higher portion of Dutton Road.
- Pressure Zone 6 (also called “Haystack Hill”) is the Haystack Hill residential area. When Haystack Hill is served by the wells in Pressure Zone 3, it is necessary to operate booster pumps in the Agnes Beach pump station in order to provide adequate pressure to the roughly 30 homes on the hill.

4.2.2.1 Fire Protection Storage

It is desirable to provide gravity flow fire protection storage for each pressure zone and to place storage strategically throughout the system. This allows the community to feed the distribution network with necessary quantities of water without reliance upon pumping and to have multiple sources to draw from in emergency situations. This represents a safe and simple way to ensure sufficient supply during a fire. Alternatively, should wells be a primary water supply for fire flows, they should be equipped with back-up power generation capabilities. This allows the wells to be used to meet the community's emergency needs, including fire fighting, during power outages. The following criteria were developed for establishing the volume of fire protection storage to be reserved:

- Sufficient storage should exist within each pressure zone for the worst-case fire that could occur within that pressure zone. If more than one storage tank serves the pressure zone, the total storage reserved for fire protection among all the tanks should be sufficient for the worst-case fire.
- It is assumed that two or more fires will not occur simultaneously.
- Where a tank serves more than a single pressure zone, the tank volume reserved for fire protection should be adequate for one fire of the worst-case condition occurring within the area served by the tank in a 24-hour period.

In addition to these criteria, specific criteria were developed for estimating the fire flow and fire duration at some of the largest and most critical buildings in Unalaska. These criteria were recommended by the Unalaska Fire Chief for the 2004 Unalaska Water System Master Plan and have been verified and updated for this master plan as shown in Table 7.

Table 7: Fire Event Criteria

Facility / Area	Flow (gpm)	Duration (minutes)	Volume (gallons)	Pressure Zone
Unisea	2,500	120	300,000	3 - Town
Alyeska	2,000	120	240,000	3 - Town
Westward	2,000	120	240,000	2 - Captains Bay Rd
Trident	1,500	120	180,000	3 - Town
North Pacific Fuel	2,000	120	240,000	2 - Captains Bay Rd
Delta Western	2,000	120	240,000	3 - Town
School	2,000	120	240,000	3 - Town
Residential	1,500	120	180,000	3 - Town; 4 - Lear
OSI	2,000	120	240,000	*Not currently served*

Using the data from Table 7, and other criteria discussed above, evaluation of each pressure zone was made to determine the amount of fire protection storage required. The evaluation considered pressure zone boundaries, existing zoning and land use patterns, projected land use, reservoir locations, and system hydraulics. This evaluation is summarized in Table 8.

Table 8: Fire Protection Storage Requirements

Pressure Zone	Volume Required (gallons)
1	Raw water distribution and treatment; Storage not required
2 - Captains Bay Rd	240,000
3 - Town	300,000
4 - Lear	180,000
5 - Nirvana	Local storage not recommended
6 - Haystack	Local storage not recommended

The recommended fire protection storage required for Unalaska, based on the established criteria, is 300,000 gallons, which represents a worst-case scenario of a fire event in the Pressure Zone 3 (Town). This storage requirement is assumed to remain the same throughout the planning horizon of this water master plan, because in most of the pressure zones a fire event at an industrial customer represents the worst-case scenario for fire storage requirements, and it is assumed that no additional industrial facilities will move into the Unalaska area – or that no new industrial facility would have a required fire flow larger than the existing worst-case fire flow already present in each pressure zone.

4.2.2.2 Operational Storage

Operational storage is defined as water held in storage to meet hourly fluctuations in demand, or a condition such as turbidity spikes at the water treatment plant, which cause a temporary disruption of water production. The industry standard operational storage requirement is 10 to 30 percent of average day demand (AWWA M32, 2005); however, due to the large demand stemming from the processing facilities, operational storage for Unalaska is recommended at 50 percent of the peak day demand. This storage requirement can be met by tanks or groundwater pumping, if wells are equipped with back-up power and if they are not already being used for production to meet current demand, as is usually the case during the latter part of the Pollock A & B seasons.

Operational Storage *(gallons)* = 0.5 * Peak Day Demand *(gallons per day)*

4.2.2.2.1 Peak Day Demand

Any water system needs to account for variations of water use throughout the day. Usually, a peaking factor is assigned to a water system so that adequate supply is available for the maximum demands that occur in the day. As Unalaska has a unique water system with industrial users creating large seasonal demands, standard peaking factor multipliers do not apply. The peak day flow and peaking factor were found using the daily recorded data from 2013 through 2017. The maximum daily production over this period of time was 7.61 MGD, which occurred during A season. The average production over this period of time was 3.32 MGD. This represents a peaking factor of 2.3.

Table 9 shows the current and future peak day demand and the associated operational storage needed for that peak demand. The data indicates an 18.25% increase in average flows from 2016 to 2036. It is assumed that the peak day demands will also increase 18.25% by 2036.

Table 9: Estimated Peak Day Demand and Operational Storage Required

Criteria	Current	Year 2024	Year 2036
Peak Day Demand (gallons per day)	7,611,000	8,353,000	9,000,000
Operational Storage Required (gallons)	3,805,500	4,176,500	4,500,000

4.2.2.3 Emergency Storage

There is a need for treated water storage to cover short-term emergencies. Examples of such a condition include natural disasters or a major failure of water transmission infrastructure. Emergency storage can be met by tanks or groundwater pumping, if wells are equipped with back-up power. A total of three days of average demand should be held in reserve to account for an emergency. Three days is the anticipated outage time that it would take to correct a situation where the water system would be out of operation. It is assumed that in an emergency situation the processing facilities will cease operation, water-intensive activities will be restricted, and water conservation practices will be implemented, so the three days of average demand is based on providing domestic service only. An assumed 100 gallons per capita per day (gpcd) will be used to calculate the average domestic demand in this scenario. To be conservative with the storage requirements, the population will be assumed during peak processing season. The total population used for emergency storage planning will be the known or projected year round residents plus additional transient workers.

The 2010 U.S. Census reported 2,277 residents not living in group quarters. The Alaska DOL 2016 population estimates show a 1.6% rise from 2010 to 2016, which results in a population of 2,315 residing outside of group quarters. According to the City website, up to 6,000 transient people can come to Unalaska during peak processing season. A conservative estimate of 9,000 total people is used for the emergency storage calculations as of 2016.

Emergency Storage = (Annual Population + Transient Population) *(people)* * 100 *(gpcd)* * 3 *(days)*

The current emergency storage requirement for Unalaska is calculated to be 2.7 MG as shown in Table 10. Since the population is projected to stay stable over the planning period, it is estimated the emergency storage required will also remain 2.7 MG until 2036.

Table 10: Estimated Population and Emergency Storage Required

Criteria	Current	Year 2024	Year 2036
Estimated Peak Season Total Population	9,000	9,000	9,000
Emergency Storage Required (gallons)	2,700,000	2,700,000	2,700,000

2.7 MG equates to only 0.9 MGD of emergency storage over a 3 day period. It is important to note that Unalaska's base domestic demand rarely drops below 1.0 MGD during non-processing seasons and could be as high as 4.5 MGD during processing season. It is assumed that water conservation measures employed during an emergency situation would drive actual demand significantly lower and that a major component of the base demand is unaccounted for. It is worthwhile exploring and fixing the causes of Unalaska's high unaccounted water use rather than oversizing storage needs to compensate.

4.2.2.4 Total Water Storage Requirements

Total water storage requirements should be the greater of either emergency storage or the sum of fire protection storage and operational storage. Based on this criteria it is concluded that the combination of operational and fire protection storage will govern in the current year and in the future as shown in Table 11. The requirements for operational and fire protection storage will be used as the basis for storage planning purposes.

Table 11: Total Water Storage Required

Criteria	Current	Year 2024	Year 2036
Fire Protection Storage Required (gallons)	300,000	300,000	300,000
Operational Storage Required (gallons)	3,805,500	4,176,500	4,500,000
Total Storage Required (gallons)	4,105,500	4,476,500	4,800,000

4.3 Pipe Life Expectancy Evaluation

The Unalaska water system consists of approximately 133,000 linear feet of water main pipe, almost all of which is ductile iron. This pipe life expectancy evaluation will focus on ductile iron pipe. Note: there is a short segment of 1940s-era cast iron water main along Biorka Drive, the last piece of original cast iron water main in the system; however this pipe is not considered in the pipe life expectancy evaluation. The Biorka Drive cast iron pipe is already on the Capital & Major Maintenance Plan (CMMP) for replacement and is addressed in this master plan as a recommended capital project.

Most ductile iron pipe diameter ranges from 6 to 24 inches, but there is a short run of 4-inch pipe on Standard Oil Hill. The two 6-inch ductile iron pipe loops in the downtown area were installed in 1976. All other ductile iron pipe was installed from approximately 1988 to the mid 1990s. Utility operators report the following observations about the ductile iron pipe:

- Most was installed with polyethylene encasement ("baggies").
- When excavated the ductile iron pipe appears to be in like-new condition on the outside.
- When cut open the ductile iron pipe appears to be in good condition on the inside with the cement mortar lining intact and little or no tuberculation.
- There have been no reported pipe breaks or major leaks due to pipe age-related deterioration or corrosion.
- The few pipe failures that have been reported were caused by some external factor such as improper construction, damage during construction, or fitting failure.

Based on a broad understanding of Unalaska geology and soils as volcanic rock and alluvial fan, soil corrosivity is estimated to be low, except for localized areas of muskeg with low pH soils or areas where pipes could contact seawater.

City water quality records indicate that drinking water from the Icy Creek surface water source has the following characteristics:

- pH 6.39 to 7.10
- Alkalinity Non-Detect to 13.2 mg/L $CaCO_3$
- Hardness 4.7 to 14.1 mg/L as $CaCO_3$
- Langlier Index -3.3 to -4.1

These parameters can be used to calculate the Aggressive Index (AI) for Icy Creek water supply. These AI calculations and guidance are based on EPA's 1984 *Corrosion Manual for Internal Corrosion of Water Distribution Systems*. AI provides a simplified version of the Langlier Index and seeks to provide information on the corrosivity of a water supply based on the propensity of $CaCO_3$ to go into solution. For Icy Creek water supply AI is calculated to range between 7 and 9. An AI<10 indicates that the water supply could be very aggressive.

These water quality parameters, Langlier Index and AI, indicate that Icy Creek water can be very aggressive and cause internal pipe corrosion.

City water quality records indicate that drinking water from the groundwater wells has the following characteristics:

- Alkalinity 22.7 to 42.8 mg/L as $CaCO_3$
- Hardness 38 to 54 mg/L as $CaCO_3$

For groundwater supply AI is calculated to be about 10, assuming a neutral pH. An AI of 10 to 12 indicates that the water supply could be moderately aggressive.

These water quality parameters, Langlier Index and AI, indicate that groundwater can be aggressive and cause internal pipe corrosion.

Based on water quality characteristics of the water supplies, the distribution pipe network contains water that could be very to moderately aggressive and cause internal corrosion of the pipe's cement mortar lining and pipe material. These indices do not indicate that corrosion is taking place, they are only indicators of potential. Internal corrosion is subject to many factors including water velocity, residence time, pipe materials, chlorine residual, and other factors (EPA 1984).

Estimated Pipe Life Expectancy

Unalaska's water distribution system is predominantly ductile iron pipe installed in a relatively short time frame with a basic corrosion protection system (polyethylene encasement ("baggies")) into soil with estimated low corrosivity. The pipes carry a water supply that is characterized as very to moderately aggressive. Pipe corrosion, exterior and interior, can lead to leaks or breaks that shorten the pipe's useful life.

Review of articles with life expectancy data for ductile iron water distribution piping report life expectancies of 60 to 100 years (*Buried No Longer*, AWWA and *The Epidemic of Corrosion, Part*

1: Examining Pipe Life, Baird & AWWA 2011). These articles focused on external pipe corrosion and its consequences. The range in life expectancies is based on differences in construction care when installing the external corrosion protection measures and the corrosion potential of the surrounding soil. These reported life expectancies indicate that Unalaska's system could have 30 to 70 years of service, likely toward the longer service life because of the use of polyethylene encasement and the low corrosivity soil conditions, before corrosion related breaks become a primary reason for systematic pipe replacement.

While the overall distribution network could have a long life expectancy, specific areas could have greater corrosion and break potential. The first is where the baggies were installed poorly and have holes in them from poor taping at joints, bedding material being dropped on them, or tears from equipment. These openings can concentrate water movement next to the pipe and cause localized accelerated corrosion resulting in leaks or breaks. Unfortunately the breaches in the encasement cannot be easily located but a regular leak detection program can identify where the subsequent leaks form and identify repairs.

The second potentially accelerated external corrosion area is where pipes are influenced by saltwater. Some pipe may be installed close to potential saltwater intrusion, Ballyhoo Spit, for example, and may be periodically inundated by tides or storm surge. This, and similar areas, should be monitored and whenever the pipe is excavated, inspected carefully for accelerated corrosion and corrective actions planned and implemented.

A third potential area that could experience accelerated external corrosion and could be the likely driver for determining useful life is corrosion at the interface of the copper service taps and the ductile iron main. Corrosion could be concentrated on the ductile iron main at this interface. If or when the City validates this issue, attaching anodes on the service is often a cost effective way to extend useful life.

Based on the AI of the water supplies and Unalaska's experience with compliance with the Lead and Copper Rule, internal pipe corrosion could occur. Unlike external corrosion, the articles reviewed did not have life expectancies based on internal corrosion issues. Internal corrosion in the distribution system is a two-step process, first the cement mortar lining is corroded (dissolved) and then the ductile iron pipe is corroded. Inspection of pipe removed from the system does not report either of these, however, the cement lining corrosion may not be readily visible to visual inspection.

Unalaska may have a mitigating circumstance which will limit the potential for rapid internal corrosion of the distribution system. Unalaska samples regularly for compliance with the Lead and Copper Rule. The sampling indicates a potential for lead and copper corrosion and the City actively manages their water supply to avoid this corrosion and maintain compliance. These activities could also help reduce the potential internal corrosion in the distribution network.

Pipe Condition Assessment Best Practices

Many older water utilities are finding themselves in the unenviable position of having a distribution system that is nearing or already beyond its useful service life. These utilities turn from one emergency repair to the next. If a utility's pipe is all generally the same age, was installed with the same design and construction practices, was installed in soils with consistent corrosivity, and is operated at the similar pressure and flow conditions, then the challenges that the utility faces are amplified because all of the pipe could begin to fail at the same time. These utilities have to reactively spend considerable amounts of money and effort repairing breaks, performing condition assessments in order to make informed decisions, and planning where to invest limited capital dollars replacing pipe.

Most of the cost of pipe condition assessment is associated with excavation and backfill. There are a variety of electronic, magnetic, and acoustic technologies on the market for performing pipe condition assessments and leak detection without having to excavate to expose the pipe; however, these methods are expensive to employ (especially in remote locations in Alaska) and are subject to inaccuracy.

For a relatively young utility such as Unalaska, which isn't yet facing systemic pipe failure issues, there are proactive steps that can be taken now to prepare for the day when Unalaska's water distribution pipe is nearing life expectancy and managers are having to start prioritizing pipe replacement. These best practices are:

1. Keeping an accurate inventory of water system assets including important attributes such as size, material, year of installation, and maintenance status. If possible, this information should be housed within GIS or a GIS-based computerized maintenance management system (CMMS).
2. Collecting detailed information on pipe breaks/leaks and pipe condition data whenever there is convenient access to the pipe. Data should include the date of the break, the location of the break (address or GPS coordinates), the type of asset (for example: main, service, hydrant, valve, blow-off, air vent), break type (for example: circumferential, longitudinal, pin hole, blow-out, joint), the cause (for example: corrosion – internal, corrosion – external, thermal contraction, poor material, poor installation, excessive pressure, improper operation, third party damage, other), the repair type (for example: clamp, plug, welded patch, replace section), number of customers impacted, duration of impact, and the unique GIS asset identifier for the asset that broke. Photos of the pipe are especially useful. This data should be housed within GIS or a GIS-based CMMS.
3. Conducting routine leak testing can identify future problematic sections of pipe as well as address water loss, a critical issue for Unalaska where minimizing losses equates to less use of stored water during dry conditions. Again, collecting detailed information about leaks and their locations in a CMMS allows the data to be analyzed in future years.
4. Analyze collected data periodically to identify trends. The collected data is only useful if you ask it questions – analyze it. Analysis can be simple and include creating maps of breaks, leaks, and repairs, updating them yearly, and watching for trends. These can alert you to areas where you may want to do additional data gathering to confirm a visual trend and plan measures before an emergency situation arises. Most modern water utility CMMS platforms have built-in analytic capabilities or they at least provide the graphic tools needed to display results in a meaningful way.

A common theme in the best practices described above is the use of a GIS-based CMMS. The City currently uses a software product from Cartegraph. Based on HDR's research of Cartegraph's products, it appears that this software offers the functionality described above.

4.4 Staffing

Observations and discussions with Water Utility staff during the site visit and during development of the master plan indicate that the Water Utility is short staffed on operators. Many necessary tasks, such as hydrant inspection and maintenance, distribution system leak detection, mainline valve exercising and maintenance, updating and maintaining the CMMS, and recordkeeping have been placed on the backburner. Operators track a growing backlog of repairs that are continually postponed due to other more pressing and immediate needs. Compliance with backflow prevention regulations have added a significant workload to the Water Utility. In addition, the Water Utility now needs to assist with in-house microbiology analyses and keeps a trained laboratory microbiology technician on staff.

Operators provided HDR with a detailed spreadsheet of typical day-to-day activities and demands on their time. Based on this information and HDR's observations, it appears that the Water Utility is short-staffed by two employees. HDR recommends that the City conduct a staffing analysis to verify the need for additional staff, determine how many more employees are needed, and look for ways to increase efficiency.

