Public

City of Kenai Water System Feasibility Study

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Alaska LNG
3201 C Street, Suite 200
Anchorage, Alaska 99503
T: 907-330-6300
www.alaska-lng.com

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0	Dec 29, 2017	For Use	Nelson Engineering P.C.		Fritz Krusen
Approver Signature*	Herlee P. Krusen				

*This signature approves the most recent version of this document.

MODIFICATION HISTORY

Rev	Section	Modification

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ACRONYMS AND ABBREVIATIONS

$ .... U.S. Dollars
AGDC .... Alaska Gasline Development Corporation
AVG .... average
COK .... City of Kenai
ft .... feet / foot
gpm .... gallons per minute
hp .... horsepower
in .... inch
k .... thousand
LF .... linear feet
LNG .... liquefied natural gas
m .... million (U.S. Dollars)
MCL .... Maximum Containment Level
mg .... million gallon
mgd .... millions of gallons per day
O&M .... operations and maintenance
PLC .... programmable logic controllers
ppb .... parts per billion
psi .... pounds per square inch
SCADA .... Supervisory control and data acquisition
VFD .... variable-frequency drive
VPS .... virtual pumping station
WTP .... water treatment plant

EXECUTIVE SUMMARY

The basis of this study is to determine the feasibility of connecting the Alaska Gasline Development Corporation (AGDG) liquefied natural gas (LNG) site to the City of Kenai (COK) drinking water distribution system via a water main extension from the northwestern section of the City near Mile 14 of the Kenai Spur Highway to the site location near Mile 20. The AGDC LNG site is anticipated to need a continuous flow of 150 gallons per minute (gpm) during operation, 250gpm during construction and 1000gpm for 24 hours to refill a firewater storage tank following a fire event. This study evaluates the existing City of Kenai water system with respect to Water Production, Water Treatment, and Water Distribution, to determine if the LNG facility water demands can be met, while maintaining adequate performance throughout the existing system.

Ultimately, the City of Kenai water system will require upgrades to increase water production and water distribution from its current configuration in order to meet the increased demands from the AGDC LNG site and the future demands both in the city limits and in the area north of the city along the Kenai Spur Highway. The City of Kenai may require upgrades to their water treatment system to meet the increased water demand and treat water with elevated arsenic. The cost of anticipated upgrades to the system have been estimated to total $18,700,000.00 in 2018 dollars.

1. INTRODUCTION

The City of Kenai water system serves both residential and commercial users over an area of approximately 8 square miles. The system serves groundwater treated to remove "color" to over 2000 services within or near the City Limits. The distribution system extends approximately 7 miles in an east-west dimension and approximately 5 miles in a north-south dimension. The existing 3 million gallon reservoir is located geographically relatively near the center of the City of Kenai water system. A separate existing 1 million gallon reservoir is located adjacent to Wellfield 2 on the east side of the City of Kenai water system and was recently constructed in 2016. The City water wells are located at Wellfield 2 near Beaver Creek on the easterly end of the system and are approximately 2 miles remote from most of the system users.

The basis of this study is to determine the feasibility of connecting the AGDG LNG site to the City of Kenai drinking water distribution system. Currently, The City of Kenai water system terminates near Mile 14 of the Kenai Spur Highway. In order to connect to the AGDC LNG site to the City of Kenai water system, the water main would need to be extended approximately 6 miles north and west to Mile 20 of the Kenai Spur Highway. This study evaluates the existing City of Kenai water system with respect to Water Production, Water Treatment, and Water Distribution. Ultimately, the base demand flows, fire flows, water quality, availability currently experienced by the City of Kenai Water Customers will need to be maintained throughout the system in order to construct the new water main extension.

This report includes recommendations for improvements to the existing city water system in order to provide the same level or better service for the existing users with the projected future water demands. A cost estimate for the proposed improvements is also included for planning.

2. WATER SYSTEM DESCRIPTION

2.1. Water Production

Water for the City of Kenai is currently provided by 4 wells located within wellfield 2. Discussion of the wellfield can be found in appendix D, "Water Source Evaluation – City of Kenai Well Field 2".

In the recent past, the City has utilized water from well 1 and well 3 during times of high water use. These wells are located along the Kenai Spur Highway approximately 1 mile to the west of wellfield 2. The wells have not been used for over a year due to low production and high arsenic. Max flow rates for the wells in 2014 were reportedly 150gpm and 50gpm for wells 1 and 3 respectively. The arsenic in the wells has historically been between 20 and 30 parts per billion (ppb) which is greater than the 10ppb allowed by drinking water standards since 2006. Water from the wells 1 and 3 was pumped directly into the water system without passing through the water treatment plant. The wells are kept active in case of emergency. In the past when the wells were used, the city has been required to get a waiver from ADEC and notify customers that their water may exceed the maximum containment level (MCL) for arsenic.

2.2. Water Treatments

The City of Kenai's water treatment plant is located near wellfield 2 and came online in June 2012. The treatment plant is housed in a manufactured steel single story building with a mechanical storage mezzanine that has plan dimensions of 70ft x 40ft.

The treatment plant has been successful in removing tannins and thereby improving water aesthetics. However, iron flocculent is present in the finished water. Minimal settling and removal of the Iron flocculent occurs in the existing 60,000 gallon day tank at Wellfield 2. The 1 million gallon (mg) reservoir increases retention time allowing for greater removal of iron flocculent, thereby increasing water quality. The treatment that the plant provides is not required by regulation for the groundwater that is produced by wellfield 2.

The plant currently treats all the water consumed by the city. The plant is designed to treat up to 1.5mg per day, (City of Kenai, 2011). The plant utilizes (3) Horizontal pressure cylinders that each house (2) pressure filter cells. The cells contain anthracite and silica sand filter media, and are currently backwashed once a day.

2.3. Water Distribution

The water distribution system consists of (3) storage reservoirs and 56 miles of transmission mains that extend approximately 7 miles in an east-west dimension and approximately 5 miles in a north-south dimension to deliver water to residential and commercial services within the City of Kenai.

The system utilizes buried water mains with pipe in sizes ranging from 6inch (in) to 16in, and materials including: asbestos cement, ductile iron and HDPE.

Water storage includes a 60,000 gallon day tank and a 1mg reservoir (reservoir 2) at Wellfield 2 and a 3mg reservoir (reservoir 1) located adjacent to the airport. All three reservoirs are ground supported, cylindrical, welded steel tanks.

The 3mg reservoir provides additional water to the system to meet peak demand flow and also to meet fire flows via two 50 horsepower (hp) vertical shaft turbine pumps. The 3mg steel reservoir has one water line that is used for both filling and drawdown. Filling and drawdown are controlled by programmable logic controllers (PLC) which have been programmed to fill the reservoir between the hours of 10pm and 5am when overall system demand is low. During filling, a PLC is used to open/close a flow control valve to limit the reservoir filling rate as required to maintain a minimum pressure in the city system. During the day, when demand is high, the PLC is used to speed up or slow down the variable speed distribution pumps as required to control pressure within the system and provide additional water to augment the output of wellfield #2. The dispatchers at the police/fire station have the ability to stop a fill cycle and boost the system pressure during a fire event by turning on the distribution pumps at reservoir 1. In addition, the system is set to automatically stop a fill cycle and turn on the reservoir 1 distribution pumps if two of the pressure sensors within the city drop below a user defined threshold.