5 REGULATORY REVIEW

Drinking water regulations attempt to ensure: that drinking water is safe from microbes and other pathogenic organisms, that it contains minimal disinfection byproducts (DBP), and that it does not contain excess levels of metals from pipe corrosion or other contaminants. Compliance with the regulations requires that each utility not only produce water that meets the regulated water quality standards, but also meet specific monitoring requirements. The EPA is currently developing or considering developing the following regulations, which could affect the Unalaska water system.

5.1 Lead and Copper Rule and Revisions

It is recommended that the City monitor the Lead and Copper Rule Long-Term Revisions as they continue to evolve. EPA currently is considering several draft approaches to changing benchmarks for maximum lead exposure. These approaches represent a variety of models to calculate a "health-based" benchmark for lead in drinking water rather than "technology-based' requirements as they currently exist (EPA, 2016). All of these approaches assume continuous exposure and are thus not appropriate for comparison against values from common methods of lead tap sampling. The City should monitor any changes in sampling and testing requirements that may be included in these revisions.

The EPA is also considering revisions to the Lead and Copper Rule to require all systems to implement corrosion control treatment (EPA, 2016). It is recommended that the possible addition of required corrosion control treatment be considered in any future upgrades to the Pyramid Water Treatment Facility or the wells so any necessary improvements can be incorporated.

Some Alaska communities add soda ash (sodium carbonate) to add alkalinity to the water and raise the water's pH to at least 8.0 to reduce corrosion potential in the water distribution system. This is important because lead and copper components in both the water distribution system and customer plumbing systems more readily dissolve in waters with pH below 7.0 compared to water with higher pH. Ketchikan Public Utilities adds soda ash, with a target pH of 8.3, and orthophosphate for corrosion control. Similarly Soldotna adds orthophosphate for corrosion control.

Most Alaska communities have switched from gaseous chlorine disinfection to on-site generated sodium hypochlorite disinfection. This has been primarily done for community and operator safety reasons, but a secondary impact has been to significantly increase pH in low alkalinity water after the switch was made.

In the wake of the Flint, Michigan lead exposure issue, some states are also revising current rules regarding lead in drinking water. These rule revisions often include: compiling inventories of lead service lines, providing notification to households with lead exposure, testing water in all schools, and requiring control treatment studies after changes in treatment. While Alaska Department of Environmental Conservation (DEC) is not currently reviewing changes to lead rules, this may change in the future so it is recommended that the City monitor any publications from the DEC for any state specific regulation changes.

5.2 Copper Limits in Wastewater Discharge

Copper leaching from supply piping within structures ultimately becomes part of the wastewater stream entering the treatment plant. After primary treatment, sludge from the Unalaska wastewater treatment plant containing copper is transferred to the landfill. The resultant leachate, containing copper, is returned the wastewater stream. This could create a loop of increasing copper concentrations. Should the State of Alaska reduce allowable copper discharge concentrations or restrict mixing zones for copper, the City of Unalaska may have to consider additional measures to control copper leaching in the system, which could include corrosion control treatment at the Pyramid Water Treatment Plant.

It is recommended that the City continue monitoring copper levels in the wastewater discharge and monitor any action from DEC on copper limits and mixing zone restrictions. Any infrastructure related to corrosion control treatment resulting from EPA or DEC Lead and Copper Rule revisions should result in lower copper levels in the wastewater discharge. Should the wastewater treatment plant install biological treatment, copper levels in the wastewater stream should be closely monitored to avoid any biological inhibition issues. Any action taken on this issue should be coordinated between the water and wastewater systems.

5.3 Perchlorate

Perchlorate is a chemical anion commonly found in rocket propellants, munitions, fireworks, airbag initiators for vehicles, matches, signal flares and fertilizers. Regulations for perchlorate are still under development with an indefinite timeline for approval. Based on the fact that there are former military areas in or near the Iliuliuk River and Icy Creek watersheds, it is possible that perchlorate could be found in those water supplies.

A Consent Decree was issued by the United States District Court to the EPA to develop a proposed Maximum Contaminant Level Goal and National Public Drinking Water Regulation for perchlorate no later than October 31, 2018. A final rule shall be issued no later than December 19, 2019 (Natural Resources Defense Council, Inc. v. United States Environmental Protection Agency, 2016). It is recommend that the City monitor EPA publications related to perchlorate. However, it would be premature to begin sampling or planning capital or operational improvements related to perchlorate.

5.4 Carcinogenic Volatile Organic Compounds

EPA is considering a regulation that would address carcinogenic volatile organic compounds (cVOCs) as a group, rather than individually as is current practice. The regulation would also add new cVOCs, such as tetrachloroethylene and trichloroethylene, to the list of those that are already regulated. A proposed regulation is not expected for several more years and there is no evidence of progress in the EPA’s Six-Year Review 3 published January 11, 2017 (82 Fed. Reg. 7). Any additional regulation would likely not take effect during the planning period of this master plan. Additionally, water testing of samples taken on 6/10/2016 showed all individual cVOCs below their respective method reporting limits. No action by the City is recommended at this time.

5.5 Revised Total Coliform Rule – Water Storage Facility Inspection

As a revision to the Total Coliform Rule, EPA is planning to propose and request comment on requirements for public water systems to periodically inspect the interior and exterior of their finished water storage facilities and to correct any sanitary defects found. The proposed storage tank inspection requirements are intended to reduce risk of contamination from waterborne pathogens. HDR understands that the City already performs periodic inspections of its tanks; therefore, this requirement may have little impact on utility operations.

5.6 Revised Total Coliform Rule – Sampling Plan

The DEC has requested that the City of Unalaska prepare a coliform sampling plan in accordance with coliform bacteria sampling requirements presented in 80 AAC 80.400. The City currently collects 10 samples per month from 4 different sampling locations. DEC regulations state that the samples must be taken from "sites that are representative of water throughout the distribution system" (80 AAC 80.405(1)).

It is recommended that the City develop a coliform testing plan in accordance with DEC regulations that include at least 10 sample sites throughout the system. Per conversations with DEC officials, sample sites should consist of places where drinking water is available, such as: businesses, city facilities, restaurants, residential buildings, or dedicated drinking water sampling sites (Carey Thissen, personal communication, September 6, 2017).

5.7 *Legionella* Bacteria

Both the EPA and Centers for Disease Control have recently focused efforts on reducing risks from *Legionella*. As part of EPA's Six-Year Review 3 published January 11, 2017 (82 Fed. Reg. 7), the EPA suggests that there is a link between maintaining a secondary disinfectant residual and the reduction of the risk posed by *Legionella*. Eventually, the EPA may set minimum measurable chlorine residuals throughout the distribution system. It is recommended that the City of Unalaska continue monitor EPA publications and notices regarding *Legionella*, but no capital projects are needed at this time.

5.8 Storage of Chlorine Gas

Under the Executive Order on Improving Chemical Facility Safety and Security (EO 13650), the EPA proposed amendments to the Risk Management Program (RMP) (70 Fed. Reg. 147) which could change the requirement for storage of chlorine gas for the City of Unalaska, especially in the well houses. Due to significant opposition from the chemical industry and utilities and pressure from both houses of Congress, the EPA delayed the RMP rule amendments until February 2019. The RMP rule amendments are unlikely to be advanced in February 2019 under the current presidential administration.

It is recommended that the City continue monitoring EPA efforts to amend in the future, but no further action or capital projects need to be taken at this time.

5.9 Total and Hexavalent Chromium

Chromium is a naturally occurring metallic element found in rocks, plants, soil and volcanic dust, and animals. Hexavalent chromium (chromium-6) occurs naturally in the environment from the erosion of natural chromium deposits but can also be produced by industrial processes and from leaking, poor storage, or inadequate disposal practices of industrial waste. Trivalent Chromium (chromium-3) is an essential human dietary element and is found in many vegetables, fruits, meats, grains, and yeast.

EPA currently limits total chromium levels at 100 micrograms per liter (ug/L) assuming that the entirety of total chromium is the more toxic chromium-6 species. EPA is considering revising the chromium drinking water regulations to limit only chromium-6 concentration. Total chromium testing performed on water samples taken on 8/17/15 showed chromium levels below the method reporting limit of 2.0 ug/l. This testing indicates that chromium is not currently an issue in the City of Unalaska water system and it is unlikely that EPA actions on chromium limits will affect the City. However, it is recommended that the City monitor EPA actions on chromium regulations, but no further action is needed at this time.

5.10 Watershed Control Program

Federal and Alaska drinking water regulations require utilities that operate under filtration avoidance to maintain a watershed control program and submit a watershed control program maintenance report annually to DEC. A watershed control program is intended to minimize the potential for contamination by *Giardia lamblia* cysts, *Cryptosporidium*, and viruses in the source water; monitor and control detrimental activities occurring in the watershed; and control land use within the watershed. These are important considerations for Unalaska, because the Icy Creek water quality is a major component in the success of Unalaska's world-renowned fish processing industry. An incident affecting the cleanliness of the watershed, even if only perceived, could have major economic implications for Unalaska's fish processing industry. A strong and proactive watershed control program is good policy both in terms of meeting regulations and for responsible stewardship of an important natural and economic resource.

At a minimum, a watershed control program must characterize the watershed hydrology and land ownership; and identify and monitor watershed characteristics and activities which may have an adverse effect on source water quality. A utility must demonstrate through ownership and/or written agreements with landowners within the watershed that the utility can control all human activities which may have an adverse impact on the quality of the source water. The public water system must submit an annual report to DEC that identifies any special concerns about the watershed and how they are being handled; describes activities in the watershed that affect water quality; and projects what adverse activities are expected to occur in the future and describes how the public water system expects to address them.

The most recent update to the Unalaska's Icy Creek Watershed Protection Plan was in September 2009. That plan included a proposed watershed district ordinance for formalization of watershed protection measures identified in the plan.

Based on the changes that have occurred in the watershed since 2009, an update to the watershed control program plan is overdue. In order to be compliant with regulations and as a supplier of a critical resource to a world-class fish processing industry it is recommended that the City maintain a proactive watershed control program, update the watershed protection plan regularly, execute the watershed improvements proposed in the plan, and meet the annual reporting requirement. Further, it is recommended that updates to the watershed control program plan be formally adopted by City Council in order to add accountability and promote awareness of issues that could affect water quality and economic prosperity.

6 CAPITAL IMPROVEMENT ALTERNATIVES

Based on the review of current system condition, operational concerns, future demands on the water system, and planning criteria, this section identifies and describes the needs, opportunities, and deficiencies of the water system; alternatives to address the needs (in cases where more than one alternative exists); and recommended capital improvements.

Improvements are categorized as being driven by Regulatory requirements, the desire for better Efficiency, or the desire to conform to Industry Standards. Project descriptions are first organized by their category; then within each category projects are ordered based on their prioritization score as shown in Table 19 at the end of this section with the highest scoring projects first.

The Efficiency category includes projects that directly improve energy efficiency as well as projects that improve operational efficiency or reduce maintenance. Projects that improve the City's water supply or distribution system resiliency, reliability, or operational flexibility are categorized under Industry Standards.

The cost estimates included with each project description vary in terms of the level of detail, contingency percentage, and other factors. This is intentional and is based on the level of project development, availability of prior studies and cost estimates, and engineering judgment. Costs are in 2018 dollars unless indicated otherwise.

The level of project detail and economic analysis for Pyramid WTP Micro-Hydroelectric Generation is significantly more developed than all of the other projects. HDR's scope of work required the full economic analysis of that one particular project.

6.1 Regulatory Improvements

The following projects are identified as being driven by regulatory requirements, either existing regulations or new regulations that have been proposed.

6.1.1 General Hill Water Pressure

Eleven residential buildings located at higher elevations on General Hill in Pressure Zone 4 require in-home booster pumps for sufficient water pressure. During times of peak demand, especially during hydrant use, homes lose water pressure, creating potential for contamination from backflow. When water pressure drops below 20 PSI in the mains, then the City is in violation of drinking water regulations and a boil-water notice is supposed to be issued to the affected customers. Fire flow to the hydrants in the area is also inadequate without external boosting.

The recommended project is to construct a booster pump station similar to the Nirvana pump station. By improving the water pressure in the General Hill area, this project should reduce the possibility of a backflow incident and the associated regulatory, health, and safety issues. The new pump station should also eliminate the need for customers to rely on in-home booster pumps. The booster station would not provide fire flow capacity, but could be able to be externally boosted in case of a fire at the higher elevations of General Hill. The project is currently included in the FY2018-2022 CMMP with an estimated total cost of $222,000.

6.1.2 Public Watering Points

There are no locations in the water system that are open to the general public where bulk water is dispensed to fill large water trucks or portable tanks. There is demand for bulk treated water in Unalaska for construction, facility maintenance, and hauling to businesses and residences without a piped connection to the City water system. Fire hydrants are often used with or without utility permission for bulk water supply, especially for filling larger tanks. A utility approved and monitored location where bulk water can be attained is often called a “watering point”.

While it is a regulatory requirement to use a backflow prevention device when filling tanks directly from the water system, backflow prevention is often ignored or an inadequate device is used. Should a backflow situation ever occur, a large amount of utility time, money, and water could be wasted isolating, flushing, and disinfecting the water system to ensure that all contaminants are removed and all the water is safe for consumption. This process may include water outages or boil water notices for some customers. The economic ramifications of water system contamination, outage, or a boil water notice on the seafood industry could be severe.

In addition to the risk of backflow into the system, continued use of fire hydrants for non-emergency uses causes excessive and premature wear and damage to hydrants, necessitating more frequent maintenance and replacement. Fire hydrants are not made for repetitive use like this, and doing so prevents hydrants from being available when they are critically needed for fire fighting and costs the Utility and its customers for their repair or replacement.

Some bulk water users request and are issued temporary hydrant meters by the utility so that there is a record of the amount of water collected from a hydrant and utility can charge the user for the water. According to water utility staff, the process of issuing and recovering the meters, customer account setup, and billing is administratively burdensome. Due to the time and administration involved with acquiring and setting up a temporary hydrant meter, theft of water from unmetered hydrants or other system connections also occurs.

There is an existing watering point at the City’s Public Works building, but that watering point is mainly intended for official City use in washing Roads Division equipment and for filling a water truck for watering gravel roads. The location is not easily accessible to the public. This location is also in Pressure Zone 4, which means that all water used must be pumped.

It is recommended that the City pursue install two publicly-accessible watering points at strategic locations. The locations should be reasonably distant from one another, close to the electrical grid, close to a water main of adequate diameter and residual pressure, easily accessed by tanker trucks and the general public, and on City-owned property or right-of-way. It is also desired that both locations be within Pressure Zone 3 for reliability of supply (water can come from Pyramid WTP or the wells) and cost of operation (water from Pyramid WTP is gravity-fed). The water utility has identified two such locations:

- Along the east shoulder of Airport Beach Road between the Grand Aleutian Hotel and Carrs-Safeway, as shown in Figure 13.
- Along East Broadway Avenue near Well House 1 and across the street from the City’s Public Works facilities, as shown in Figure 14.

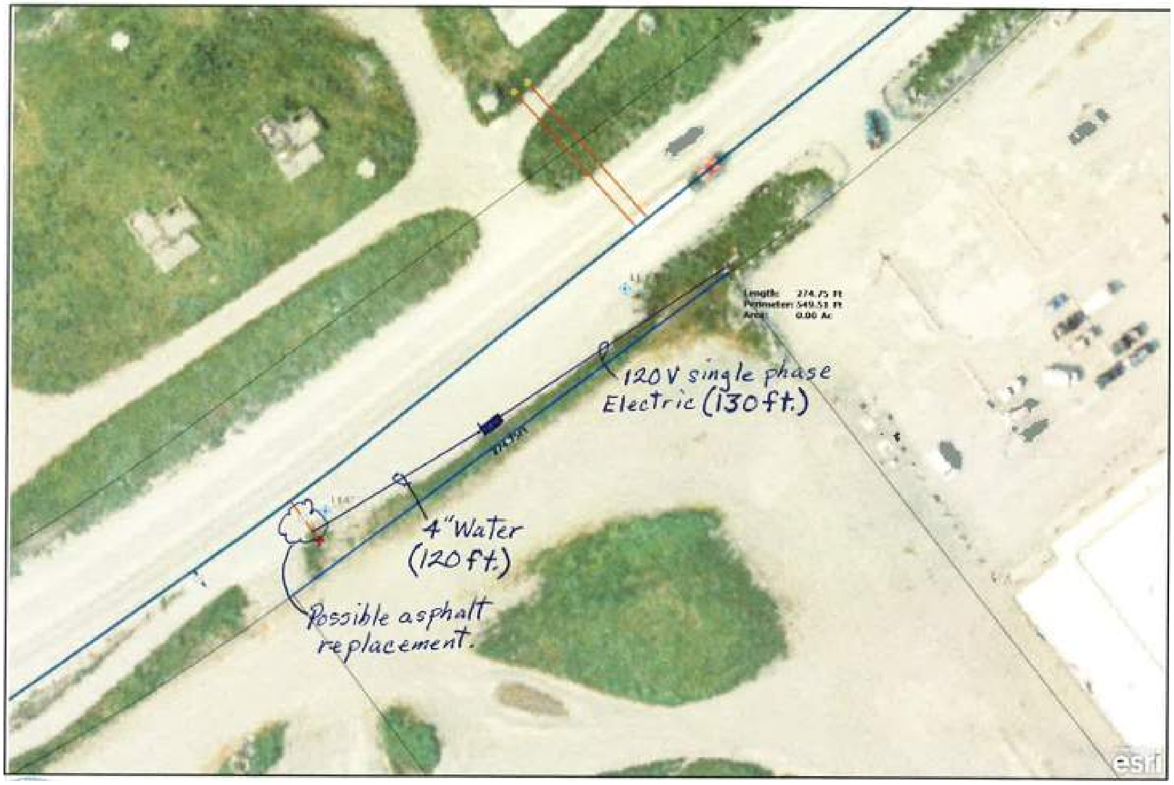


Figure 13: Recommended watering point location Airport Beach Road
(image source Unalaska Water Utility)

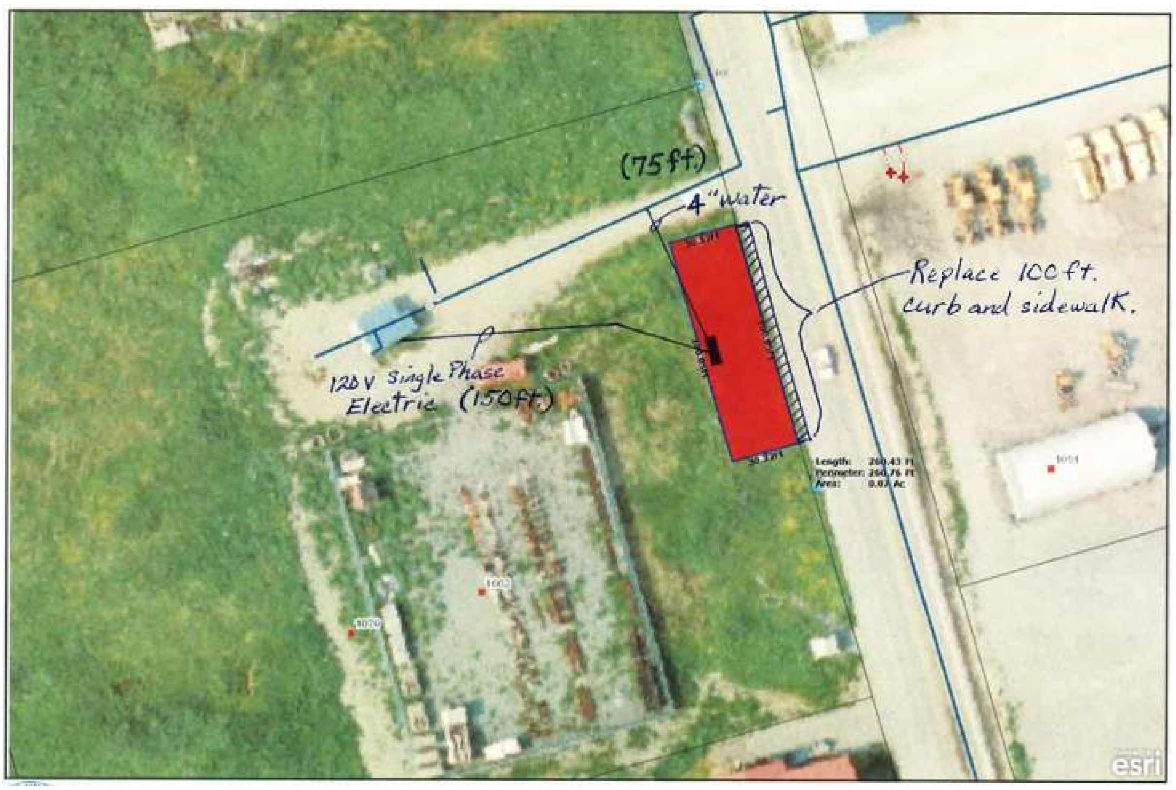


Figure 14: Recommended watering point location near Well House 1
(image source Unalaska Water Utility)

The watering points are envisioned to be pre-manufactured skid-mounted systems with the following components and capabilities:

- Capable of filling a water truck at roughly the same rate as a fire hydrant
- Integral approved reduced pressure zone backflow preventer
- Integral water meter that will interface with the City's existing metering system
- Users set up an account with the City Finance Department and receive a user-specific access fob and PIN code. They must swipe the fob and enter the PIN before the system will dispense water.
- Able to individually track customer water use and provide data for account billing
- Remote access to water use data for Utility staff through the City's existing communications network
- Not susceptible to freeze damage

The Utility solicited quotes for such systems in 2014 and received a bid from The Birks Company for an Aqualoader Bulk Water Truckfill System, model TFS3A, as shown in Figure 15, for approximately $40,000 each including equipment and startup support. Installation would be additional and by others.

Figure 15: Aqualoader Bulk Water Truckfill System
(image source Birks Company)

The watering points would require site improvements such as grading, gravel surface course, curb and sidewalk, a concrete pedestal for the water dispensing system to be mounted, signage, and utilities. Utilities would include a minimum 4-inch connection from a nearby water main, 120-volt electricity, and cellular or Ethernet communications.

This solution should eliminate the current contamination risk in the system due to inadequate backflow prevention, reduce water theft, simplify account management and billing for bulk water purchases, reduce maintenance and repair costs for fire hydrants, and reduce the risk that a hydrant could be inoperable during a fire event.

The total opinion of probable project capital cost for two watering points is $286,000 and includes 10% for engineering and a 10% construction contingency.

6.2 Efficiency Improvements

The following projects are identified as being driven by the desire for improved efficiency, either in terms of energy efficiency or indirectly through improved operational efficiency or reduced maintenance.

6.2.1 Pyramid WTP Micro-Hydroelectric Generation

Water flowing from the Icy Creek Reservoir into the Pyramid WTP contains excess hydraulic head which must be reduced to the operating levels within the plant. Currently the head is reduced by a pressure reducing valve (PRV) and the energy is dissipated via heat and noise. Inline hydroelectric turbines can capture that energy as electricity. The WTP design included piping space and a spool piece for future turbine installation.

A financial analysis must be performed to determine if the costs of installation and operational and maintenance are offset by the monetary benefit of electricity production.

6.2.1.1 Previous Hydroelectric Studies

Hydroelectric power generation on the Icy Creek/Pyramid Creek watershed has been the subject of numerous studies over the years. Most of these studies focused only on the larger hydroelectric project to capture the energy of the water that spills over the Icy Creek reservoir dam, but some studies also addressed the topic of inline turbines to capture excess head through the Pyramid WTP. Below is a brief chronology of these studies:

- U.S. Army Corps of Engineers, 1984
- Energy Stream Inc., 1985
- Polarconsult Alaska Inc., 1994
- Locher Interests LTD and Harza Northwest for the Alaska Department of Community and Regional Affairs, Division of Energy, 1998
- Financial Engineering Company for the City of Unalaska, 1998
- HDR Alaska, Inc., Preliminary Design and Permitting Report, for the City of Unalaska, 1999

6.2.1.2 Hydroelectric Potential

Energy potential of any hydroelectric system is governed by the available hydraulic head and the total flow. Higher head and flows result in higher total energy production. The Icy Creek Reservoir level stays fairly constant throughout the year, resulting in stable hydraulic head through the system. In contrast, due to the cyclic nature of the water demands in Unalaska, WTP flow varies through the year as shown in Figure 16. During fish processing seasons, the average daily WTP plant flows range from 2,500 gpm to over 4,000 gpm. However during non-processing periods, the WTP averages a daily flow of between 600 and 1,300 gpm.

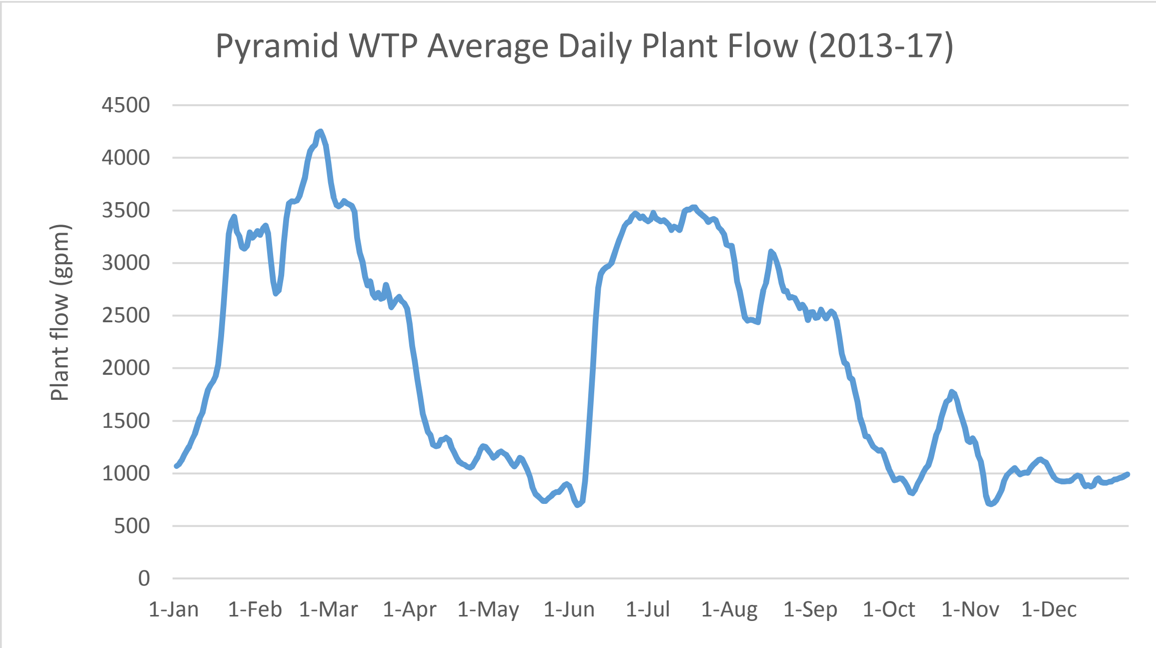


Figure 16: Pyramid WTP Flow

Hydroelectric turbines have a range of flows in which they are capable of producing electricity efficiently. Selection of a specific turbine must take into account the amount of available power through different flow ranges in each turbine and the duration during the year the turbine could run. For example, a turbine sized for the peak flows during fish processing season would not be able to operate during the non-peak period as there is not sufficient flow to turn the turbine. Conversely, a turbine sized for low-flow periods would over speed in the higher flow regimes of fish processing season.

6.2.1.3 Hydroelectric Production

In order to utilize the hydraulic potential available at the Pyramid WTP, multiple turbines are required. For this evaluation of generation potential two turbines are assumed to be installed, one for high flow and one for low flow. The Cornell Pump company was contacted to provide turbine and generator sizing and pricing information for a financial analysis of hydroelectric installation. Based on the daily average flow data in Figure 16, two different turbines were recommended. At approximately 175 feet of head, the 6TR1 turbine produces between 90 kilowatts (kW) and 20 kW of power from flows ranging from 3,800 gpm to 2,470 gpm and the 4TR2 turbine produces between 33 kW and 6 kW of power from flows ranging from 1,210 gpm to 720 gpm. Figure 17 below shows the available flow ranges for the two selected turbines compared to the average daily plant flow.

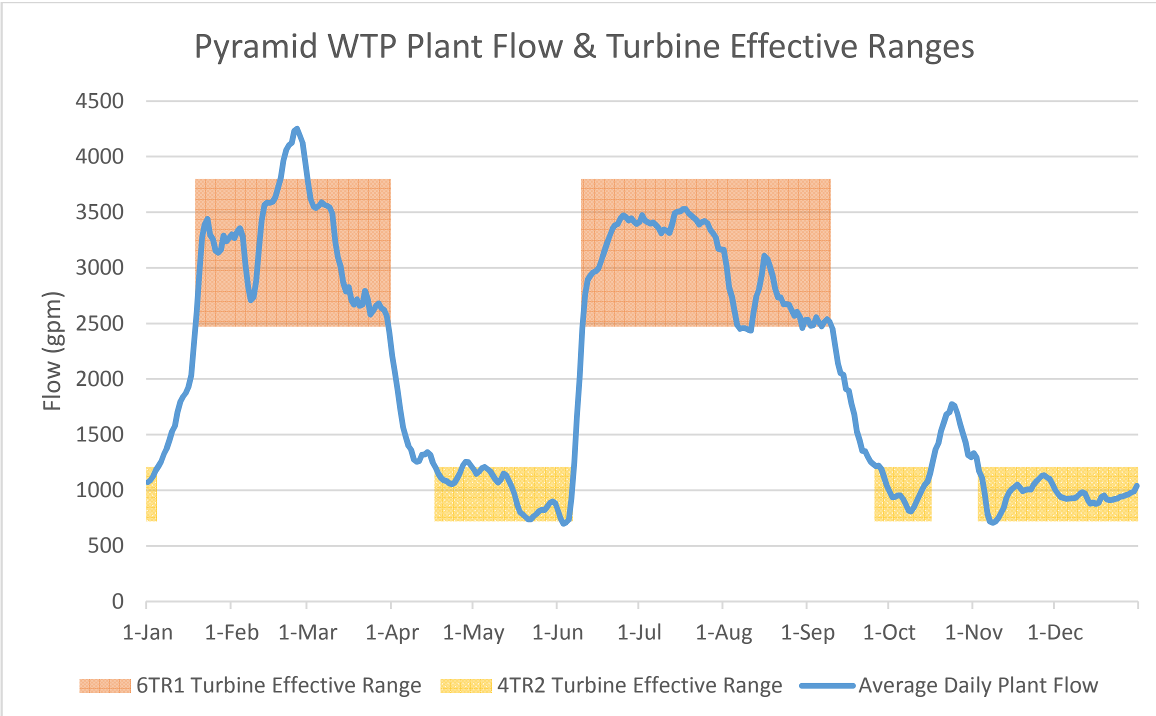


Figure 17: Pyramid WTP Flow and Proposed Turbine Effective Ranges

Accounting for estimated 85% operating inefficiencies, the two turbines combined could produce approximately 210 megawatt-hours (MWh) of electricity annually based on the average daily flows. Figure 18 below depicts the estimated turbine production vs the average monthly electric demand. The green area represents the total benefit to the utility. It is assumed that the total benefit to the utility is the smaller of either the average annual plant electrical demand or the estimated turbine production. However, the turbines could produce more power than the plant currently consumes during peak plant flow periods. For the purposes of this analysis, it assumed that excess power could be converted into heat for the WTP, thereby decreasing the amount of heating fuel oil consumed to heat the WTP during colder periods. Capital costs for electric heating provisions are accounted for in the economic analysis.

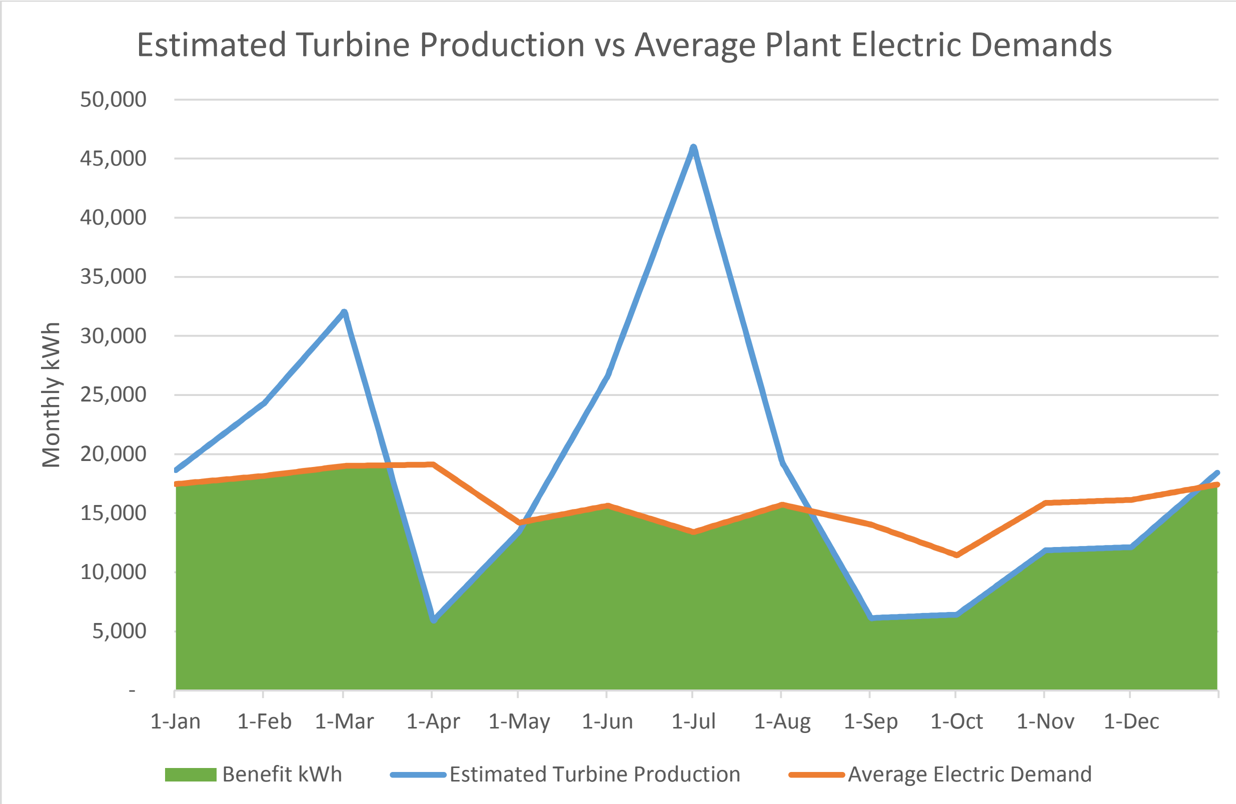


Figure 18: Estimated Electric Production and Plant Electric Demands

The estimated bulk rate of electricity was valued at $0.329 per kilowatt-hour (kWh) with 10% of the total electric income spent on operations and maintenance (O&M). The cost of electricity was assumed to stay constant through the analysis and includes the electric rate per kWh ($0.144/kWh), the Cost of Power Adjustment (COPA) ($0.165/kWh) and an additional $0.02 per kWh to cover other costs such as the monthly meter fee and the industrial demand fee. Any increases in the electrical rate should increase the return on investment of the turbines; decreases in the electrical rate will lower the return. The annual benefit shown in Figure 18 is based on the installation of both turbines. The analysis of each turbine installed separately is also presented in Table 12.