The 1mg reservoir was constructed in 2016. The reservoir is fed by the water treatment facility and gravity drains into the 60,000 gallon day tank. Three 40hp distribution pumps with variable-frequency drive (VFD) controllers are mounted on the side of the 60 thousand (k) gallon day tank and pump water into the transmission mains. Normally only one pump is operating at any given time and the pumps operate on a set speed determined by the water operators.

The city water system is controlled and monitored by water operators via computer interfaces in the water treatment plant (WTP), at the water operator's offices, at the reservoir 1 pumphouse, and via mobile device remote login.

3. WATER SYSTEM EVALUATION

3.1. Water Production

See appendix D, "Water Source Evaluation – City of Kenai Well Field 2" for details regarding the water production analysis.

The executive summary from the report referenced above reads:

> *This reconnaissance-level evaluation of the City of Kenai Well Field 2 found that additional development of the water resources at Well Field 2 to supply water for the proposed LNG facility and associated additional demand in the area appears to be feasible. This includes projected population and water-use growth in the existing and future City of Kenai water service area. While it is unlikely that expanded water production would draw in significant amounts of salt water or human-caused contamination from surrounding areas, an increase in concentrations of naturally-occurring arsenic to levels above the MCL is a risk considering the common presence of arsenic in surrounding areas.*
>
> *Also, some surrounding private wells could be adversely affected by the increased withdrawal at distances up to a few miles away. These adverse effects could result either from a reduced ability to pump water from existing private wells or from worse quality of water either from existing, deepened, or new wells. To some extent, however, increases in future pumping at Well Field 2 to meet City water demands, even without development of the LNG facility, could result in increased arsenic in City wells or adverse effects on surrounding wells.*
>
> *Additional baseline data collection and analysis, facility maintenance and capital improvements, establishment of long-term monitoring networks, and planning for mitigative actions are suggested for consideration should water use from Well Field 2 increase as proposed.*

3.1.1. Water Production Recommendations

See appendix D, "Water Source Evaluation – City of Kenai Well Field 2" for details regarding the water production recommendations.

Section 8.3 Design from the report referenced above reads:

> *The analysis presented indicates that at least one new well will be needed in the well field to provide the required water. An additional well would also be useful to spread pumping out among more wells, provide robustness in case of temporary outage of any of the other five pumping wells, or to provide a factor of safety to compensate for the uncertainties of the analysis and the long-term nature of the predictions.*
>
> *It may also be useful to plan for eventual treatment of arsenic should levels of arsenic rise at Well Field 2. Treatment facilities could potentially be used to treat water from other City of Kenai wells that pump water exceeding the MCL for arsenic.*

Two new 12in diameter production wells have been included in the estimated construction cost for the water system upgrades. Arsenic treatment is not needed at this time, however, the likelihood of needing arsenic treatment is increased due to increased withdrawal from the aquifer. Arsenic treatment is discussed further in section 3.2.

Prior to increasing water production at the site, baseline data collection and analysis should be conducted at wellfield 2 and surrounding private wells. Also long term monitoring networks for the aquifer should be installed and planning for mitigative efforts at surrounding wells should be completed.

3.2. Water Treatment

3.2.1. Water Treatment Analysis

Please see section 3.3.1.2 Demand Characteristics for information regarding the water use in the City of Kenai. The projected Maximum Daily Demand water use in 2025 including the North Kenai Service area and the AGDC LNG plant is 2 millions of gallons per day (mgd), the Peak Month avg. Daily Demand is 1.56mgd and the Average Daily Demand is 1.42mgd.

According to the construction contract documents the water treatment plant has a design capacity of

1.5mgd (City of Kenai, 2011). The Operations and Maintenance (O&M) manual for the filters in the WTP list a total system capacity of 1,560gpm (2.25mgd).

3.2.2. Water Treatment Results and Discussion

It is not required by state or federal regulations that the city treat part or all of the water from wellfield 2 since the treatment technically only improves the water aesthetics and the water produced directly from the wells does not exceed the regulated maximum contaminant levels. The treatment plant does however dramatically improve the color of the water and this is easily identifiable with the naked eye when observing even a single glass of water. It is unlikely that the city and its current customers would be willing to revert back to the water color previously observed prior to the treatment plant construction. Treating a portion of the water from wellfield 2 and blending the treated and untreated water would be a possible emergency solution to produce more water than can be treated by the treatment plant. However, this blending would still produce an inferior water product and is likely to be undesirable to the City and its water customers.

The 1.5mgd design capacity of the existing plant listed in the construction contract documents is less than the Maximum Daily Demand of 2mgd and the Peak Month Average Daily Demand of 1.56mgd. However, the system capacity as reported by the filter manufacturer is 2.25mgd. It is therefore possible that the current treatment plant would have the capacity to meet the future needs of the City thru 2045. A pilot study on the existing plant that reduced the working filters cells from 6 to 3 would approximate the flow rates in the filters experienced during the design demands and give an indication of how the treatment plant would operate under increased flows. If the filters are able to handle the increased flows it is possible that significant upgrades to the plant would not be required to continue treatment for color. If more filters are necessary, it is anticipated that the treatment plant building could be expanded to the north to provide room for additional filters.

Treatment for arsenic is not currently required since all wells in use have arsenic levels below the MCL of 10ppb. Based on the results in Appendix D, it is possible that the increased rate of withdrawal from the aquifer at wellfield 2 to meet the demands of AGDC and city expansion will result in an increase in arsenic levels to the point where treatment is required.

TONKA WATER, the manufacturer of the existing filters, has stated it is likely that the existing filters could be used to remove arsenic via co-precipitation with iron if the chemical feed is modified. It is also likely that additional filters would be required to provide the same filtering capacity if the filters are removing arsenic and color. Because the interaction of the color producing organics and the iron/arsenic oxidizer are difficult to predict, a pilot study should be conducted to verify the treatment methods prior to plant design.

A range of costs for small water treatment systems was recently determined by an EPA study. (Wang and Chen, 2011) The study reported initial capital improvement costs as well as O&M Costs for 19 test systems in use with output greater than 100gpm. The range of capital improvement costs varied from $477/gpm to $1932/gpm. Using an anticipated max design flow of 2.5mgd, a 1.07 cost of living increase for Kenai and 2% average Inflation rate for construction costs from 2012 to 2019 the range of initial investment is anticipated to be between $1 million (m) and $4M. The O&M costs for an average daily demand of 1.42mgd is anticipated to range from $178k to $3.6M per year with an average of $440k per year.

If the existing treatment plant can be upgraded to include treatment for arsenic as well as color the Initial capital improvement costs are expected to be $4 million to add more filters and additional chemical injection. O&M costs of less than $400k per year are anticipated to cover more staff, chemicals for injection and the routine monitoring/testing associated with removal of a regulated contaminant.

3.2.3. Water Treatment Recommendations

The existing water treatment capacity is near the anticipated maximum water usage in the year 2025. It is recommended to prepare for expansion of the existing water treatment facility to allow treating more than 2.5mg per day.