Table 12: Estimated Electric Production and Associated Benefits and Costs

	Production (kWh)	Benefit	O&M
Both Turbines	155,290	$ 51,083	$ 5,108
6TR1 Only	102,480	$ 33,711	$ 3,371
4TR2 Only	54,900	$ 18,059	$ 1,806

6.2.1.4 Hydroelectric Installation Costs

The estimated cost to purchase and install the turbines is presented in Table 13. Installation, labor, and local administration costs were estimated based on data in several hydroelectric studies including the 1994 study by Polarconsult and are calculated as percentages of the turbine capital cost or the subtotal of total installation costs.

Table 13: Estimated Construction Costs

	Both Turbines	6TR2 Only	4TR1 Only
Turbine & Generator - 6TR2	$ 30,000	$ 30,000	$ -
Turbine & Generator - 4TR1	$ 10,000	$ -	$ 10,000
Valves and Pipes	$ 35,000	$ 30,000	$ 30,000
Controls	$ 15,000	$ 10,000	$ 10,000
Materials Subtotal	$ 95,000	$ 70,000	$ 50,000
Shipping	$ 6,000	$ 3,000	$ 3,000
Installation Costs	$ 95,000	$ 70,000	$ 70,000
Engineering + Management	$ 14,250	$ 10,500	$ 10,500
Subtotal	$ 210,250	$ 153,500	$ 133,500
Contingency (50%)	$ 105,125	$ 76,750	$ 66,750
Total	**$ 315,375**	**$ 230,250**	**$ 200,250**

Installation costs assume the hydroelectric system is not configured to backfeed power to the Unalaska power grid. It is assumed that power generated by the turbines can be used exclusively within the WTP, thereby avoiding the greater complexity and cost of a backfeed system. Should the City desire a backfeed system, an additional feasibility study should be performed.

6.2.1.5 Hydroelectric Flow Optimization and Additional Power Generation Opportunities

Once the Captain's Bay road upgrades are completed, the minimum water level in the Pyramid WTP Chlorine Contact Tank reduces as it is no longer necessary to maintain higher pressures to effectively serve the North Pacific Fuel facility. With more operational flexibility, WTP flow could be optimized for hydroelectric production, which could increase the return on investment of the project. In addition, a lower level in the tank could result in higher hydraulic head through the turbines, which increases power production of the turbines, further increasing return on investment.

During periods of lower plant flow, water overtops the dam at the Icy Creek Reservoir. There is an opportunity to use this excess flow to produce additional power using the larger turbine. The ideal turbine location would be as the water enters the WTP in a 30 foot long section of pipe initially designed for turbine installation. The plant bypass pipe connects to the system after this point. It is possible to allow water to enter the plant and turbines during off-peak production periods and expel any excess water over what is needed to fulfill city demand through the bypass pipe. This installation could allow the larger turbine to run consistently for a greater period of the year, yielding more power than what can be produced with the regular flow through the WTP. Operation of the turbine system in this way would require automatically actuating valves to be installed in place of the current ClaVal system. An additional feasibility study should be performed to determine the power generation capacity of this configuration.

During shoulder seasons just after or before processing seasons, WTP flow is too low to operate the large turbine, but too high to operate the smaller turbine. By installing a bypass pipe and modulating control valve system around the smaller turbine, a sufficient flow could be directed through the small turbine to allow for year-round power generation. The additional cost of this bypass pipe and valve system should be explored during the turbine design phase.

6.2.1.6 Excess Hydroelectric Power for Heating Pyramid WTP

During A-season flows, the estimated turbine production is greater than the average electrical demand of the Pyramid WTP. This excess power could be converted into heat to lessen the annual heating oil cost to the Water Utility. An analysis was performed to determine the potential for heating the plant with electric power.

Record keeping for heating oil deliveries has been unreliable in the past, thus it is difficult to determine the exact heating oil usage of the Pyramid WTP versus the Icy Creek Reservoir Dam Building. For the analysis, it is estimated that 80% of the annual heating oil consumption was from the Pyramid WTP. Taking the average annual heating degree days from 2010-2017 resulted in an average of 1.0 gallons of heating oil per heating degree day. The average degree days per day was calculated on a monthly basis resulting in an approximate usage rate of 20 to 32 gallons of heating oil per day during the winter months (October to April) and 11 to 18 gallons of heating oil per day during the summer months.

The excess electricity generated per day was converted into equivalent gallons of heating oil per day based on U.S. Department of Energy publications on energy density of various fuels. Taking into account inefficiencies of converting electricity or heating oil into heat resulted in an approximate conversion factor of 70 kWh per gallon of heating oil.

The total annual power used for heating was calculated by summing the minimum of either the excess kWh production converted to heating oil consumption or the estimated daily heating oil usage. The total annual estimated heating oil use reduction is 3,950 gallons. At the current rate of $2.30 per gal, the annual yearly benefit is $9,100. The annual O&M costs were assumed to be 10% of the annual benefit, or $910.

There are several methods of converting power into heat such as electric unit heaters or electric heat exchangers built into the existing heating system. Capital costs for further study, design, and installation of the electric heating system was assumed to be $35,000. Based on that assumed capital cost the approximate payback of this system could be 4.3 years.

The yellow zone in Figure 19 shows the portion of turbine-generated electricity that could be used for WTP heat.

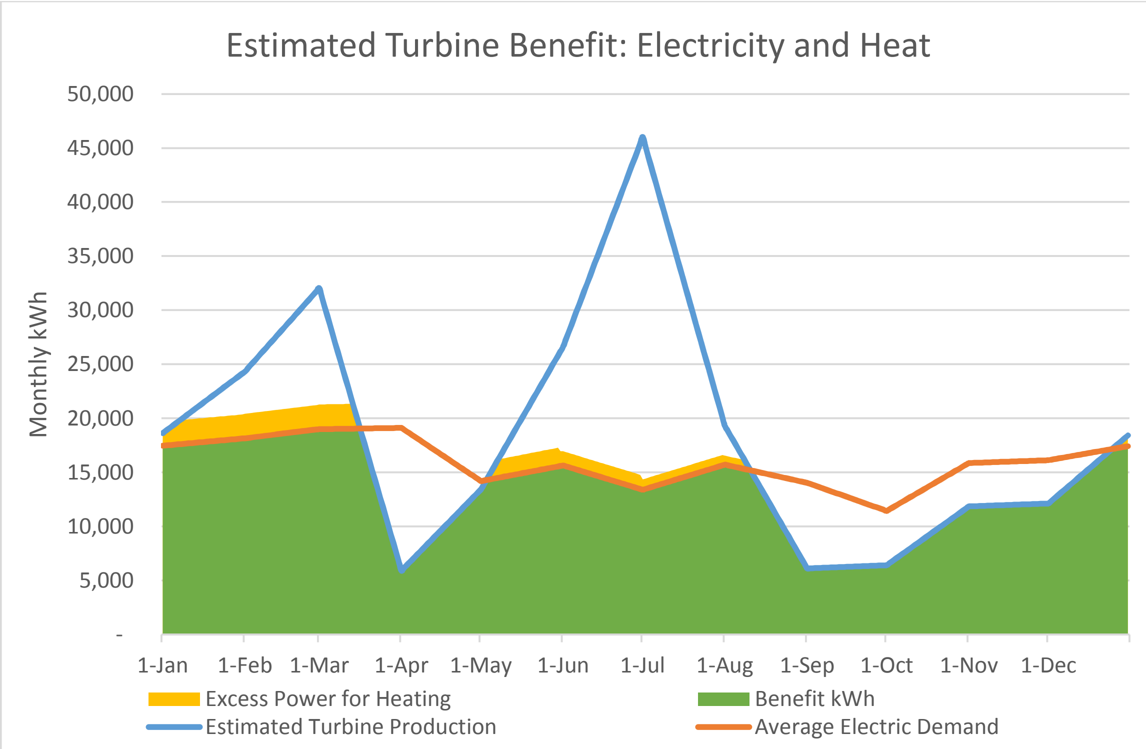


Figure 19: Estimated Electricity Available for WTP Heating

6.2.1.7 Conclusion

The payback of the project, shown in Table 14, is calculated by dividing the total project capital costs by the annual income less O&M costs. It is assumed that the price of electricity will increase with inflation. If a loan is required, the annual loan payment should be subtracted from the annual income, which would increase the payback period.

Table 14: Turbine Construction Payback

	Annual Net Benefit	Capital Cost	Payback (years)
Both Turbines	$ 45,974	$ 315,375	6.9
6TR1 Only	$ 30,340	$ 230,250	7.5
4TR2 Only	$ 16,253	$ 200,250	12.3

The installation of both turbines could result in a payback in just under 7 years. It is recommended that the City pursue installing both turbines as over the lifetime of the project and the 20-year master planning period, this option should result in the highest economic return. The City should also pursue converting excess electricity produced during the winter months into heat to reduce heating oil usage.

6.2.1.8 Other Future Water System Hydroelectric Opportunities

Additional hydroelectric energy recover opportunities exist within the Unalaska water system that should be considered in future master plans and after the Pyramid WTP Micro Hydroelectric

Turbine system is installed and operating. One of these opportunities is at the Agnes Beach PRV station. The Agnes Beach PRV reduces pressure from approximately 120 PSI to 70 PSI as the water moves from Pressure Zone 2 to Pressure Zone 3. The flow through the Agnes Beach PRV is approximately equal to the Pyramid WTP tank outlet flow minus customer demands from Westward Seafoods, North Pacific Fuel, and Haystack Hill. An inline hydroelectric turbine and generator could be installed at the Agnes Beach PRV station to capture this otherwise wasted energy.

The theoretical hydroelectric power generation potential of an inline turbine at the Agnes Beach PRV station could be approximately 13 kilowatts using the following input values:

- 2,059 gpm for the average daily flow through Pyramid WTP
- 1,076 gpm assumed total average demand from Westward Seafoods (based on the latest 12 months of meter records), North Pacific Fuel, and Haystack Hill
- 50 PSI pressure differential
- 85% efficiency

Installation of an inline hydroelectric system at the Agnes Beach PRV station could be more expensive and complicated than the Pyramid WTP turbine project described above, because it is likely that a building addition would be necessary at Agnes PRV station to create the additional space for the turbine and piping.

Hydroelectric generation at Agnes Beach PRV is worthy of further consideration and study, but would fall outside of the planning horizon of this master plan in comparison to other more critical needs of the water system.

6.2.2 Additional Solar Panels for Icy Lake Valve Station

The Icy Lake valve and monitoring station is powered by one solar panel array, a backup propane thermoelectric generator, and a battery system, because the station is too remote to be connected to the electric grid. Two small wind turbines had been installed at one point, but the turbines failed in high winds. The solar array, shown in Figure 20, does not supply enough power to charge the battery system to operate the station during the darker winter months. The propane thermoelectric generator supplies some additional battery charging, but requires periodic replacement of the propane tank and the unit only produces about half of the power that it did when it was new.

Serious safety concerns arise if travel to the station is required to switch out propane tanks or make repairs during bad weather, especially in the winter or when the creek is at flood-stage. A water system operator was badly injured several years ago on a snow machine trip to the station for routine maintenance. If the thermoelectric generator fails or runs out of propane during bad weather and it is impossible to safely access the station, then a water shortage and possible fish processor shutdown could result. A low-maintenance solution that eliminates the need for unsafe travel to the station during unfavorable conditions is necessary to improve reliable operation of the station.

Figure 20: Existing Solar Panel Array at Icy Lake Valve Station

It is recommended that the City proceed with the installation of a second solar panel array at the Icy Lake valve and monitoring station. The second solar panel array should be installed near the existing one to provide the additional solar generating capacity to charge the batteries year-round. This upgrade should provide reliable, inexpensive power to the valve station with no maintenance; change the propane thermoelectric generator to a purely backup power role, which is how the system was originally intended to operate; and reduce the need to travel to the station on short notice during bad weather.

The rough order of magnitude opinion of probable project capital cost is $50,000 and includes the solar panel array, a steel support frame, foundations, and wiring. It is assumed that the new solar panel array can be wired to the existing one to minimize the amount of new wire and conduit needed. It is also assumed that the existing battery system is adequate.

6.2.3 UPCH Automated Controls

The Unalaska Pump Control House (UPCH) contains a pump to supply water from the Pressure Zone 3 to Pressure Zone 4 and PRVs to allow the movement of water produced by wells in Pressure Zone 4 back to Pressure Zone 3. The pumps and valves located in the control house are manually operated and controlled based on overall system configuration. This leads to a higher workload for Utility workers and inefficient movement of water.

Automating the pump and PRV controls should allow the system to determine when to use the pump verses the wells. Pumps and valves would turn on and off based on water system criteria such as demand, tank levels, and system pressures. The project would include installation of electronic controllers on the UPCH pump and PRVs valves and additional programming of the programmable logic controllers (PLCs) at UPCH, Agnes Beach PRV Station, Icy Creek Reservoir, and Icy Lake. It should turn the Water Utility SCADA into a "smart system" that could rapidly make decisions regarding prioritization of water sources from Icy Lake to the wells. The only additional hardware required should be at UPCH. All of the hardware is currently in place at all of the other facilities.

An automated system could reduce the workload of the Utility as constant UPCH monitoring should no longer be necessary, and only a cursory check could be needed to ensure the proper controls are active. This project could allow utility workers to focus on overall system operation, improvements, maintenance.

The total rough order of magnitude opinion of probable project capital cost of UPCH automation is $300,000 and includes the PLC programming required at the other related facilities.

Once the system is installed and functioning, the O&M costs of the system is predicted to decrease as less labor should be needed to operate the UPCH systems.

As an additional comment about UPCH, it should be noted that Utility operators believe that there are rocks and debris piled up inside the water main along East Broadway Avenue adjacent to UPCH. It is believed that the rocks are piled up against a closed butterfly valve in the main line pipe near where a smaller pipe branches off to UPCH. If the rocks are still moving through the system then it could be a matter of time before the main line branch tee is plugged with rocks and flow through UPCH is restricted. Operators believe that water main flushing will not be effective due to the size of the rocks. Prior to repaving East Broadway Avenue in the future it is recommended that this issue be verified and corrected if necessary.

6.2.4 Meter Reading System

As of April 2018 the City of Unalaska Water System contains a combination of 306 metered service connections and 291 unmetered service connections. All new service connections are installed with meters and there has been an ongoing effort over recent years to install meters on all existing unmetered services. Existing meters use Automatic Meter Reading (AMR) technology which consists of a radio transmitter that wirelessly sends the meter reading to a handheld data recording device. In order to retrieve monthly water usage data, an operator must drive to each of the 306 metered customers to read meters with the data recording device. This process consumes several days per month and diverts operator time and budget away from more urgent tasks necessary for the successful operation of the utility. The water utility is already short-staffed of operators to attend to the long and growing list of deferred repair projects on top of an already full load of regular operation and maintenance tasks.

In addition to the time investment to read every meter, there is no ability to collect real-time usage data. Real-time usage data would be a useful tool for water management. For example, real-time usage data, especially on high demand customers, would be useful for leak detection and in cases of water rationing due to low reservoir levels or other water production issues by enabling operators to know who is using too much water.

6.2.4.1 Alternative 1 – Advanced Metering Infrastructure

This alternative would retrofit all metered services and replace meter reading systems with Advanced Metering Infrastructure (AMI). Although AMI can have many variations and levels of sophistication, AMI is basically a system that allows communication, often wireless and two-way, between water meters and a one or more permanently installed central hubs. Water meters require the proper radio communications transmitter/receiver equipment, usually powered by long-life lithium batteries. Some water meters may need to be replaced all together for proper interface with the communication system. The central hub generally consists of an antenna, radio transmitter/receiver, and a computerized data collection system. The central hub would ideally be installed at a City-owned property if there is an available location with adequate signal coverage to/from each meter. Otherwise, the central hub could be installed at an elevated location such as Haystack Hill for better reception and connected to the City's information systems through an internet connection.

AMI systems often integrate customer account and billing functions with meter data collection and management in a complete software package. Meters can be set up to transmit data at a preset frequency, daily for example. AMI systems with two-way communication allow utilities "on-demand" capability to signal any meter at any time for a reading, enabling access to real-time water usage data. In addition, AMI systems can be configured to "alert" utilities of outages or potential customer service line leaks as they occur, serving as "silent sentinels" that constantly monitor the distribution network to provide near real-time notification of such occurrences.

An AMI system should allow the Utility to gather billing information, water use amounts, and monitor usage patterns quickly and efficiently without the time and expense of driving to each meter. It is understood that the City's water and electric utility are currently planning a joint AMI system for which the central hub, data collection hardware, and data management and billing software would be used and shared by both utilities. In this scenario of a shared AMI system, the water utility would still need to retrofit existing meters with new AMI communications equipment.

As with most technology-based systems, a downside to this alternative is that the AMI system will eventually become obsolete. For example, it may become difficult to find new meters that will work with the old communications equipment. It may become difficult to maintain the interface between the City's finance software and the AMI customer account/billing software. Also, the batteries that power the communications equipment at each meter will eventually fail and require replacement.

6.2.4.2 Alternative 2 – Dedicated Meter Reader Employee

Alternative 2 would be to hire a dedicated meter reader employee. This new City employee would be dedicated to the task of meter reading in order to avoid diverting operator time away from more urgent tasks. The meter reader employee could potentially be shared by the water and electric utility and also handle customer service and billing functions. In order to also gain real time water use data, at least for high-demand customers, this alternative would incorporate a transmitter into select existing meters (if existing meters are capable of this upgrade) and a SCADA link to feed real time water use data into the utility SCADA system.

In order to make this alternative financially viable it would be necessary for the electric and water utilities to jointly hire and manage the meter reader employee. This alternative would be challenged by administrative issues with having one employee who is effectively working for two different enterprise-fund utilities – a problem that could potentially be solved by having the new meter reader position fall under the City's Finance Department.

6.2.4.3 Recommended Meter Reading System

Based on the potential of joint ownership and cost-sharing, it is recommended that the water utility pursue Alternative 1 for an AMI system to be shared with the electric utility. Under this scenario it is assumed that the water utility would bear the full cost to upgrade existing water meters and half the cost to purchase and install the central hub and software systems.

Remotely monitoring water use has advantages for the Utility in terms of efficiency of employee time and overall system operation. Monitoring use in real time could allow city employees to detect and locate leaks in the system much quicker than current methods. By looking at real time water usage, the Utility can determine if large water users are complying with requests to lower water usage in times of water shortage or emergencies. The Utility could spend less time with the billing as the process should be mostly automated. This should free up Utility employees to focus efforts on maintaining the water distribution system and improving system operations rather than reading meters for billing purposes.

The total opinion of probable capital costs to the water utility for half of the AMI system is $262,000 and includes the following items:

- Purchase water meter upgrade equipment: $170/each for 306 existing meters = $52,000 (based on Ferguson 2013 quote of Sensus MXU Endpoint of $150/each plus 2.5% annual inflation)
- Install water meter upgrade equipment: $120/each for 306 existing meters = $37,000
- Half of the cost to purchase and install the central hub: $105,000 (based on Ferguson 2013 quote of Sensus equipment plus 2.5% annual inflation)
- Subtotal: $194,000
- Planning and engineering, 20% of the subtotal: $39,000
- Contingency, 15% of the subtotal: $29,000

6.3 Industry Standard Improvements

The following projects are identified as being needed to meet Industry Standards. Projects that improve the City's water supply or distribution system resiliency and reliability are also categorized under Industry Standards.

6.3.1 Captains Bay Road Water Main

The lack of a water main along Captains Bay Road between Westward Seafoods and North Pacific Fuel is an important water system issue that the City should address within this master planning period. The full potential of the Unalaska water system has been hydraulically limited since the installation of the existing pipe serving North Pacific Fuel and many other projects contemplated in this (and previous) master plans are dependent on a Captains Bay Road water main extension being installed. A water main along Captains Bay Road to North Pacific Fuel should improve the hydraulic operation, failure resiliency, and operational flexibility of the entire Unalaska water system as well as reduce the capital cost associated with other important, and needed, water system improvements.

While North Pacific Fuel only counts as one customer with one meter, the facility includes water demand from 8 residential units, business use, and dock use. The North Pacific Fuel facility is currently served by a 6-inch pipe of wood stave and other materials. The pipe starts at a tee in the Pyramid water transmission main that follows Lower Pyramid Creek Road and serves the entire City. The tee is located approximately 1/3-mile downstream of the Pyramid water storage tank. The North Pacific Fuel pipe then flows over a hill with a maximum elevation of approximately 310 feet. The top of this hill is nearly at the same elevation as the middle of the 2.6 million gallon (MG) Pyramid water storage/ chlorine contact tank. Utilities have a regulatory obligation to maintain water service to all customers at the regulated pressure. Therefore, in order to provide water service to North Pacific Fuel, the water level in the Pyramid tank must be maintained above approximately 29 feet.

The Pyramid tank height is 38 feet (to the overflow), so maintaining the water level above 29 feet means that the useful storage is only 0.5 MG, thereby preventing a large amount of treated water in the tank from being utilized by any other customers in the system. It is impossible to use much of the water stored in the Pyramid tank without cutting off water service to North Pacific Fuel. The inability to use almost two thirds of the storage capacity of the Pyramid water tank means that the rest of the City's water customers do not benefit from the value of this asset.

For many years the City has had inadequate water storage capacity and has wavered over the location and size of a new storage tank. The main dilemma that has hampered execution is that the ideal location and size of the tank changes depending on whether or not a water main to North Pacific Fuel is installed along Captains Bay Road. A new pipe along Captains Bay Road to North Pacific Fuel could allow the tank to be operated down to 8 feet, making an additional 1.5 million gallons of stored water available for operational demands, fire flow, and emergency use throughout the City. Freeing 1.5 million gallons of existing storage capacity by installing the new pipe along Captains Bay Road to North Pacific Fuel means that 1.5 million gallons less new storage tank capacity must be installed elsewhere.

The City has long contemplated installing the needed additional storage capacity with a second storage tank adjacent to the existing Pyramid tank and WTP. The second tank at Pyramid WTP was envisioned to enable taking the existing tank offline for draining, cleaning, and maintenance, because it is currently impossible to take the existing tank offline without cutting off water service to North Pacific Fuel and to a lesser extent Westward Seafoods. (Water service to Westward Seafoods can be maintained at limited flow and pressure by back-feeding through the existing Captains Bay water line from the wells in Pressure Zone 3. This supply scenario is not sufficient for fish processing or fire protection while other processors are processing.) In recent CMMPs, the City has scaled back the idea of a second tank at Pyramid WTP but is still considering at a minimum installing a smaller-diameter standpipe tank adjacent to the existing tank in order to enable taking the existing tank offline for maintenance without cutting off water service to North Pacific Fuel.

The City has also considered constructing a pump station to pump water over the hill to North Pacific Fuel to enable full use of the water in the existing Pyramid tank. A 2015 Preliminary Engineering Report by HDL describes building a second tank next to the existing Pyramid tank and this booster station at the North Pacific Fuel service line tee along Lower Pyramid Creek Road. HDR's opinion is that constructing a new facility, which will consume electricity and operator labor, to pump water to a downhill customer is an unattractive option when an entirely gravity solution is available. The pump station option also does not provide some of the system-wide benefits of hydraulic operational flexibility as a water main to North Pacific Fuel could. If the pump station were also sized to provide fire flow to North Pacific Fuel then the higher pressure could jeopardize the existing wood stave pipe.

The City has delayed the Captains Bay Road water line project and the second tank project for so long that the need to perform maintenance on the existing Pyramid tank is becoming critical. If the City chooses to cancel or delay the Captains Bay Road water line project much longer, then the additional tank at Pyramid will be necessary, potentially forcing the City into a reactive mode of having to build on short notice a piece of infrastructure that is neither recommended nor an efficient use of limited funds.

A new water main along Captains Bay Road to North Pacific Fuel should eliminate the need for a second Pyramid tank of any size, because it enables taking the existing tank offline for maintenance during non-fish processing periods, perhaps longer. A Captains Bay Road water main to North Pacific Fuel should eliminate the hydraulic dependency that North Pacific Fuel has on the tank level and should eliminate the chlorine contact dependency that North Pacific Fuel has on the existing tank. With a new Captains Bay Road water main to North Pacific Fuel the required chlorine contact should be met in the water transmission main between Pyramid WTP and Westward Seafoods.

Additionally, the existing wood stave pipe to North Pacific Fuel leaks at a rate of approximately 90 gpm, or 130,000 gallons per day. The installation of a new pipe along Captains Bay Road should eliminate this leak, decrease North Pacific Fuel's water bill, and provide a noticeable benefit to the City's water supply situation, especially during times of limited supply and high demand.

The recommended project is to install approximately 1-mile of new 12-inch (minimum) diameter water main along Captains Bay Road from Westward Seafoods to North Pacific Fuel, as shown in Figure 21. The water main installation could be part of a larger project that the City has had planned for many years to improve drainage, install pavement, and build other utilities along Captains Bay Road; however, the water main could be installed independent of the road upgrades and provide benefits to the City's water system. After the new water main is operational, the existing 6-inch pipe to North Pacific Fuel should be disconnected from the water transmission main along Pyramid Creek Road and abandoned.

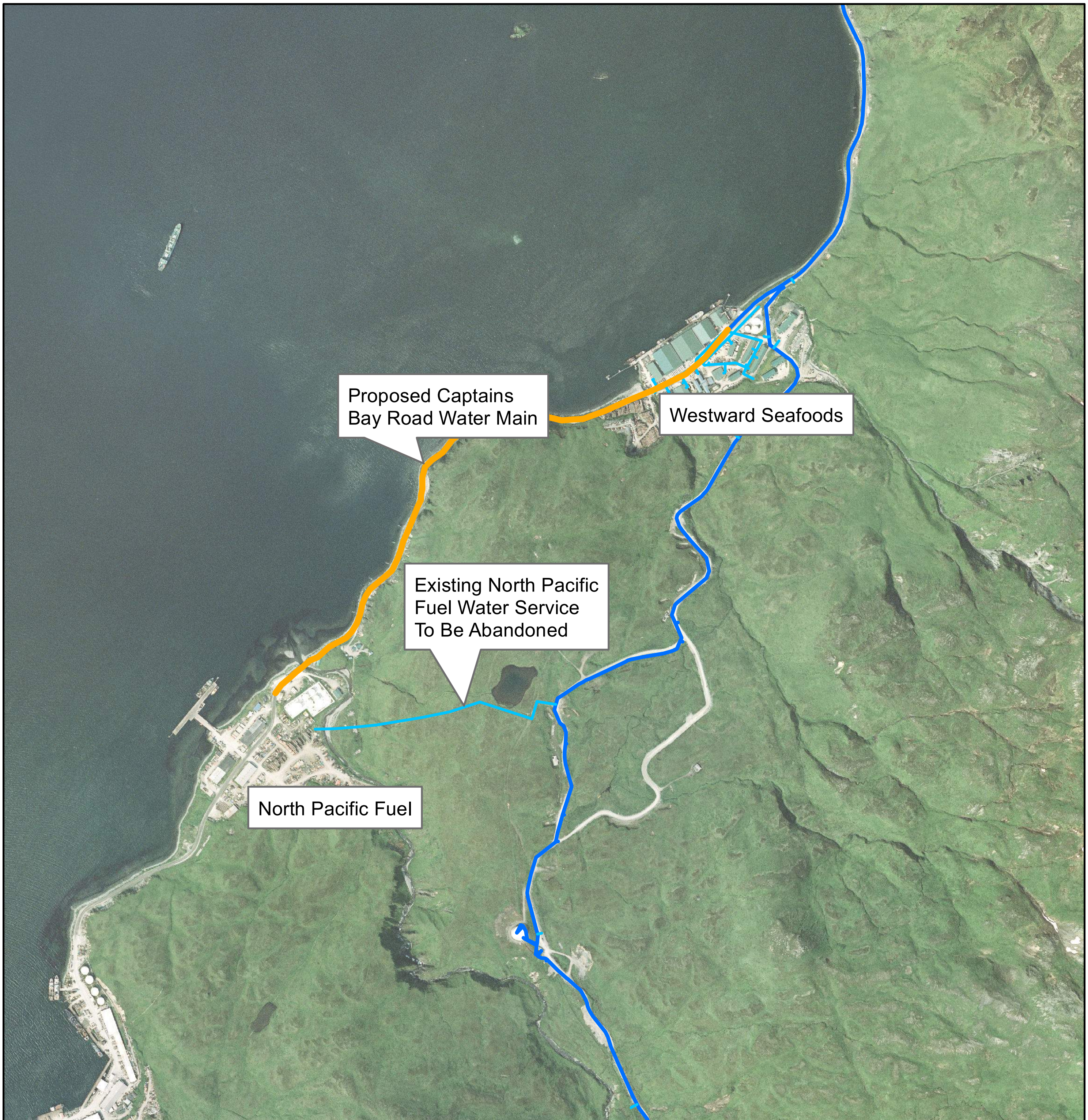
The City could explore a public-private partnership (PPP) approach to fund the project. According to water system staff, North Pacific Fuel approached the City approximately 2 years ago about partnering on the project. OSI operates a fuel and dock facility along Captains Bay Road approximately ½ mile south of North Pacific Fuel. According to water system staff, OSI also approached the City approximately 8 years ago about a joint project to extend a new Captains

Bay Road water main all the way to OSI. When the water main project never materialized, OSI constructed their own private onsite water supply and treatment system at a cost of $2M. OSI's private water system cannot meet their demands, so OSI purchases and trucks water in from the City water system. North Pacific Fuel and OSI could stand to benefit from more reliable water and fire flow service along with the possibility of reduced operating costs and fire insurance premiums. Therefore it is recommended that the City consider exploring PPP development to fund this important project.

At this point the recommended project brings the new water main only as far as North Pacific Fuel, but prior to capital planning and design of the project it is recommended that the City discuss a partnership on the additional ½ mile extension with OSI and any other land owners who may benefit from the addition of these services. When sizing the new Captains Bay water main it is recommended that the City consider the possibility of future water service to OSI and other new customers in that area.

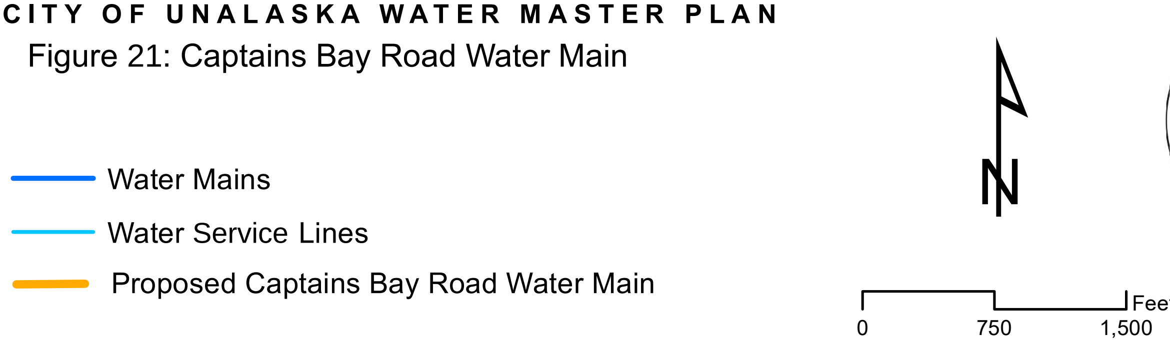
When sizing the new Captains Bay water main it is also recommended that the City consider the the potential that the pipe could one day serve as a transmission main for a future source of water in the Shaishnikoff River Valley. The City recently performed geophysical exploration of the Shaishnikoff River Valley for groundwater supply potential. Water from the Shaishnikoff River Valley would be piped into Unalaska along Captains Bay Road, potentially requiring additional pipe capacity. While the development of a new water source in the Shaishnikoff River Valley would most likely occur outside the 20-year planning period of this master plan, it would be wise to consider upsizing the pipe during design.

The total estimated cost for the water main component of the Captains Bay Road and Utilities project as presented in the current CMMP is $3.15 M. This cost is to bring the new water main to North Pacific Fuel only.



CITY OF UNALASKA WATER MASTER PLAN

Figure 21: Captains Bay Road Water Main



6.3.2 Backup Generators for Groundwater Wells

The Unalaska water system has less treated water storage tank capacity than it should. This issue is partially addressed in this master plan with a recommended project to construct a new water storage tank. However, additional storage is still needed in order to meet the recommended long term criteria for emergency storage. According to water utility standards the flow capacity of groundwater wells can be counted toward the required fire or emergency water storage volume if the wells are equipped with backup power systems. None of the groundwater wells in Unalaska are equipped with backup power generators. If the existing Wells 1A, 2, and 3 were equipped with backup power systems, the additional storage capacity realized should adequately address the additional storage needed to meet the long term criteria.

It is recommended that the City install one backup generator system to serve Well 1A and another backup generator system sized to simultaneously serve both Well 2 and Well 3. As an alternative it could also be possible to install only one large generator near Well 2 and Well 3 to power all three wells with a long electrical conduit and cable run to Well 1A. This alternative could be evaluated further in a predesign study. The potential for a new well on Whittern Lane should be considered when sizing generators and weighing alternatives.

Backup generators would be diesel powered packaged units with a sound-attenuating enclosure and an integral fuel tank. The generators would be mounted on concrete pads just outside the well houses. The project would also involve installation of an automatic transfer switch, load bank (if required), various electrical upgrades, and cabling.

The opinion of probable project cost is $600,000 and includes engineering, equipment purchase, construction, and construction administration. This cost is based on 2017 bid results from a similar project to install backup power at the wells in Valdez.

6.3.3 Icy Lake Hydrographic Survey

Icy Lake provides impounded water storage for Unalaska and is used during periods of low water and/or significant demand. The Lake is impounded behind a sheet pile dam at its outlet. Water from the lake is released with a remote controlled valve at the sheet pile dam when needed to fill the Icy Creek Reservoir. The exact volume of the lake is unknown but estimates range from between 52 MG and 61 MG, with a volume of 57 MG at the spillway elevation.

Without accurate bathymetry of the lake bottom, the Utility must estimate stage-storage of the lake in order to know how much available water remains in the lake at any given water surface elevation. If the Utility is overly conservative with the estimate of water remaining, then the result could be premature water rationing, causing negative effects on utility customers, especially the fish processors. If the Utility overestimates how much water remains, then the result could be running out of water sooner than expected. An accurate hydrographic survey of the lake could allow the Utility to precisely determine the available water in the lake and more effectively manage water supplies.

The recommended project is a hydrographic survey of Icy Lake. The survey can be performed either with a small manned boat or a remotely controlled boat equipped with hydrographic survey and GPS equipment. A trailered boat would be challenging to transport to the lake due to the poor road condition. An outboard-powered inflatable boat, cataraft, or small aluminum boat could be feasible to transport to the lake in the back of a pickup.

The remote controlled boat option, called Z-Boat, is available in Alaska from SurvBase, LLC and could be ideal for this application. The boat, shown in Figure 22, is 6 feet long, electric powered, and includes integral survey grade GPS, hydrographic mapping equipment, and data collection systems. For more information about Z-Boat contact John Kerr, PLS, with SurvBase, LLC at 907-338-7878 or John.Kerr@survbase.com or visit http://www.survbase.com/downloads/2014-survbase-hydro-z-boat.pdf.