It is possible that the existing water treatment facility may be able to provide treatment of up to 2.2mgd which would exceed the max daily demand of 2mgd. However, this level of treatment has not been tested, and is in exceedance of the 1.5mgd design listed for the existing facility.

It is recommended to conduct a study inside the existing plant that would turn off 3 of the 6 filter cells and utilize the existing cells at roughly double the "normal" throughput. This testing will show the ability of the existing filters to treat water at a much higher flow rate than they are currently being utilized. Based on the results of this testing it can be determined if the plant would need to be upgraded with more filters. Until this study is performed and the filter capacity is verified, it is prudent to plan for an expansion to the existing plant.

Treatment for Arsenic is not currently required but may be required if higher pumping rates result in higher arsenic in the water at wellfield 2. Planning for future arsenic treatment should be completed as a contingency in the event elevated arsenic levels are observed. The planning should include the cost for an initial capital investment as well as O&M costs. A pilot study should be conducted to determine if the existing filters could be used to remove arsenic In addition to color.

3.3. Water Distribution

3.3.1. Water Distribution Analysis

The City of Kenai water system was analyzed via a digital computer model analysis using Bentley Systems Inc. "WaterCad" software for design and analysis of pressure flow piping systems. WaterCad allows the user to construct a graphical representation of a pipe network in an AutoCAD drawing environment. Within the model, the physical properties of the infrastructure including piping, pumps, and reservoirs are defined. The output from Water Cad includes numerical reports, color-coded network mapping, contouring and profile/graph generation.

3.3.1.1. Graphical Model

The City of Kenai water system was modeled using existing City water system maps and available as-builts. Graphical data entry consisted of digitizing individual sheets from the water system as-built drawings to create a comprehensive map database of the entire City of Kenai water system. Information entered into the database includes; Pipe location, length, size, material and connectivity; Water supply location, and; Water storage location.

3.3.1.1.1. Model Validation

The digital model was validated by recreating the flow rates and pressures observed on May 29, 2014. The City of Kenai water system has a supervisory control and data acquisition system (SCADA) that remotely monitors and controls all production, storage and distribution pumping. The SCADA system control room is located in the Kenai water system maintenance shop. A second monitoring and control system is located in the Kenai Fire/Police dispatch office which provides capability to manually increase fire flow by activating or speeding up distribution pumps in the 3 million gallon Reservoir pump house during a fire event. Monitor and control of individual pumps is also available at each well location.

Using the SCADA data available in the water system maintenance building, flow rates and pressures throughout the system were recorded. A summary of the model verification data is shown in Figure 1.

Using the observed flow rates, the pressures in the model matched within 0 to 10% of the observed pressures. This 10% correlation was determined to provide suitable accuracy for this study.

Figure 1. Model Validation Results

	Actual		Model				Difference	
Location	Flowrate (gal/min)	Pressure (psi)	**Pump Speed**	**Junction**	Flowrate (gal/min)	Pressure (psi)	% Difference in Flow	% Difference in Pressure
Wellhouse 1	38.1	67.2	**1**	**J-40**	40	67	5	0
Wellhouse 2	531	78	**0.93**	**J-21**	538	79	1	1
Wellhouse 3	50	na	**0.695**	**J-2050**	50	64	0	
Reservoir	302.4	50	**0.78**	**J-3001**	293	55	-3	10
Police Station		50.4		**J-272**		55		9
Aliak St		59.9		**J-100**		55		-8
Mile 13		49.8		**J-2165**		53		6

Well House 3 Flowrate Estimated by Operator

3.3.1.2. Demand Characteristics

The City of Kenai water use and billing records were obtained in order to establish base daily demand flow rates. Monthly water consumption records were obtained for Well #1, #2, and #3 for the years of 2006-2007 and 2011-2017. The records as seen in Figure 2 and Figure 3 were used to compute average and peak daily production for the city. Based on an analysis of these records, average daily demands and maximum daily demands were determined for the present Kenai population.

Figure 2. Monthly Water Usage in the City of Kenai (millions of Gallons)

Month	2006	2007	2011	2012	2013	2014	2015	2016	2017
January	30.52	29.13	27.05	28.44	31.91	23.43	24.22	20.71	21.40
February	28.32	26.07	24.21	26.56	24.35	21.07	22.19	19.26	19.58
March	31.82	28.40	27.19	28.41	27.40	23.33	23.35	20.75	22.38
April	30.84	29.71	28.16	26.66	26.72	23.02	22.93	21.75	22.03
May	38.48	-	32.32	29.94	28.35	27.33	24.85	25.53	22.26
June	37.40	-	33.35	30.42	30.88	24.43	26.69	25.97	26.33
July	40.47	-	35.11	32.88	30.61	28.20	25.99	28.05	26.20
August	33.36	-	31.19	28.83	25.22	26.28	26.44	22.19	-
September	29.88	-	29.15	27.36	23.67	23.34	24.79	20.82	-
October	29.71	-	28.10	23.82	24.35	22.83	20.12	19.61	-
November	29.54	-	27.18	28.77	22.74	22.09	20.00	21.17	-
December	29.96	-	27.97	32.38	23.36	22.91	20.39	20.10	-
Total	**390.29**	**113.31**	**350.97**	**344.47**	**319.53**	**288.25**	**281.94**	**265.90**	**160.17**
Avg. Daily	1.07	0.92	0.96	0.94	0.88	0.79	0.77	0.73	0.74

Figure 3. Daily Water Usage in the City of Kenai (Millions of Gallons)

Daily Water Use in Millions of Gallons

Jun-15						
S	M	T	W	TH	F	SA
	0.8	0.9	0.73	0.64	0.71	0.95
0.86	0.84	0.76	0.75	0.89	0.93	1.05
1.24	1.24	1.43	1.22	1.04	0.81	0.72
0.68	0.54	0.89	0.81	0.93	0.73	0.81
0.67	0.71	0.85				
AVG =	0.87					
Max =	1.43					
90 % =	1.22					

Jul-16						
S	M	T	W	TH	F	SA
					0.84	0.89
0.76	0.64	0.69	0.84	0.70	0.82	0.94
0.71	0.96	1.02	1.03	0.89	1.03	0.85
1.87	0.23	1.10	1.19	1.13	1.04	0.75
0.84	0.78	0.84	0.88	0.86	0.91	0.88
0.88						
AVG =	0.90					
Max =	1.87					
90 % =	1.10					

Jun-17						
S	M	T	W	TH	F	SA
				0.89	1.15	0.90
0.91	0.63	0.83	0.84	0.85	0.76	0.81
0.72	0.72	0.77	0.90	0.78	0.92	1.05
0.90	0.83	0.89	0.78	0.81	2.76	0.00
0.89	0.78	0.82	0.82	0.87	0.8	
AVG =	0.88					
Max =	2.76					
90 % =	0.94					

Water use records revealed that peak domestic demands typically occur during the summer months. The peak monthly domestic demand for Kenai over the past 3 years occurred during a 30-day period in June 2015 as seen in Figure 3. The total yearly demand was divided by the number of days to arrive at an average daily demand of 0.79mgd for 2014 which is the highest of the previous 3 full years of data.

Distribution System Requirements for Fire Protection (AWWA M31, 1998) recommends designing for the 'maximum daily demand' plus the fire flow requirement as well as the 'maximum hourly demand' without fire flows. Insurance Services Office (ISO) also requires the fire flow analysis be coupled with the maximum daily demand flow for the purpose of design (Insurance Services Office, 2014).