Figure 22: Z-Boat remote controlled hydrographic survey tool
(image source www.survbase.com)

The survey effort would include a topographic survey of the shoreline and shallow areas around the lake. The hydrographic and topographic survey results would be analyzed by a water resources engineer to determine the precise stage-storage relationship and curve. The stage-storage curve should allow operators to be able to quickly determine the exact volume of available water at various water surface elevations. The stage-storage relationship could also be added to the utility SCADA system so that the SCADA system automatically calculates and displays the volume of available water in the lake in real-time.

The total opinion of probable project cost for the hydrographic survey using the Z-Boat and topographic survey of the shoreline is $45,000. That cost includes $35,000 for surveying, a $ 2,000 budget for water resources engineering support to develop the stage-storage curve, a $2,000 budget for a controls technician to write the code to add the stage-storage calculation to the SCADA system, and a 15% contingency.

6.3.4 Increase Treated Water Storage Capacity

The amount of treated water storage required for the system to meet emergency, fire, and operational storage needs was calculated in Section 4.2.2 and is summarized in Table 11.

Table 15: Total Water Storage Required

Planning Year	Total Water Storage Required (MG)
Current	4.1
Year 2024	4.5
Year 2036	4.8

The existing 2.6 MG Pyramid chlorine contact tank (Pyramid CT Tank) near the Pyramid WTP can only operate at a nearly full level in order to supply North Pacific Fuel. As such, the Pyramid CT Tank has an operating range of only 0.5 MG, which represents the top 8 feet of the 38 foot tall tank. Should a water line be installed along Captains Bay Road to supply North Pacific Fuel, the existing Pyramid CT Tank could then provide an additional 1.5 MG of operational storage.

The total existing water storage available is shown in Table 16 for both scenarios of whether the new Captains Bay Road water line is installed or not. Groundwater well capacity can be included in the treated water storage available if the wells are equipped with backup generators. Currently, none of the wells have backup power; therefore, the wells are not included in the treated water storage values.

Table 16: Existing Water Storage Available

Location	Available Storage (MG), if CBR[1] water line is installed	Available Storage (MG), if CBR[1] water line is NOT installed
Lear Road Tank	0.5	0.5
Pyramid CT Tank	2.0	0.5
Total	2.5	1.0

[1] CBR = Captains Bay Road

Table 17 and Table 18 show how the volume required for a new water storage tank varies by planning year and depending on whether the Captains Bay Road water line is installed or not.

Table 17: New Water Storage Required, if Captains Bay Road water line is installed

Planning Year	Total Water Storage Required (MG)	Available Storage (MG), if CBR[1] water line is installed	New Water Storage Required (MG)
Current	4.1	2.5	1.6
Year 2024	4.5		2.0
Year 2036	4.8		2.3

[1] CBR = Captains Bay Road

Table 18: New Water Storage Required, if Captains Bay Road water line is NOT installed

Planning Year	Total Water Storage Required (MG)	Available Storage (MG), if CBR[1] water line is NOT installed	New Water Storage Required (MG)
Current	4.1	1.0	3.1
Year 2024	4.5		3.5
Year 2036	4.8		3.8

[1] CBR = Captains Bay Road

HDR recommends sizing the new storage tank based on the primary assumption that the Captains Bay Road water line project will happen in the near future. That assumption means that Table 17 will drive the tank size. It is further recommended to use the year 2024 storage requirement for sizing the new tank resulting in a recommended new tank storage capacity of 2.0 MG. If backup power is added to the wells at some point in the future as is recommended in this master plan, then the well capacity can count toward the recommended fire or emergency storage volume, which should more than satisfy the year 2036 storage criteria.

The City has long contemplated resolving the need for additional storage capacity with a second storage tank adjacent to the existing Pyramid tank and WTP. The second tank at the Pyramid WTP was envisioned to enable taking the existing tank offline for draining, cleaning, and maintenance, because it is currently impossible to take the existing tank offline without cutting off water service to North Pacific Fuel and to a lesser extent Westward Seafoods.

Water service to Westward Seafoods can be maintained at limited flow and pressure by back-feeding through the existing Captains Bay water line from the wells in Pressure Zone 3. This supply scenario is not sufficient for fish processing or fire protection while other processors are processing.

In recent CMMPs, the City has scaled back the idea of a second tank at Pyramid WTP but is still considering at a minimum installing a smaller-diameter standpipe tank adjacent to the existing tank in order to enable taking the existing tank offline for maintenance without cutting off water service to North Pacific Fuel.

A second tank of any size at Pyramid WTP is not recommended, because a) it would be a reactionary solution to a short term and infrequent issue; and b) it would do nothing to solve the more important issues of storage imbalance and pressure surge for the distribution system as a whole. A new water main along Captain's Bay Road to North Pacific Fuel offers a more strategic solution to both the North Pacific Fuel water supply issue and the Pyramid CT Tank maintenance issue, while also providing a number of operational flexibility benefits to the whole water system.

HDR recommends locating the new storage tank in Pressure Zone 3 (Town). Pressure Zone 3 covers the largest water demands, has the largest fire flow requirements, includes a groundwater supply well (Well 1A), serves the largest population, and includes a distribution network on Amaknak Island with major processor and industrial customers. However, this pressure zone does not have any water storage.

Well 1A is capable of being controlled automatically based on preset pressure or flow control. Pressure control does not work well because without a storage tank in Pressure Zone 3 the system pressures fluctuate too much. Operators must be vigilant in monitoring system pressure when a well feeds directly into the water distribution system to prevent pressures from becoming too high and causing damage to the system and in-home plumbing. Locating the new tank in Pressure Zone 3 should solve these pressure issues, maximize the operational efficiency of Well 1A, and reduce the short cycling of the Well 1A pump.

To provide a maximum operating pressure of 80 PSI at sea level, the top of tank (maximum water surface elevation) should be located at approximately 185 feet. A 24 foot tall, 2 MG tank with a top elevation of 185 feet would have a base of tank elevation of 161 feet and a diameter of 120 feet. A 35 foot tall, 2 MG tank with a top elevation of 185 feet would have a base of tank elevation of 150 feet and a diameter of 100 feet. A number of locations within Pressure Zone 3 are within this ground elevation range of 150 to 161 feet and are shown in Figure 23 and described below as tank location alternatives. During design it is recommended that the elevation of Nirvana Pump Station and the required suction head of the pumps be taken into account when setting the final elevations of the new tank.

6.3.4.1 Tank Alternative Location 1: Strawberry Hill

Strawberry Hill is located above the East Point Village Area. It consists of a series of roads and open fields dating back to World War II. The elevations in the area range from 150 to 170 feet. There are two locations with elevations to provide adequate pressure to the water system.

6.3.4.1.1 Tank Alternative Location 1a

One pipe routing could continue the 12" ductile iron pipe (DIP) line along Strawberry Hill Road to a suitable tank location using existing roads and clearings for construction. Approximately 750 linear feet of 12" DIP would need to be installed along existing roads. The highest elevation in this area is approximately 150 feet.

6.3.4.1.2 Tank Alternative Location 1b

An alternate location on Strawberry Hill would install a water line along existing roads, meeting the existing water main near East Point Crossing at Bendiksen Road. The elevation of this hill is up to 170 feet so a shorter tank would be desired. This location would require approximately 1,300 linear feet of pipe and improvement of 800 feet of old roadbed for construction access.

6.3.4.2 Tank Alternative Location 2: Above Unisea

Above the Unisea processing plant there is a large hill with possible tank locations at 130 feet and 220 feet ground elevation. Neither location would provide ideal tank pressure without significant earthwork, pumps, or PRVs. Each location would require at least 600 linear feet of piping, much of which would have to be exposed and attached to cliffs. In addition, construction access would be difficult as the terrain is steep with bedrock near or at the surface.

6.3.4.3 Tank Alternative Location 3: Airport

To the north of the airport on the south side of Mt. Ballyhoo, there are possible tank locations at the necessary elevations. These location would most likely involve excavation into the hillside and/or partially burying the tank in order to create sufficient space for a 2 MG tank footprint. There are many existing roads and trails in the area to use for construction and operational access; however, this location would require over 2,000 linear feet of pipe. This tank location would be over a mile straight-line distance from the major water demands of the seafood processors, which could result in high head losses in emergency situations.

6.3.4.4 Tank Alternative Location 4: Little South America

The hill above the Little South America area harbor to the south of the South Channel crossing contains several locations with appropriate elevations. However, these locations would require excavation to provide a flat surface for tank installation and a long distance of pipe to connect to the existing water distribution system.

6.3.4.5 Recommended Water Storage Tank Project and Location

In order to meet the treated water storage requirements, it is recommended that the town install a 2 MG water storage tank in Pressure Zone 3. This tank should allow more flexibility in water distribution management, meet most of the operational and emergency treated water storage requirements, and decrease the risk of water shortages in the case of turbidity spikes or other issues affecting the Pyramid WTP.

The recommended location for a water storage tank is Alternative 1B, on Strawberry Hill above Bendiksen Road. This alternative allows the tank to be built at the proper elevation with minimal excavation, utilizes existing roadbeds, and allows for a shorter tank, which should minimize wind loads. It is recommended to install a 2 MG tank that is 24 feet tall (plus freeboard) and approximately 120 feet in diameter. This location provides a relatively short distance of pipe to existing large diameter transmission mains. All of the new pipe and tank construction access could be along existing roads and trails to minimize impacts and cost. The recommended tank location on Strawberry Hill above Bendiksen Road is on land owned by the Ounalashka Corporation. The City would need to work with the Ounlashka Corporation for property acquisition and easements.

The opinion of probable project cost for a 2 MG tank is $9.24 M and includes sitework, access road improvement, pipe, property acquisition, engineering, construction, construction management, and a 15% construction contingency.

CITY OF UNALASKA WATER MASTER PLAN

Figure 23: Pressure Zone 3 Storage Tank Locations

- Water Mains
- Road Centerlines
- Proposed Tank Locations

N

0 1,250 2,500 Feet

CITY OF UNALASKA INTERNATIONAL PORT OF DUTCH HARBOR 53° 54' N 166°32' W

HDR

6.3.5 East Point Crossing

The existing underwater pipe crossing to Amaknak Island at East Point is a 12-inch ductile iron pipe installed in 1977. The crossing, shown in Figure 24, is approximately 1,000 linear feet including a buried portion of pipe that runs through the Alyeska Seafoods property and under their fish meal plant. Ductile iron pipe in a seawater environment is prone to external corrosion.

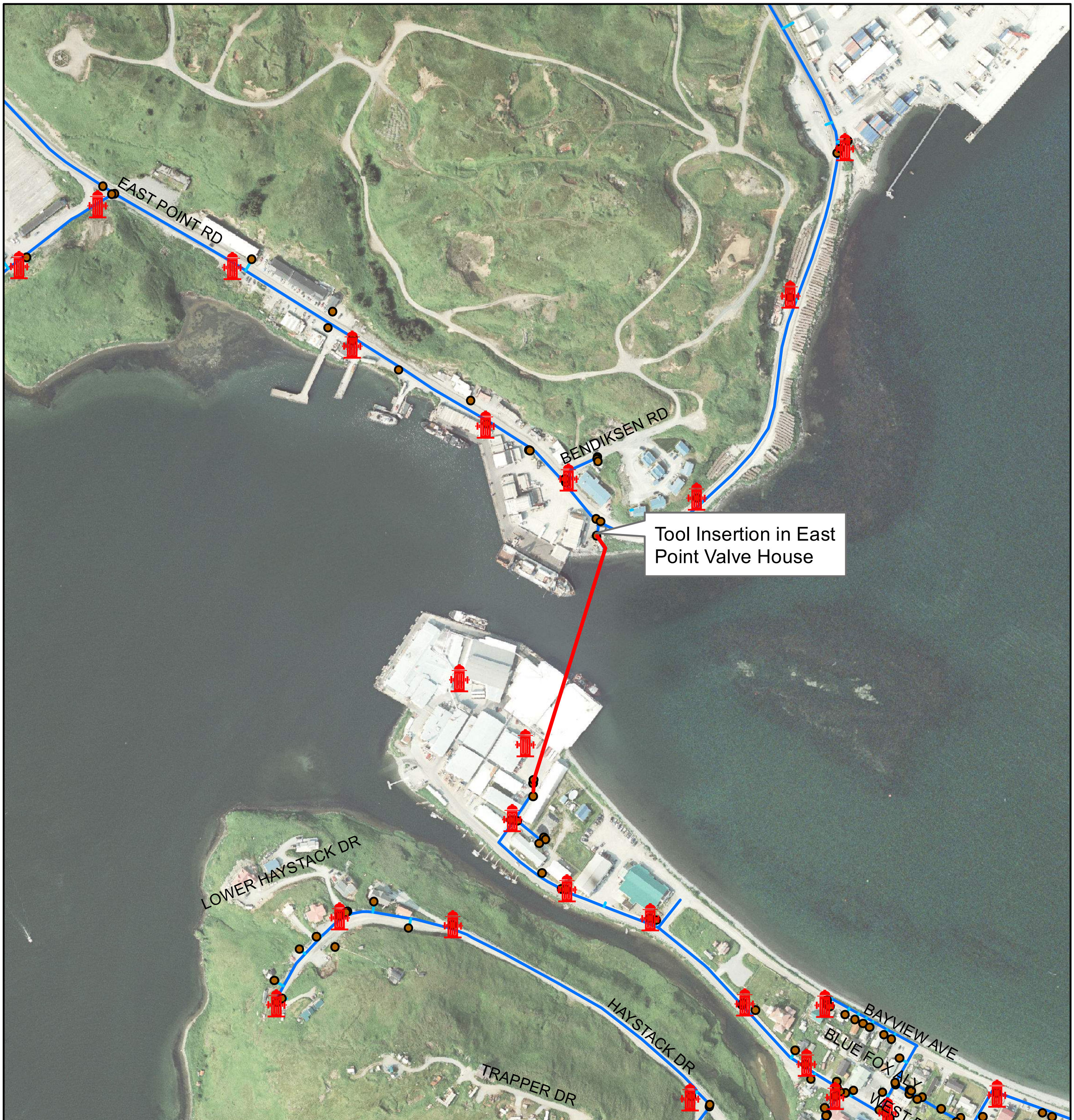
The East Point Crossing pipe is one of only two water system connections to Amaknak Island. Should this pipe ever fail, especially during processing season, the consequences could be a shutdown of all water service to Amaknak Island for a short time until the break can be located and isolated. Flow of water to Amaknak Island could be restricted for a period of at least several weeks while waiting for the pipe to be repaired by divers or a new pipe installed. If the break occurs under the Alyeska Seafoods facility the washout from the flow could cause structural damage to buildings.

Another consequence of a catastrophic break of the East Point Crossing pipe (or any pipe serving a fish processor) is that the resulting increased flows stir up silt in the pipe and flush the silt downstream, which can negatively impact processors. Processors have to throw away any fish product that is exposed to silty water.

Given the criticality, age, and seawater exposure of this pipe, action is recommended to perform condition assessment and/or replace the pipe.

Many non-destructive pipeline condition assessment technologies have been developed in recent decades and these technologies continue to evolve. The platforms vary from non- (or minimally) invasive tools that do not require a tool to be inserted into the pipe, to invasive condition assessment tools that must be inserted into a flowing pipe. Technologies include a variety of video, acoustic, and electromagnetic sensor arrays. Some systems combine multiple types of technologies into one tool. Many systems are capable of performing precise leak and air pocket detection. A few systems are capable of measuring the approximate percentage of pipe wall thickness remaining, termed “pipe wall condition assessment” or “pipe wall integrity testing”, and detecting flaws or anomalies in the pipe wall (pits, unknown service taps, etc.).

Key factors in identifying applicable technologies for the Unalaska East Point Crossing application are pipe type (ductile iron), pipe diameter (12-inch), the fact that the pipe carries water, the fact that the pipe is not readily accessible for much of its length (being under Alyeska Seafoods and underwater), and the desire to minimize the length of time that the pipe must be taken out of service. Condition assessment options were discussed and vetted with HDR specialists who often collaborate with technology vendors on projects and research efforts. HDR also contacted several of the primary technology vendors in the pressure water pipe condition assessment market, described the Unalaska application to the vendors, and identified the following alternatives.



CITY OF UNALASKA WATER MASTER PLAN

Figure 24: East Point Crossing Condition Assessment

Fire Hydrants

Water Mains

Water System Valves

Pipe Segment to be Inspected

0 375 750 Feet

6.3.5.1 Alternative 1 – Perform Non Invasive Pipe Condition Assessment

Echologics "ePulse" technology, shown in Figure 25, involves attaching acoustic sensors to fire hydrants, valves, or directly to the pipe at a known spacing along a pipe segment. A noise (such as a blow from a hammer) is generated at one end of the pipe segment and the strength and speed of the sound waves passing through the pipe are recorded by the acoustic sensors. ePulse computer programs analyze the data and report the estimated average pipe stiffness for the segment of pipe.

Pipe stiffness can yield estimates of remaining effective pipe wall thickness. Comparing estimated remaining pipe wall thickness to the original pipe wall thickness provides an estimate of how much the pipe has deteriorated in 41 years of service. That rate of deterioration can be extrapolated to estimate the remaining useful life of the pipe. This technology can also locate pipe leaks and gas pockets, but is not capable of locating localized flaws in the pipe wall.