The ISO bases design demand on the highest demand during the previous 3 years. The data from 2015, 2016, and 2017 are the three most recent years therefore they were used to determine the design demands.

The maximum daily demand used for design is 1.22mgd, 848gpm. This value represents the fourth highest use day (90 percentile value) during the highest use month in the last 3 years, as shown in Figure 1. The fourth highest used day was chosen because the three highest use days had unusual or excessive uses of water or inconsistent measuring procedures.

The maximum hourly demand was determined by applying a peak factor of 1.6 multiplied by the maximum daily demand. The calculated maximum hourly demand is 1357gpm.

Water service billing records were used to determine the location of domestic demands throughout the system. Twenty metered commercial services with individual recorded usage greater than 1% of total Commercial usage were assigned demand flows based on historical data for each particular service. The remainder of commercial and residential services were assigned an assumed daily demand based on the remainder of the flow divided by the remaining number of services. Domestic demand was then applied to the model at "demand nodes" located at pipe intersections, based on the actual number of services located within the vicinity of each particular node. This method of appropriating demand loading is intended to result in an accurate representation of distribution of actual domestic demand flow throughout the system.

The current ISO Fire Suppression Rating for the City of Kenai is 3500gpm (Insurance Services Office, 2014) supplied during average daily flow. This rating is based on the fifth largest non-sprinklered commercial building fire flow demand in the City. The required fire flows for one and two family dwellings which do not exceed two stories in height, and are greater than ten feet apart, is 1000gpm. If the buildings are ten feet or less apart, the fire flow requirement is 1500gpm. For the purposes of this study, 1000gpm fire flow for residential fires and 3500gpm for commercial fires were used as the minimum basis for analysis.

3.3.2. Demand Flow States

Two fire flow demand states were analyzed to determine the ability of the system to meet the Insurance (ISO) requirements for each scenario. The base maximum daily demand was adjusted for each scenario based on future demand.

3.3.2.1. Projected Water Demands

Water demands for the City of Kenai have been projected for the years 2025 and 2045 based on current and projected population information harvested from AGDC Resource Report No. 5 (RR05), Socioeconomics. The Kenai Peninsula Borough overall is expected to have a population increase of 7 % for 2025 and 13% for 2045 relative to the population in 2015 (AGDC Resource Report #5, 5-21). The population growth experienced in Kenai from 2000 to 2013 was recorded as 4% (AGDC Resource Report No. 5, 5-18). The estimated change in resident population for Kenai and Nikiski during AGDC LNG Project Construction from 2019 to 2027 is 4% and 6% respectively (AGDC Resource Report No. 5, 5-159).

Based on the information presented in RR#5 a City of Kenai population increase of 7% for 2025 and 13.3% for 2045 relative to 2015 was used for design. Also, a Nikiski population increase of 9% for 2025 and 13.3% for 2045 relative to 2015 was used for design.

The water use in the respective areas was assumed to correlate closely with the change in population.

The water use in the proposed North Kenai service area was estimated based on an assumed area served by the proposed 6 miles of pipeline from mile 14 to mile 20 of the Kenai spur highway. The assumed service area includes the existing development within roughly 1 mile of the highway corridor between the end of the existing City of Kenai waterline and Aaron Ave near mile 20. Homer Electric Association provided information that they had 505 existing electric meters in the subject area. The city of Kenai has 2005 services with a max daily demand of 1.22mgD. This gives an average service use of 608 gallons per day. The projected 2015 use in the North Kenai Service Area is 505 services x 608 gal/service/day = 0.307mgd.

Figure 3 gives the Existing and projected City of Kenai Water use for the years 2025 and 2045. A summary of the current and future population estimates is shown in Figure 3.

Figure 4. Existing and Projected COK Water Use

	2015	2025	2045
Percent increase (Kenai)	0.00	7.00	13.30
Percent increase (Nikiski)	0.00	9.00	13.30
Design Max Daily Demand (MGD)			
Existing City System	1.22	1.31	1.38
AGDC LNG Facility	0.00	0.36	0.22
North Kenai Service Area	0.00	0.33	0.34
Sum	1.22	2.00	1.94
Peak Month Avg Daily Demand (MGD)			
Existing City System	0.90	0.96	1.02
Liquefaction Facility	0.00	0.36	0.22
North Kenai Service Area	0.00	0.24	0.25
Sum	0.90	1.56	1.49
Avg Daily Demand (MGD)			
Existing City System	0.79	0.85	0.90
Liquefaction Facility	0.00	0.36	0.22
North Kenai Service Area	0.00	0.21	0.22
Sum	0.79	1.42	1.33

AGDC has provided projected flow rates of 250gpm during construction, 150gpm during operation after construction is complete and 1000gpm for 24 hours to refill a firewater storage tank following a fire event. The proposed LNG facility will have an onsite reservoir that will provide fire flow capacity and absorb the fluctuations of peak water demands. Therefore, the flow rates provided by AGDC were assumed to correspond to the Max Daily Demand and the average daily demand for the site.

For the purposes of this study, the demands used for each scenario were for the year 2025 in order to analyze the impacts of the AGDC LNG site during its construction. The Max Daily Demand for the City was 1.31mgd (910gpm), the AGDC LNG Facility was 0.36mgd (250gpm) and the Kenai Spur Highway Service area along the new AGDC water main extension was 0.33mgd (232gpm).

3.3.2.2. Existing City System (2025 Demand)

- Max Daily Demand and 3500gpm Fire Flow: 910gpm + 3500gpm = 4410gpm
- Max Daily Demand and 1000gpm Fire Flow: 910gpm + 1000gpm = 1910gpm

Max hourly demand without fire flow 1456gpm was not included in this study because it is less than the max daily demand combined with the 1000gpm fire flow.

This demand was utilized for Fire Flow Analysis Scenario 1.

3.3.2.3. Existing City System + AGDC LNG Facility Construction (2025 Demand)

- Max Daily Demand and 3500gpm Fire Flow: 1160gpm + 3500gpm = 4660gpm
- Max Daily Demand and 1000gpm Fire Flow: 1160gpm + 1000gpm = 2160gpm

Max hourly demand without fire flow 1856gpm was not included in this study because it is less than the max daily demand combined with the 1000gpm fire flow.

This demand was utilized for Fire Flow Analysis Scenario 2

3.3.2.4. Existing City System +AGDC LNG Facility Construction Demand + North Kenai Service Area (2025 Demand)

- Max Daily Demand and 3500gpm Fire Flow: 1392gpm + 3500gpm = 4892gpm
- Max Daily Demand and 1000gpm Fire Flow: 1392gpm + 1000gpm = 2392gpm

Max hourly demand without fire flow 2228gpm was not included in this study because it is less than the max daily demand combined with the 1000gpm fire flow.

This demand was utilized for Fire Flow Analysis Scenarios 3-6.

3.3.3. System Pressures

The maximum distribution line design pressure is 100 pounds per square inch (psi)

. It should be noted that normal test pressures for the new construction on the City of Kenai water system is 150psi and that the maximum recommended operating pressure for the water system should not exceed 100psi.

The minimum pressure in the distribution system is 20psi by ADEC regulation. All fire flow scenarios were analyzed with a minimum residual pressure of 20psi and a maximum pressure of 100psi.

3.3.4. Fire Flow Analysis Scenarios

Six (6) water system configurations were analyzed for each of the two demand flow states resulting in twelve (12) independent scenarios.

The six (6) different water system configurations are meant to compare the existing water system performance to possible future system configurations for system operation. The six (6) water system configurations are described below.

The base water demand during the year 2025 as described above was used to estimate the performance of each system configuration during fire flows.

3.3.4.1. Scenario 1: 2017 Infrastructure

In this configuration, the city system includes all the improvements currently constructed in 2017. To determine the fire flow response, both of the existing 3 million gallon Reservoir distribution pumps are pumping at full capacity, along with one (1) of the three (3) existing distribution pumps at wellfield 2. This scenario was used as a baseline to determine the performance of the existing system in response to the 2025 baseline and fire flow demands.

3.3.4.2. Scenario 2: 2017 Infrastructure + North Kenai Transmission Main

Scenario 2 uses the same water system configuration as Scenario 1 but includes the proposed water main extension to the AGDC LNG site from approximately Mile 14 to Mile 20 on the Kenai Spur Highway. A 250gpm construction demand is added to the end of the line within the limits of the AGDC LNG site. No additional service connections are allowed under this scenario to the new transmission main between mile 14 and mile 20 of the Kenai spur highway. The transmission main is modeled as a 20in diameter HDPE water line to minimize frictional losses.

3.3.4.3. Scenario 3: 2017 Infrastructure + North Kenai Distribution Main

Scenario 3 uses the same configuration as Scenario 2 but includes demands for the service area north of the City of Kenai limits up to the AGDC LNG site. The demands are projected for the year 2025.

3.3.4.4. Scenario 4: 2017 Infrastructure + North Kenai Distribution Main + Upgraded Pumphouse at Wellfield 2

In Scenario 4, the distribution system at wellfield 2 has been updated to provide increased pumping capacity, and eliminate a bottleneck in the distribution piping. Pump improvements consist of replacing the three (3) existing 40hp distribution pumps with two (2) 100hp and one (1) 30hp vertical shaft split case centrifugal pumps to boost line pressure coming out of the 1 M-gal Reservoir. The new water lines include replacing approximately 500 linear feet (LF) of 10in and 12in water main that extends from Wellfield 2 to the first tee on the north side of the Kenai Spur Highway opposite Beaver Loop Rd. The replacement line was modeled as a 16in diameter Ductile Iron Pipe.

3.3.4.5. Scenario 5: 2017 Infrastructure + North Kenai Distribution Main + Seward Ave. Virtual Pump Station

Scenario 5 uses the same configuration as Scenario 3 but includes an additional virtual pump station located at the north end of the City of Kenai limits near Seward Ave. Because the Seward Ave. Virtual Pump Station is boosting pressures, the North Kenai distribution main is modeled as a 16in diameter HDPE water line to reduce potential construction costs.

3.3.4.6. Scenario 6: 2017 Infrastructure + North Kenai Distribution Main + Upgraded Pumphouse at Wellfield 2 + Seward Ave. Virtual Pump Station

Scenario 6 uses the same configuration as Scenario 4, but includes an additional virtual pump station located at the north end of the City of Kenai limits near Seward Ave. The North Kenai distribution main is modeled as a 16in diameter HDPE water line.

3.3.4.7. Pumping Summary for Scenarios 1-6

The pumping stations that are active in each individual scenario can be seen in Figure 4.

Figure 5. Pumping Summary for Scenarios 1-6

Scenario	WH#2 ORIG Pumps	WH#2 Revised Pumps	Reservoir Pump Station	Seward Ave Virtual Pump Station
1	Pump Operating	Pump Not Operating	Pump Operating	Pump Not Operating
2	Pump Operating	Pump Not Operating	Pump Operating	Pump Not Operating
3	Pump Operating	Pump Not Operating	Pump Operating	Pump Not Operating
4	Pump Not Operating	Pump Operating	Pump Operating	Pump Not Operating
5	Pump Operating	Pump Not Operating	Pump Operating	Pump Operating
6	Pump Not Operating	Pump Operating	Pump Operating	Pump Operating

(Blue) = Pump Operating
(Yellow) = Pump Not Operating

3.3.5. *Fire Flow Analysis Results*

The results of the analysis for each scenario are summarized in Figure 5. See Appendix B for a graphical representation of the pressure vs. distance in the water system while moving from east to west for each scenario.

Figure 6. Fire Flow Analysis Results for Scenarios 1 through 6

Description	Scenario		Base Demand (Max Daily Demand) GPM	Design Fire Flow (GPM)	# Nodes Checked	# Nodes Passed	# Nodes Failed	% Nodes Passing	Does J-220 (Spur Hwy and Bridge Access) Meet Fire Flow?	Calc Fire Flow @ J-220 with 20 psi Residual	Calc Fire Flow @ J-2165 with 20 psi Residual	J-21 (WH#2) Pressure w FF @ J-2165 (psi)	J-20 (Tomp Park) Pressure w FF @ J-2165 (psi)	J-50 (Swires Rd and Alaak) Pressure w FF @ J-2165 (psi)	J-2131 (Swires Rd and Lawton) Pressure w FF @ J-2165 (psi)	J-190 (Lawton and Walker) Pressure W FF at J-2165 (psi)	J-240 (Willow and Main St Lp) Pressure w FF @ J-2165 (psi)	J-365 (Birch Rd and 3rd Ave)Pressure w FF @ J-2165 (psi)	J-7013 (Milepost 20)Pressure w FF @ J-2165 (psi)
2017 Infrastructure	1	a	910	3500	395	0	395	0	N	2635	1930	100	77	56	59	56	56	52	N/A
		b	910	1000	395	390	5	99	Y										
2017 Infrastructure + North Kenai Transmission Main	2	a	1160	3500	409	0	409	0	N	2303	1650	78	69	57	60	57	57	53	20
		b	1160	1000	409	404	5	99	Y										
2017 Infrastructure + North Kenai Distribution Main	3	a	1392	3500	409	0	409	0	N	1964	1382	79	69	58	61	58	58	54	20
		b	1392	1000	409	395	14	97	Y										
2017 Infrastructure + North Kenai Distribution Main+Upgraded Pumphouse at Wellfield 2	4	a	1392	3500	409	69	340	17	N	3366	1825	99	90	75	78	70	67	60	20
		b	1392	1000	409	404	5	99	Y										
2017 Infrastructure + North Kenai Distribution Main + Seward Ave. Vutural Pump Station	5	a	1392	3500	409	0	409	0	N	2267	1673	72	62	50	49	50	50	45	85
		b	1392	1000	409	402	7	98	Y										
2017 Infrastructure + North Kenai Distribution Main+Upgraded Pumphouse at Wellfield 2 + Seward Ave. Virtual Pump Station	6	a	1392	3500	409	92	317	22	Y	3501	2182	98	89	73	76	65	62	53	87
		b	1392	1000	409	404	5	99	Y										

3.3.5.1. Scenario1:2017 Infrastructure

3.3.5.1.1. Residential Fire Flow (Scenario 1B)

Under the existing conditions with increased future demand, the system was able to meet the 1000gpm **Residential Fire Flow** for all but 5 nodes throughout the City of Kenai for maximum daily demand flow conditions (99% passing). The 5 failing nodes are located near the end of Julie Anna Dr. and along Florida Ave. in West Kenai. See Appendix A for a graphical representation of the nodes passing and failing the fire flow criteria in each scenario.