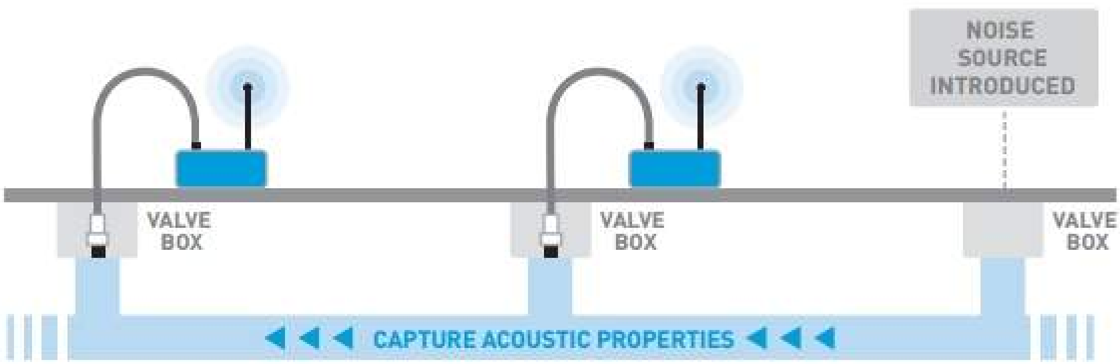


Figure 25: Echologics ePulse®
(image source www.echologics.com)

The ideal spacing of the sensors is 300 feet. Although there have been successful applications with sensor spacing of over 900 feet, the accuracy of the results decreases and the likelihood of error from external noise sources increases. Since ePulse reports the average wall thickness over the entire segment of pipe, a greater spacing between sensors means lower resolution of results.

For the East Point Crossing it would be necessary to excavate the pipe just outside the water's edge to minimize the sensor spacing to about 550 feet, which still further than ideal. This could also require an excavation under one of Alyeska Seafoods' buildings. Underwater installation of a sensor to the outside of a pipe by a diver is not possible.

In an underwater pipe application ePulse could also be susceptible to acoustic interference from boat propeller noise and other industrial/harbor area noises. Also, for best results Echologics recommends testing be performed on a pipe while it is pressurized, but with minimal flow – a potentially difficult scenario to achieve.

Echologics' minimum deployment cost for up to 2 miles of pipe condition assessment with ePulse is $60,000. Factoring in additional mobilization of the technology to a remote Alaska location and the costs associated with logistics, engineering assistance, and excavating down to the pipe for sensor attachment, a total cost of $120,000 is estimated for the use of ePulse at the East Point Crossing.

Echologics contact: Corey Keefer, 760-607-2333, ckeefer@echologics.com

6.3.5.2 Alternative 2 – Perform Invasive Pipe Condition Assessment

PICA Corporation's See Snake system, shown in Figure 26 and Figure 27, is the only insertion-type tool that HDR was able to identify that offers pipe wall condition assessment capability in a 12-inch pipe application. See Snake is a device that uses an electromagnetic Remote Field Technology to measure wall thickness and detect internal and external flaws as it moves through a pipe. See Snake can also detect and locate external stress on a pipe due to soil movement, bridging, inadequate support, rippling, or denting.

Figure 26: PICA Corporation See Snake pipe condition assessment tool
(image source www.picacorp.com)

The tool is pushed through the pipe by the flow of water. The articulating mechanical design of See Snake can accommodate inside diameter variations, bends, tees, and fittings. See Snake can be either tethered for applications up 3,000 feet or free-swimming up to 20 miles. Data is stored in onboard memory that is downloaded after retrieval and can be processed immediately after.

See Snake should not be affected by boat propeller or other underwater harbor area noises.

See Snake provides high-resolution results that are precisely located along a segment of pipe, rather than being averaged over the entire segment of pipe. However, this high quality data comes at the price of having to excavate and tap the pipe for tool insertion. The East Point Crossing application would likely use the tethered tool to avoid having to install a separate tool retrieval port. The tool could be launched and pulled back through the same insertion port. The pipe can remain in service during the test.

Figure 27: PICA Corporation See Snake and tool insertion port
(image source www.picacorp.com)

PICA Corporation's minimum cost for See Snake use is approximately $60,000 plus a mobilization cost that is conservatively estimated at $40,000 to Unalaska (versus a typical See Snake mobilization cost in the lower 48 of $20,000). Factoring in additional costs associated with logistics, engineering assistance, excavating down to the pipe, and installation of the insertion port, a total cost of $150,000 is estimated for the use of See Snake at the East Point Crossing.

PICA Corporation contact: Chris Garrett, 704-236-3771, cgarrett@picacorp.com

6.3.5.3 Alternative 3 – Replace Pipe

Replacing the East Point Crossing with a new pipe should improve hydraulics and eliminate the concern about age/corrosion-related failure of this critical piece of infrastructure for many years. Under this alternative the crossing would be replaced with a new pipe preferably of a corrosion resistant material and in a slightly different location so that the existing pipe can remain in service until the new pipe is operation. An ideal choice for submarine pipelines in seawater is high-density polyethylene (HDPE) pipe due to the durability, flexibility, corrosion resistance, and light weight properties of this material. In this underwater HDPE pressure pipe application a sidewall to diameter ratio (SDR) of 11 is recommended for a 160 PSI pressure rating and for constructability reasons.

The new pipe should be upsized at a minimum to match the inside diameter of the upstream 16-inch ductile iron pipe to which it connects along West Broadway Avenue. A 16-inch Class 52 ductile iron pipe has an inside diameter of 16.80 inches. To approximately match that inside diameter an SDR 11 HDPE pipe would need to be 20-inch nominal diameter for an inside diameter of 16.22 inches. The next larger commonly available HDPE SDR 11 pipe size would be 24-inch nominal diameter with an inside diameter of 19.46 inches. An engineering hydraulic design analysis should be performed to verify the appropriate pipe size.

Ideally, the new pipe would be routed so that it is not under any buildings. There is an existing 16-inch spur pipe along Cathedral Way one block southeast of Alyeska Seafoods. The end of that pipe is a potential connection point at the south end of the new crossing. This connection point is already in close proximity to the shoreline, is in a public right-of-way, and is not obstructed by any buildings. The connection point at the north end of the new crossing should be moved into the existing utility easement approximately 235 feet to the east which would also reduce the length of the submarine pipe.

The total length of new pipe would be approximately 1,250 feet including the short segment of pipe that is buried on land at each end. The submarine pipe would be trenched into the sea floor to prevent accidental damage from dragging anchors. The submarine pipe would also need to be anchored with specially designed concrete blocks to resist buoyancy.

At an assumed unit price of $1,000 per foot for construction, the opinion of probable construction cost for a new pipe is $1,250,000. With an additional 20% for survey, engineering, permitting, and construction management and an additional 25% for contingency, the total opinion of probable project cost is $1,812,500.

6.3.5.4 East Point Crossing Recommended Project

It is recommended that the City pursue Alternative 2 – Invasive Pipe Condition Assessment with See Snake or a similar device to determine the anticipated remaining life of the East Point Crossing pipe. That information should allow the City to plan an appropriate strategy to reassess the condition or replace the pipe at a future date.

Due to the significant mobilization costs of getting a specialized technology such as See Snake out to Unalaska, it is recommended that the City identify other critical pipes they would like to have inspected in order to take advantage of economy of volume. Another critical pipe to have inspected in the same mobilization would be the 24-inch South Channel Crossing pipe for similar reasons as the East Point Crossing pipe. There is also the possibility of using a free-swimming See Snake and running it over a longer distance of pipe on both sides of East Point Crossing in order to maximize value as long as there aren’t any butterfly valves to obstruct the tool.

Due to the difficult access to the pipe for launching and retrieval of a tool on Alyeska Seafoods property, it may be advantageous to attempt changing the direction of flow through the pipe and launching and retrieving the tool from the north side of the crossing.

Alternative 1 – Non Invasive Condition Assessment (acoustic method) is not recommended due to the potential incompatibilities with a submarine application and the low resolution of the results that could be yielded.

Alternative 3 – Replace Pipe is not recommended because to date there have been no known breaks or leaks in the pipe and based on the age of the pipe alone it could be premature to replace it at the considerable capital cost involved.

6.3.6 Water Meter Installation

The City of Unalaska Water System contains a combination of metered service connections and unmetered service connections. All new service connections are installed with meters and there has been an ongoing effort over recent years to install meters on all existing unmetered services. As of April 2018 there were 597 total water services, 306 of which are already metered and 291 which are unmetered. Most large diameter water services and most high water demand customers are metered. The unmetered services are predominately residential or small commercial users.

With a large number of unmetered water service connections, it is impossible to know how much water is actually used and it is difficult to determine the extent of water leakage and unaccounted water usage. Residential water use figures from unmetered water service connections are all estimates based on a crude assumption of 200 gallons per day per service. Without meter data, it is difficult to determine the extent and locations of pipe leaks or to find previously unidentified high-water users. A large portion of total water usage is classified as unaccounted. Accurate water usage data could allow the Utility to effectively reduce this unaccounted for water.

The recommended project is to phase in the installation of water meters on remaining unmetered services over a 5 year period. Installation of water meters should allow for accurate water billing, provide incentives for water conservation, and assist with the detection of leaks and the large amount of unaccounted water use in the system.

The cost of each meter installed is estimated at $600 and includes $175 for a ¾-inch meter, $155 for the radio, $30 for the tail-ways (per pair), $40 for adapters and hangers, and $200 for installation labor. At the unit cost of $600 per meter installed, the total opinion of probable project capital cost to install all 291 meters is $210,000 and includes a 20% contingency.

6.3.7 Icy Lake Capacity Increase and Snow Basin Diversion

Icy Lake provides impounded water storage for Unalaska and is used during periods of low precipitation or during significant demand. The Lake is impounded behind a sheet pile dam at its outlet as shown in Figure 28. Water from the lake is released with a remotely controlled valve at the sheet pile dam when needed to fill the Icy Creek Reservoir. The exact volume of the lake is unknown but estimates of live storage (above the intake elevation of 715) range from between 52 and 61 MG, with a volume of 57 MG at the spillway elevation. There have been instances where a lack of water in Icy Lake has caused difficulty in meeting demand during periods of high seafood processing activity and dry weather or when the level in Icy Lake is low enough to allow wave action to create high turbidity.

Figure 28: Icy Lake north sheet pile dam and spillway

Water system operators use the lake to “bank” surplus water between processing seasons when demand is low, with the intent that by the beginning of a processing season the utility is starting out with a full lake. During heavy processing the lake level gradually drops as demands exceed the combined capacity of Icy Creek and the wells and operators release lake water into Icy Creek. This operational strategy has been stressed in recent years when dry weather coincides with processing seasons and the lake is drawn nearly empty. If the lake is run empty and the water system is not able to meet demands, then the result would be water rationing and having to reduce fish processing throughput or diverting fish to processors in other communities.

Additional raw water storage capacity at Icy Lake would be beneficial to help span processing seasons that occur during the more prolonged and frequent dry weather periods.

A 1994 Icy Lake Feasibility Study by Golder and Associates (Golder) estimated water storage could be increased by approximately 30 MG by raising the north dam height five feet and increasing the length to 98 feet from the existing 67 feet and building a new six-foot high approximately 150 foot long dam on the south side of the lake (see Figure 29). Golder performed additional work on this topic in 2006 with a letter report titled “Cost Estimate for Raising Icy Lake Dam”.

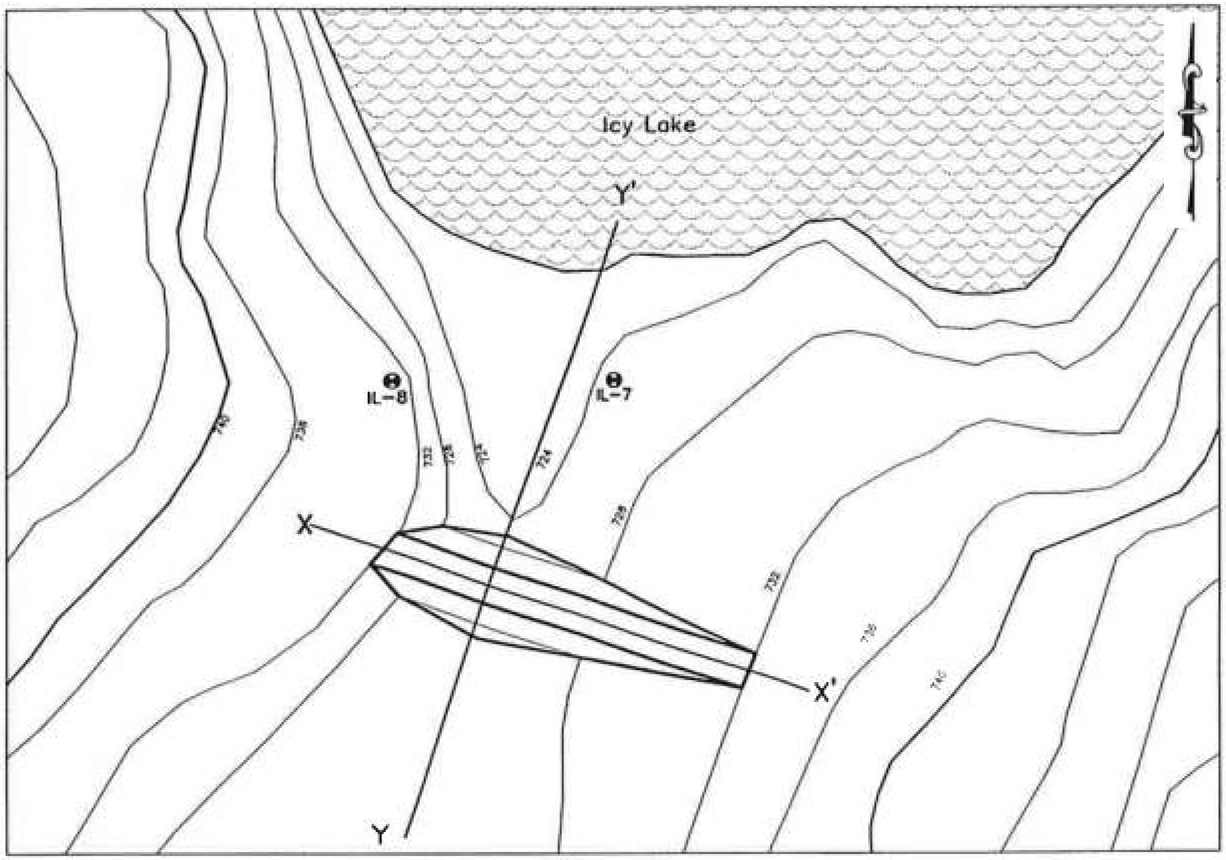


Figure 29: Proposed six-foot high dam at south end of Icy Lake
(image source Golder Associates, Icy Lake Feasibility Study, 1994)

It is recommended that the City increase the height of the existing dam on the north side of Icy Lake and construct a new dam on the south end of Icy Lake. As described in the 2006 Golder letter the project includes the following:

- The existing sheet pile dam at the north end of the lake would be raised 5 feet and the dam length increased from 67 to 98 feet.
- A new sheet pile dam, approximately 6 feet tall by 193 feet long would be built at the south end of the lake.
- Additional grading and riprap would be required for a larger spillway apron at the north dam.
- Riprap would be required for wave erosion protection of the south dam.
- Grouting at the north and south dams would be required to seal fractured bedrock.
- The lake level could be reduced to 715 feet to facilitate contractor access to the south end of the lake.

Increasing the size of the watershed so that more runoff is available to fill the lake is equally important as the need to increase lake storage capacity. At its current size, the lake already has ample capacity to store the rainwater runoff from its small watershed. However, as the City experiences more frequent winters with low snowpack in the mountains, there is less runoff available in the Icy Lake watershed in late spring and summer to meet the high water demands of “B” season fish processing. There are times when the water level in Icy Lake has dropped to within several days of running out of water.

An additional source of water, especially snowpack runoff, into the Lake should provide the additional flow needed to fill the increased lake storage volume. A diversion of runoff from the nearby Snow Basin could provide the additional watershed needed to fill the lake.

The outlet of Snow Basin is approximately 2,000 feet to the east of Icy Lake. Runoff from Snow Basin flows through a narrow gorge below the upper cirque and flows into Icy Creek above the Icy Creek Reservoir but below the Icy Lake Dam. In times of high customer demand and low runoff, flow from Snow Basin can be captured in the Icy Creek Reservoir and used for treated water production. However, in times of low demand and high runoff when water is overtopping the Icy Creek Reservoir dam and when operators are trying to “bank” water in Icy Lake for an upcoming processing season, the flow from Snow Basin is wasted over the Icy Creek Reservoir dam.

A Snow Basin diversion system would capture the flow from Snow Basin and send the water to Icy Lake for storage, effectively increasing the Icy Lake drainage area. This project would install a diversion structure and diversion pipeline to divert flow from the Snow Basin into Icy Lake. Runoff from Snow Basin enters a 30 foot wide by 50 to 80 foot deep gorge, where an appropriate diversion structure could be located. A 1994 Feasibility Study of Icy Lake by Golder Associates described a possible alignment and location for the diversion pipeline, which would extend approximately 2,000 feet from the diversion structure to an outlet in Icy Lake.

This diversion should allow more water to be stored in the lake in times of low water use rather than overflowing the dam at the Icy Creek Reservoir. A surface water runoff calculation should be done in conjunction with the design of the diversion system to adequately size the diversion system as well as provide a planning estimate of the amount of water operators can expect to be diverted into Icy Lake.

To reiterate, the Icy Lake Capacity Increase project offers little value unless completed in conjunction with the Snow Basin Diversion project, and vice-versa.

A Golder Associates 2006 letter report titled “Cost Estimate for Raising Icy Lake Dam” estimated the cost of raising the Icy Lake Dam and construction of the Snow Basin diversion and pipeline at $1.653 M and $810,000, respectively. These figures included engineering, construction management, survey, permitting, and a 20% construction contingency. Escalating these costs for inflation by 2.5% annually results in a 2018 opinion of probable project costs of $2.22 M for raising Icy Lake and $1.09 M for Snow Basin diversion. The combined total opinion of probable cost for both projects is $3.31 M.

The additional raw water supply and storage created should allow more flexibility in the operation of the Icy Lake / Icy Creek Reservoir system. The additional water stored could also provide a buffer against periods of low precipitation and high demand, reducing the risk of water shortages, rationing, and economic impact from the resulting decreased fish processing through-put.