3.3.5.1.2. Commercial Fire Flow (Scenario 1A)

None of the nodes in the system are able to provide a **Commercial Fire Flow** of 3500gpm in addition to the maximum daily demand (Scenario 1A).

Under maximum daily demand flow plus Fire Flow, selected system pressures vary as follows:

- 100 pounds per square inch (psi) at Well #2;
- 77psi at Thompson Park subdivision;
- 56psi at the intersection of Swires Rd and Aliak St and;
- 59psi at the intersection of Swires Rd and Lawton Dr;
- 52psi at the intersection of Birch Rd and 3rd Ave.

3.3.5.2. Scenario 2:2017 Infrastructure + North Kenai Transmission Main

3.3.5.2.1. Residential Fire Flow (Scenario 2B)

Under the existing conditions with increased future demand, plus the AGDC water main extension with a 250gpm construction demand (excluding the KSH Service Area), again the system was able to meet the 1000gpm **Residential Fire Flow** for all but 5 nodes throughout the City of Kenai for maximum daily demand flow conditions (99% passing). The 5 failing nodes are located near the end of Julie Anna Dr. and along Florida Ave. in West Kenai. See Appendix A for a graphical representation of the nodes passing and failing the fire flow criteria in each scenario.

3.3.5.2.2. Commercial Fire Flow (Scenario 2A)

None of the nodes in the system are able to provide a Commercial Fire Flow of 3500gpm in addition to the maximum daily demand (Scenario 2A).

Under maximum daily demand flow plus Fire Flow, selected system pressures vary as follows:

- 78psi at Well #2;
- 69psi at Thompson Park subdivision;
- 57psi at the intersection of Swires Rd and Aliak St and;

- 60psi at the intersection of Swires Rd and Lawton Dr;
- 53psi at the intersection of Birch Rd and 3rd Ave;
- 20psi at the proposed tank located on AGDC LNG site.

3.3.5.3. Scenario 3: 2017 Infrastructure + North Kenai Distribution Main

3.3.5.3.1. Residential Fire Flow (Scenario 3B)

Under the existing conditions with increased future demand, the expanded KSH Service Area, plus the AGDC water main extension with a 250gpm construction demand, the system was able to meet the 1000gpm **Residential Fire Flow** for all but 14 nodes throughout the City of Kenai for maximum daily demand flow conditions (97% passing). Five (5) of the failing nodes are located near the end of Julie Anna Dr. and along Florida Ave. in West Kenai. The remaining nine (9) nodes are located along the new AGDC main extension to the north of the city. See Appendix A for a graphical representation of the nodes passing and failing the fire flow criteria in each scenario.

3.3.5.3.2. Commercial Fire Flow (Scenario 3A)

None of the nodes in the system are able to provide a Commercial Fire Flow of 3500gpm in addition to the maximum daily demand (Scenario 3A).

Under maximum daily demand flow plus Fire Flow, selected system pressures vary as follows:

- 79psi at Well #2;
- 69psi at Thompson Park subdivision;
- 58psi at the intersection of Swires Rd and Aliak St and;
- 61psi at the intersection of Swires Rd and Lawton Dr;
- 54psi at the intersection of Birch Rd and 3rd Ave;
- 20psi at the proposed tank located on AGDC LNG site.

3.3.5.4. Scenario 4: 2017 Infrastructure + North Kenai Distribution Main + Upgraded Pumphouse at Wellfield 2

3.3.5.4.1. Residential Fire Flow (Scenario 4B)

With the pumphouse at Wellfield 2 upgraded the system was able to meet the 1000gpm Residential Fire Flow for all but 5 nodes throughout the City of Kenai for maximum daily demand flow conditions (99% passing). Five (5) of the failing nodes are located near the end of Julie Anna Dr. and along Florida Ave. in West Kenai. The demand was met for the new AGDC main extension to the north of the city. See Appendix A for a graphical representation of the nodes passing and failing the fire flow criteria in each scenario.

3.3.5.4.2. Commercial Fire Flow (Scenario 4A)

69 out of the 409 nodes (17% passing) were able to meet the 3500gpm Commercial Fire Flow plus the maximum daily demand. However, the system is not able to provide 3500gpm with maximum daily demand flow at the intersection of Kenai Spur Highway and Bridge Access Rd.

Under maximum daily demand flow plus Fire Flow, selected system pressures vary as follows:

- 99psi at Well #2;
- 90psi at Thompson Park subdivision;
- 75psi at the intersection of Swires Rd and Aliak St and;
- 78psi at the intersection of Swires Rd and Lawton Dr;
- 60psi at the intersection of Birch Rd and 3rd Ave;
- 20psi at the proposed tank located on AGDC LNG site.

3.3.5.5. Scenario 5: 2017 Infrastructure + North Kenai Distribution Main + Seward Ave. Virtual Pump Station

In Scenario 5, an additional virtual pumping station (VPS) is added to the system at the start of the new AGDC water main extension to provide a boost in performance.

3.3.5.5.1. Residential Fire Flow (Scenario 5B)

Under the existing conditions with increased future demand and a VPS, the expanded KSH Service Area, plus the AGDC water main extension with a 250gpm construction demand, the system was able to meet the 1000gpm Residential Fire Flow for all but seven (7) nodes throughout the City of Kenai for maximum daily demand flow conditions (98% passing). Five (5) of the failing nodes are located near the end of Julie Anna Dr. and along Florida Ave. in West Kenai. The remaining two (2) failing nodes are located along the new AGDC main extension to the north of the city. See Appendix A for a graphical representation of the nodes passing and failing the fire flow criteria in each scenario.

3.3.5.5.2. Commercial Fire Flow (Scenario 5A)

None of the nodes in the system are able to provide a Commercial Fire Flow of 3500gpm in addition to the maximum daily demand.

Under maximum daily demand flow plus Fire Flow, selected system pressures vary as follows:

- 72psi at Well #2;
- 62psi at Thompson Park subdivision;
- 50psi at the intersection of Swires Rd and Aliak St and;
- 49psi at the intersection of Swires Rd and Lawton Dr;
- 45psi at the intersection of Birch Rd and 3rd Ave;

- 85psi at the proposed tank located on AGDC LNG site.

3.3.5.6. Scenario 6: 2017 Infrastructure + North Kenai Distribution Main + Upgraded Pumphouse at Wellfield 2 + Seward Ave. Virtual Pump Station

3.3.5.6.1. Residential Fire Flows (Scenario 6B)

With the Well House #2 upgraded and a new virtual pumping station at Seward Ave, the existing conditions with increased future demand, the expanded KSH Service Area, plus the AGDC water main extension with a 250gpm construction demand, the system was able to meet the 1000gpm Residential Fire Flow for all but 5 nodes throughout the City of Kenai for maximum daily demand flow conditions (99% passing). Five (5) of the failing nodes are located near the end of Julie Anna Dr. and along Florida Ave. in West Kenai. The demand was met for the new AGDC main extension to the north of the city. See Appendix A for a graphical representation of the nodes passing and failing the fire flow criteria in each scenario.

3.3.5.6.2. Commercial Fire Flows (Scenario 6A)

92 out of the 409 nodes (22% passing) were able to meet the 3500gpm Commercial Fire Flow plus the maximum daily demand. This relatively low number of nodes able to meet domestic flow with the commercial fire flow is somewhat misleading. The system can provide 3500gpm plus the maximum daily demand flow along the main transmission lines in east and central Kenai. In addition to the main transmission lines, Scenario 6 is the only scenario that is able to provide 3500gpm plus the maximum daily demand at the intersection of the Kenai Spur Highway and Bridge Access Road. This is near the center of the business district where the governing 5th largest commercial fire flow facility was identified by the ISO report.

Under maximum daily demand flow plus Fire Flow, selected system pressures vary as follows:

- 98psi at Well #2;
- 89psi at Thompson Park subdivision;
- 73psi at the intersection of Swires Rd and Aliak St and;
- 76psi at the intersection of Swires Rd and Lawton Dr;
- 53psi at the intersection of Birch Rd and 3rd Ave;
- 87psi at the proposed tank located on AGDC LNG site.

3.3.6. Reservoir #1 Fill Scenarios

The scenarios previously described in the report were analyzed to determine the rate the 3 million gallon Reservoir #1 can be fill at night time, when overall city demand is lower, while maintaining a minimum pressure of 45psi throughout the system. For each scenario, the pumps at Reservoir #1 were turned off to simulate the tank filling with water from pressure generated from the pumphouse at Wellfield 2.

Figure 7. Reservoir #1 Fill Scenario Results

Description	Scenario	Base Demand GPM	Reservoir #1 Fill Rate GPM @ Minimum 45 PSI Residual	J-3001 (Res #1) Pressure (PSI)	J-21 (WH#2) Pressure w Flow @ J-3001 (PSI)	Minimum System Pressure w/ Flow @ J-3001 (PSI)
2017 Infrastructure	EXISTING	300*	370	48	72	45
2017 Infrastructure	1	592†	700	47	85	45
2017 Infrastructure + North Kenai Transmission Main	2	842‡	260	62	93	45
2017 Infrastructure + North Kenai Distribution Main	3	993§	84	63	94	45
2017 Infrastructure + North Kenai Distribution Main+Upgraded Pumphouse at Wellfield 2	4	993§	333	63	99	45
2017 Infrastructure + North Kenai Distribution Main + Seward Ave. Virtual Pump Station	5	993§	269	50	86	45
2017 Infrastructure + North Kenai Distribution Main+Upgraded Pumphouse at Wellfield 2 + Seward Ave. Virtual Pump Station	6	993§	665	49	97	45

Footnotes:

*-Base Demand from City of Kenai Utility for Existing System at Night

†-Base Demand = 65% of MDD Existing System 2025

‡-Base Demand = 65% of MDD Existing System 2025 + 250 GPM for AGDC

§-Base Demand = 65% of MDD Existing System/KSH Area 2025 + 250 GPM for AGDC

3.3.6.1. Existing System Reservoir Fill Scenario

The existing water system configuration was tested first to verify flowrate information provided by the City of Kenai Utility Department. Currently, the City of Kenai turns off both pumps at Reservoir #1, leaving one (1) pump on at Wellfield 2 (set to 95%) to pressurize the system and fill the 3 million gallon tank. The given base demand at night was 300gpm based on observations by city operators during September 2017. The results of the scenario are as follows:

- Base Demand = 300gpm
- Reservoir #1 Fill Rate = 370gpm
- Pressure at Reservoir 1 during fill = 48psi
- Pressure at Wellfield 2 during fill = 72psi
- Minimum System Pressure during fill = 45psi
- The results of this scenario show that the existing water system has the capability of filling the 3mg reservoir during the night. During the daytime, The Reservoir 1 Pumps and Wellfield 2 distribution pumps can be adjusted via VFD controllers so that the water exiting the Reservoir 1 3mg tank closely approximates the amount the reservoir is filled each night. This scenario was used for model verification for the reservoir filling and to establish a baseline for the current reservoir fill rate. The nighttime base demand of 300gpm is roughly 35% of the maximum daily demand of 1.22mgd. The fill rate of 370gpm corresponds to a total fill of 155,000 gallons over the 7-hour fill cycle.

3.3.6.2. Reservoir Fill Scenario #1: 2017 Infrastructure + Two (2) Wellfield 2 Pumps on at 100%

This scenario tests the existing water system for the future nighttime design base demand, equivalent to 65% of the maximum daily demand for 2025. The 65% was determined by averaging the ratio of Hourly Demand to Maximum Day Demand for the filling time of 10pm to 5 am (AWWA M31, pg 26). The water system configuration is the same as the Existing System Scenario, except two (2) pumps are on at Wellfield 2 (set to 100%). This scenario tests the maximum capability of the existing water system to fill Reservoir 1 using the design base demand. The results of the scenario are as follows:

- Base Demand = 592gpm (65% of 2025 Maximum Daily Demand)
- Reservoir #1 Fill Rate = 700gpm
- Pressure at Reservoir 1 during fill = 47psi
- Pressure at Wellfield 2 during fill = 85psi
- Minimum System Pressure during fill = 45psi

The results of this scenario show that the existing water system has the capability of filling of the 3mg reservoir during the night for the future 2025 design base demand. In order to meet the demand and still fill the tank, two (2) pumps at Wellfield 2 need to be turned on during the night. The fill rate of 700gpm corresponds to a total fill of 294,000 gallons over the 7-hour fill cycle.

3.3.6.3. Reservoir Fill Scenario #2: 2017 Infrastructure + Two (2) Wellfield 2 Pumps on at 100%+ North Kenai Transmission Main

This scenario has the same configuration as Scenario #1, but adds the AGDC Transmission Main extension with a 250gpm construction demand at the proposed AGDC LNG site. The results of the scenario are as follows:

- Base Demand = 842gpm (65% of 2025 Maximum Daily Demand+250gpm AGDC Demand)
- Reservoir #1 Fill Rate = 260gpm
- Pressure at Reservoir 1 during fill = 62psi
- Pressure at Wellfield 2 during fill = 93psi
- Minimum System Pressure during fill = 45psi

The results of this scenario show that the adding the AGDC water main extension and the 250gpm construction demand onto the existing City of Kenai water system reduces the filling rate of the 3mg reservoir during the night for the future 2025 design base demand even with two (2) pumps running at 100% at Wellfield 2. The fill rate of 260gpm corresponds to a total fill of 109,000 gallons over the 7 hour fill cycle.