If the Icy Lake dam and Snow Basin diversion projects move into design and construction, then the City should use the opportunity to improve road access to the lake and to extend grid power to the valve station at a potentially discounted cost since a contractor will need to improve access for construction anyhow. Also, the construction of additional solar panels to power the Icy Creek Dam could be combined with this project.

6.3.8 Increase Groundwater Supply

The current groundwater supply is from a wellfield in the Iliuliuk Valley and includes three wells operating with a maximum production of approximately 4 MGD. The wells are operated by the City to provide water to meet peak demands or when the Icy Creek surface water is not available due to low water yield or high turbidity.

While the current groundwater production can meet the projected year 2036 average daily demands, it cannot meet the current peak day demand of 7.61 MGD. Additionally, there is no redundancy in the groundwater system. In the event of an upset to operating conditions (pump failure, well failure, controls failure, power outage, etc.) the affected well(s) could be offline until the upset condition is remedied. In the event of a well or pump failure this outage could last weeks. If one of these scenarios occurs during a peak day demand or when Icy Creek water is not available, then the result would be water rationing and likely decreased through put or shutdown of seafood processing.

6.3.8.1 Alternative 1: Install a New Well in the Iliuliuk Valley

An additional well in the Iliuliuk Valley could provide additional groundwater capacity as well as redundancy for the current wellfield. The safe yield of the Iliuliuk Valley is unknown and is expected to vary based on climatic conditions. A prior study (H4M Corporation *Iliuliuk River Valley, Groundwater Resource*, 1993) estimated the safe yield of the Iliuliuk Valley at 6 MGD. The variation in the Iliuliuk Valley safe yield varies with recharge (primarily precipitation) and likely mimics the changes in surface water availability from Icy Creek.

A potential new well site near the end of Whittern Lane has been studied. This location has the advantage of being close to existing infrastructure and should only require about 1,200 feet of water main installation to be connected into the distribution system. It is anticipated that a well constructed at this location could produce between 1.4 and 2.0 MGD. Even if the safe yield of the valley limits production from this well, it could serve as an important backup to maintain uninterrupted groundwater production in the event of a well or pump failure at one of the other wells. It could also be used to meet firefighting flows instead of tank storage, if the well is equipped with backup power.

6.3.8.2 Alternative 2: Install a New Well in the Shaishnikoff Valley

The results of a 2014 geophysical survey by Shannon & Wilson indicate that subsurface conditions in the Shaishnikoff Valley are likely similar to the Iliuliuk Valley. In general, bedrock was encountered at depths around 40 feet below ground surface (bgs). However, one of the geophysical lines encountered an area where the depth to bedrock appeared to be on the order of 100 feet bgs. This could be an area of weathered or sheared bedrock that may be able to produce significant quantities of groundwater if the feature extends across the valley. Assuming a well installed in this feature would behave similar to wells operated in Iliuliuk Valley, an estimated 1 to 2 MGD of groundwater may be available. Any groundwater wells installed in the Shaishnikoff

Valley could have a potential to capture surface water and should be evaluated for GWUDISW as well as the potential for saltwater intrusion.

Challenges to developing a groundwater source in the Shaishnikoff Valley include private ownership of the land (private individuals and Ounalashka Corporation) and being approximately 2.5 miles from the existing distribution system.

While the geophysical study of Shaishnikoff Valley is important information to consider in future water supply decisions, the high capital costs for the access roads and pipe to reach Shaishnikoff Valley make that alternative less economically attractive in comparison to Iliuliuk Valley, even if the safe yield of Iliuliuk Valley is in question. Further study of Shaishnikoff Valley water resources is not recommended within this master planning period unless Iliuliuk Valley is ruled out as a potential for additional water supply in future safe yield tests.

6.3.8.3 Recommended Groundwater Supply Project

The recommended project is a new well in Iliuliuk Valley. A new well in Iliuliuk Valley could be used to increase short-term production and potentially long-term production with additional studies on the safe yield of the aquifer. Additionally, another well in the Iliuliuk Valley could serve as an important backup groundwater source in the event of a disruption to one of the existing wells. The preferred location of a new well in Iliuliuk Valley is near the end of Whittern Lane.

The estimated costs of additional studies to evaluate the safe yield of the Iliuliuk Valley aquifer are estimated at $150,000. The opinion of probable project cost to install a production well of a similar capacity to Well 3 is $1.6 M and includes land acquisition, drilling a production well, the production pump, controls, gas chlorine systems, backup generator system, a building, a pipe connection to the existing distribution system, a 25% construction contingency, and 20% for engineering, permitting, and construction administration. It is important to note that approximately half of the cost of drilling the well is the mobilization of the rig and equipment. If a rig is mobilized to Unalaska the City should consider having replacement wells drilled for the older, existing wells, even if they will not be put into production in the near future.

6.3.9 Meter and Booster Pump at Agnes Beach PRV Station

The Agnes Beach PRV station drops the pressure of water from Pressure Zone 2 (Captains Bay Road) to Pressure Zone 3 (Town) hydraulic grade. The station also allows for water to flow to the higher elevation areas of Haystack Hill with an option to allow external boosting in the event of a fire demand on Haystack Hill. The current PRV set up does not allow any method of measuring water flow through the station and severely limits the ability to reverse flow from the wells in Pressure Zone 3 to Westward Seafoods (Pressure Zone 2) in the event of a shutdown of the Pyramid WTP due to, for example, high turbidity.

The recommended project would add water metering and a booster pump system at the Agnes Beach PRV station. Improved water metering should aid in leak detection, and utility management and understanding of where water is being used and when. The booster pump should provide water supply redundancy to Westward Seafoods, one of the largest customers in the water system, as well as redundancy to any further development along Captain’s Bay Road.

The opinion of probable capital project cost for water metering and a booster pump system at the Agnes Beach PRV station is $300,000. This cost assumes that there is sufficient space available in the existing building, retrofit of the existing piping is minimal, and the existing electrical system has the capacity to power the new equipment. This cost also includes about $50,000 for a hydraulic study to explore all of the different operational scenarios and hydraulic improvements that could be achieved with upgrades to the Agnes Beach PRV station.

6.3.10 Sediment Traps between Icy Lake and Icy Creek Reservoir

Large amounts of rock and sediment move downstream along Icy Creek during high flow events. The rocks accumulate at the inlet end of the Icy Creek Reservoir as seen in Figure 30 and heavier sediment accumulates behind the dam. The rocks and sediment reduce the capacity of the reservoir. Draining of the reservoir and removal of rocks and sediment is a challenging exercise that is required periodically and also requires a lengthy shutdown of the Pyramid WTP. Turbidity issues due to suspended fine-grained sediments during high flow events also regularly cause shutdown of the Pyramid WTP.

Figure 30: Gravel bar that has accumulated at inlet end of Icy Creek Reservoir

The recommended solution is to construct one or more sediment traps in Icy Creek upstream of the reservoir. The sediment trap system should essentially be a series of deep, wide step pools with rock check dams along the creek that decrease the flow velocity and allow rocks and sediment to settle out. The sediment traps should also create a location for rocks and sediment to accumulate that would be easier for heavy equipment to access, easier to clean out, and potentially allow the reservoir and Pyramid WTP to remain in service while the sediment traps are being cleaned. Although the sediment traps will not eliminate shutdown of the Pyramid WTP due to turbidity spikes during high flow events, it could reduce the occurrence and duration of shutdowns.

The rough order of magnitude opinion of probable project cost for the sediment trap is $500,000 and includes property acquisition, a construction contingency, engineering, permitting, and construction management. This project could be paired with other civil projects proposed in the Icy Creek watershed such as raising the Icy Lake dam or improving the Icy lake access road. Combining these projects could help lower the overall costs of all of the work. The City would need to work with the Ounalashka Corporation, the current land owner, to purchase the property where the sediment traps would be constructed as well as the location where rocks and sediment from the traps would be disposed of. This material could be used for upgrades to the Icy Lake access road.

6.3.11 Raven Way Water Main Extension

Several property owners along Raven Way on Haystack Hill have installed long service lines in the City's street right-of-way in order to obtain City water and sewer service. There are currently two lots that contain one business and three residential units that are adjacent to the proposed Raven Way Water Main Extension area. The City has already approved one subdivision on one lot that does not meet the City Ordinance requirement for a maximum 300 foot distance to the City's water main. There is the potential for subdivisions to produce an additional four lots along the extension area. These subdivisions could create two more residential units and produce one more lot that would be out of compliance with City Ordinance.

As a result of this development there could be eight water service lines with a length between 150 and 560 feet within the right-of-way and 8 service connections within a 50 foot section of water main. The furthest distance to the closest hydrant is approximately 550 feet. This could also place eight sewer services within the same right-of-way.

Within the City water utility service area, it is desirable to have all buildings served by the City water system from water mains that are adjacent to the served lot. This ensures compliance with water utility tariff requirements, opens up additional lots for development, promotes safe drinking water, and increases fire protection for the area.

The recommended project is to extend a water main along Raven Way to provide appropriate water service and fire protection to the already served lots and the developable lots. The water main should be installed in cooperation with the wastewater utility to allow for simultaneous construction of utility lines. The project would include approximately 550 feet of new 8-inch ductile iron water main in the Raven Way right-of-way and one new fire hydrant.

The opinion of probable project capital cost is $308,000 and includes 20% for surveying, engineering and construction management, and a 20% construction contingency.

6.3.12 Biorka Drive Cast Iron Waterline Replacement

Most of Unalaska's water mains are ductile iron pipe installed between 1988 and the mid 1990s. Small portions of pipe are made of older, less resilient materials. Approximately 600 linear feet of 8-inch water line along Biorka Drive consists of cast iron pipe that was installed in the 1940s – the last section of cast iron pipe in Unalaska's water system. This segment of pipe, as shown in Figure 31, has experienced breaks in the past.

Cast iron is a brittle material that is also susceptible to corrosion. Cast iron pipe often fails catastrophically when subjected to excessive pressure surge or ground movement. Pipe failure becomes more frequent with a cast iron pipe as it ages and loses wall thickness to corrosion. Emergency repairs after an unexpected catastrophic pipe failure are usually many times more expensive than proactive pipe replacement due to incidental damage, overtime, lack of in-stock repair materials, and general disruption of utility operations. Preventative replacement of pipes with high failure risks is a good practice in order to avoid the more costly emergency repair situation brought by a pipe failure.

It is recommended that the City replace the cast iron pipe segment under Biorka Drive with ductile iron. HDR understands from the City that the replacement of this pipe was designed already by Regan Engineering, but the project was dropped when paving of Biorka Drive, which was the driving factor, was shelved. If the City has an opportunity to inspect the existing pipe while installing a service connection or performing a repair, it is recommended that the condition of the pipe be carefully documented. Pipe condition information is helpful to determine when to schedule replacement and how to prioritize the project with other capital needs. The best scenario is that the pipe is already leaking moderately and that the leakage rate increases gradually without leading to a sudden pipe failure.

The opinion of probable capital cost to replace 600 linear feet of pipe with new 12-inch ductile iron is $354,000 and includes the following:

- 600 linear feet of 12-inch pipe at $450 per linear foot including surface restoration: $270,000
- Reconnection of 1 one-inch service connection at $2,000 each: $2,000
- Subtotal of above items: $272,000
- Construction management, 10% of subtotal: $27,200
- Contingency, 20% of subtotal: $54,400

While this project is not a priority, if the City decides to pave the currently unpaved portion of Biorka Drive, then the water main replacement should be combined with the paving project.

CITY OF UNALASKA WATER MASTER PLAN

Figure 31: Biorka Drive Cast Iron Waterline

Water Main Material

Cast Iron Pipe

Ductile Iron Pipe

0 250 500 Feet

CITY OF UNALASKA
INTERNATIONAL PORT OF DUTCH HARBOR
53° 54' N 166°32' W

HDR

6.3.13 Icy Lake Road and Power

Safe access to the Icy Lake valve and monitoring station is often difficult and sometimes impossible. Operator access to the station is required periodically for routine maintenance, to replenish fuel, and make repairs. Many creek crossings require a high clearance off-road 4-wheel drive vehicle. Deep snow often precludes the use of wheeled vehicles and operators use snow machines instead. If there is enough snow to close the road but not enough to make the gullies passable by snow machine then the only other option is to walk in on foot. This has been done a few times in the past.

The station is solely reliant on off-the-grid electrical systems. Currently the station is powered by a single array of solar panels and a backup propane thermoelectric generator (TEG), both of which charge a battery system. This electrical system is insufficient to meet the electrical needs of the station at times when valve operation is frequent. Wind turbine installations in the area have been unsuccessful due to high winds that physically destroyed the turbines.

The Utility requested that this master plan consider a project to construct a graded access road on the east side of Icy creek from Icy Creek Reservoir to Icy Lake. During the construction of the road, grid power should also be installed to provide reliable electricity to the Icy Lake valve and monitoring station. This project could eliminate the existing off-road access to Icy Lake as well as the need for solar power and TEG at the valve station.

It is not recommended that the City pursue a road and power to Icy Lake as a standalone project during this planning period. Although installation of a road should make access easier and safer, and installation of grid power should improve reliability of the valve station, the high capital cost for and limited use of the infrastructure is difficult to justify. There are other less expensive projects considered in this master plan that should alleviate concerns about the inadequate electrical system and potentially reduce the number of maintenance and refueling visits to the station.

If the Utility had to choose between road improvements or extending grid power to the Icy Lake, extending power should provide better value. If the valve station had reliable grid power, then the need to visit the valve station should decrease; and therefore, the need for road improvements should decrease as well.

Other proposed projects in the Icy Lake drainage including the Snow Basin diversion project and the project to increase Icy Lake capacity would require movement of a large amount of construction materials and equipment to Icy Lake. If either of those projects were to move forward, then the feasibility of and need for a better access road to Icy Lake changes. The contractor would need a suitable road for construction access and the dam and diversion projects could use some of the same pieces of construction equipment. These factors could result in the City obtaining Icy Lake access road improvements at a discount and is something that should be considered during planning of the Icy Lake dam and/or Snow Basin diversion projects.

6.4 Capital Project Prioritization Plan

An effective project evaluation methodology provides a basis for recommending the a logical prioritization strategy for executing numerous projects over the planning period. Each project is scored using the following seven categories and definitions. Not all categories are applicable to all projects, but a "not applicable" or "N/A" score does not count against a project's total score. If a project has a detrimental impact on any category, it is rated a zero.

Level of Service

5 Major Improvement – The project provides a major improvement in service level, and/or has rapid economic payback (7 years is ideal).
3 Moderate Improvement – The project improves service level, but project payback is long term (past the planning period).
1 Maintains Current Level – The project only prevents service level from degrading.

System Capacity

5 Significant capacity increase
3 Moderate capacity increase
1 Little to no capacity increase

Modernization

5 Significant system modernization
3 Moderate system modernization
1 Little to no system modernization

System Failure Criticality

5 The project solves a point of failure for a critical asset or component that would otherwise result in significant impacts to large portions of the water system and no workarounds exists that could mitigate the impacts if the project is never done.
3 The project solves a point of failure for an asset or component that would otherwise result in impacts to portions of the water system; but at least one workaround exists that could mitigate the impacts if the project is never done.
1 There are few points of failure that the project would solve; or failure will cause little to no impact on the water system if the project is never done.

Resource Efficiency

5 Reduces energy/resource demands and increases energy/resource efficiency in the system
3 Reduces energy/resource demands or increases energy/resource efficiency in the system
1 Little to no reduction of energy/resource demands or increase in efficiency

Regulatory, Health, and Safety Compliance

5 Large impact on regulatory, health, or safety compliance issues
3 Moderate impact on regulatory, health, or safety compliance issues
1 Little to no impact on regulatory, health, or safety compliance issues

Cost and Benefit

5 Low cost and high benefit
3 Low cost and moderate benefit or high cost and high benefit
1 High cost and moderate or limited benefit

Table 19: Capital Project Scoring and Prioritization Matrix

Project Name	Level Of Service	System Capacity	Modernization	System Failure Criticality	Resource Efficiency	Regulatory, Health, and Safety	Cost and Benefit	Sum	Average Score
Pyramid WTP Micro-Hydroelectric Generation	5	N/A	4	N/A	5	N/A	4	18	4.5
Captains Bay Road Water Main	5	5	4	5	N/A	4	3	26	4.3
Additional Solar Panels for Icy Lake Valve Station	4	N/A	4	3	3	5	5	24	4.0
Backup Generators for Groundwater Wells	4	4	4	4	N/A	3	5	24	4.0
Icy Lake Hydrographic Survey	N/A	3	4	N/A	3	N/A	5	15	3.8
Increase Treated Water Storage Capacity	4	5	3	4	N/A	4	3	23	3.8
UPCH Automated Controls	4	N/A	5	N/A	2	N/A	4	15	3.8
East Point Crossing	3	N/A	4	5	N/A	2	4	18	3.6
Meter Reading System	3	N/A	5	N/A	4	N/A	2	14	3.5
Water Meter Installation	4	N/A	4	N/A	4	N/A	2	14	3.5
Icy Lake Capacity Increase & Snow Basin Diversion	3	5	N/A	3	N/A	2	4	17	3.4
General Hill Water Pressure	3	3	N/A	N/A	2	5	3	16	3.2
Increase Groundwater Supply	3	4	N/A	3	N/A	2	3	15	3.0
Meter and Booster Pump at Agnes Beach PRV Station	4	3	3	3	2	2	4	21	3.0
Public Watering Points	2	N/A	3	2	3	4	2	16	2.7
Sediment Traps Between Icy Lake and Icy Creek Reservoir	3	3	N/A	3	2	N/A	2	13	2.6
Raven Way Water Main Extension	2	1	2	1	N/A	4	3	13	2.2
Biorka Drive Cast Iron Waterline Replacement	1	1	4	1	N/A	1	3	11	1.8

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