3.3.6.4. Reservoir Fill Scenario #3: 2017 Infrastructure + Two (2) Wellfield 2 Pumps on at 100%+ North Kenai Distribution Main

This scenario has the same configuration as Scenario #2, but adds the 2025 demand for the future North Kenai service area between the existing system and the AGDC LNG site. The results of the scenario are as follows:

- Base Demand = 993gpm (65% of 2025 MDD & North Kenai Service Area + 250gpm AGDC Demand)
- Reservoir #1 Fill Rate = 84gpm
- Pressure at Reservoir 1 during fill = 63psi
- Pressure at Well #2 during fill = 94psi
- Minimum System Pressure during fill = 45psi

The results of this scenario show that the adding the AGDC water main extension with services to the North Kenai service area and the 250gpm construction demand onto the existing City of Kenai water system greatly reduces the filling rate of the 3mg reservoir during the night for the future 2025 design base demand even with two (2) pumps running at 100% at Wellfield 2. The fill rate of 84gpm corresponds to a total fill of 35,000 gallons over the 7-hour fill cycle.

3.3.6.5. Reservoir Fill Scenario #4: 2017 Infrastructure + Upgraded Pumphouse at Wellfield 2 + North Kenai Distribution Main

This scenario has the same configuration as Scenario #3, but adds an Upgraded pumphouse and distribution piping at wellfield 2. The two (2) new Well House #2 pumps are set at 88% to provide a maximum 100psi pressure during the 3 M-gal Reservoir #1 fill cycle. The results of the scenario are as follows:

- Base Demand = 993gpm (65% of 2025 MDD & KSH Service Area + 250gpm AGDC Demand)
- Reservoir #1 Fill Rate = 333gpm
- Pressure at Reservoir #1 during fill = 63psi
- Pressure at Well #2 during fill = 99psi
- Minimum System Pressure during fill = 45psi

The results of this scenario show that upgrading the pumphouse at wellfield #2 improves the fill rate of the 3mg reservoir over Scenario #3, but still falls short of the fill rate of the existing system configuration. The fill rate of 333gpm corresponds to a total fill of 140,000 gallons over the 7-hour fill cycle.

3.3.6.6. Reservoir Fill Scenario #5: 2017 Infrastructure + Two (2) Wellfield 2 Pumps on at 100%+ North Kenai Distribution Main + Seward Ave. Pump Station

This scenario has the same configuration as Scenario #3, but adds a virtual pumping station at the start of the AGDC water main extension near Seward Avenue. The results of the scenario are as follows:

- Base Demand = 993gpm (65% of 2025 MDD & KSH Service Area + 250gpm AGDC Demand)
- Reservoir #1 Fill Rate = 269gpm
- Pressure at Reservoir #1 during fill = 50psi
- Pressure at Well #2 during fill = 86psi
- Minimum System Pressure during fill = 45psi

The results of this scenario show that adding the virtual pumping station at Seward Ave improves the fill rate of the 3mg reservoir over Scenario #3, but still falls short of the fill rate of the existing system configuration. The fill rate of this Scenario also falls short of Scenario 4 with the upgraded Wellfield 2 pumphouse. The fill rate of 269gpm corresponds to a total fill of 113,000 gallons over the 7-hour fill cycle.

3.3.6.7. Reservoir Fill Scenario #6: 2017 Infrastructure + Upgraded Pumphouse at Wellfield 2 + North Kenai Distribution Main + Seward Ave. Pump Station

This scenario is a combination of both Scenario 4 and 5, adding Well House #2 upgrades and the virtual pumping station at Seward Ave. The results of the scenario are as follows:

- Base Demand = 993gpm (65% of 2025 MDD & KSH Service Area + 250gpm AGDC Demand)
- Reservoir #1 Fill Rate = 665gpm
- Pressure at Reservoir #1 during fill = 49psi
- Pressure at Well #2 during fill = 97psi
- Minimum System Pressure during fill = 45psi

The results of this scenario show performance results similar to Scenario #1. In order to meet the performance of the 2017 infrastructure with the additional demands of the north Kenai service area and the AGDC construction demand, the system would require upgrading wellfield 2 and providing a pumping station along the AGDC water main. The fill rate of 665gpm corresponds to a total fill of 279,000 gallons over the 7-hour fill cycle.

3.3.7. Fire Flow Discussion

The fundamental purpose of this study is to determine the City of Kenai water system performance that can be expected if the AGDC water main extension is constructed, and the increased demands are applied to the system. The six (6) different scenarios represent different demands and improvements to the water system in an attempt to recreate the performance of the existing system after the AGDC water main is constructed. The six (6) different scenarios were each analyzed for two (2) different fire flow demands, resulting in twelve (12) independent fire flow scenarios. In addition to the fire flow analysis, each scenario was analyzed to determine the capability of filling the Reservoir #1 3 million gallon tank.

3.3.7.1. Evaluation of Fire Flow Operating Scenarios

The sequentially numbered fire flow scenarios began with a model of the existing water system configuration with the 3 million gallon reservoir pumps online and one (1) Well House #2 pump online with the future 2025 Maximum Daily Demand applied. For the purpose of this study, existing conditions represented by Scenario 1 was selected as the baseline for comparison of subsequent scenarios. Scenario 1 provides needed fire flow to 99 percent of all nodes under max daily demand plus Residential fire flow, but as it stands, the current system configuration is unable to provide the ISO recommended fire flow to the commercial district. The calculated fire flow at the intersection of the Kenai Spur Highway and Bridge Access Rd. resulted in 2635gpm, below the required 3500gpm. Additional capacity is available from the existing distribution pumps at wellfield 2, but these pumps must be manually turned on or sped up by the water operators and may not be available during a fire event. The evaluations were performed with (1) wellfield 2 distribution pump set at 95% unless otherwise noted since this is the most common current usage.

3.3.7.1.1. Scenario 2 – Fire Flow Results

As expected, Scenario 2 decreased the performance of the water system by extending a new 20in water main approximately 6 miles northwest of the existing system and adding 250gpm demand for the AGDC LNG site. The scenario still provided the max daily demand plus 1000gpm Residential fire flow to all the nodes, except the same five (5) nodes that failed in Scenario 1. The max daily demand plus 3500gpm Commercial fire flow again is not met on any of the existing nodes or any of the additional nodes added on the main extension (409 nodes total).

3.3.7.1.2. Scenario 3 – Fire Flow Results

Scenario 3 further decreases the performance of the water system by applying the future demands from the surrounding developed areas along the water main extension. For this scenario, for the max daily demand plus 1000gpm Residential fire flow, seven (7) nodes failed within the city limits, and the nodes beyond Milepost 17 on the water main extension also failed (14 failing nodes total). As expected, the max daily demand plus 3500gpm Commercial fire flow performance further decreased from Scenario 2, failing at all nodes again.

3.3.7.1.3. Scenario 4 – Fire Flow Results

Well House #2 upgrades for Scenario 4, increases the performance from Scenario 3. Scenario 4 provides needed fire flow to all but five (5) nodes (99 percent of all nodes) under max daily demand plus 1000gpm Residential fire flow. Under max daily demand, plus 3500gpm Commercial fire flow, the performance improves by providing the needed fire flow to 69 out of the 409 nodes (17% total). Although the Commercial fire flows improve, the node at the intersection of the Kenai Spur Highway and Bridge Access Road is 3366gpm, which is slightly less than the desired 3500gpm.

3.3.7.1.4. Scenario 5 – Fire Flow Results

By adding a virtual pumping station near the start of the AGDC water main extension at Seward Ave., under max daily demand plus 1000gpm Residential fire flow, seven (7) nodes failed within the city limits (97 percent of all nodes passed). Adding the virtual pumping station does nothing to improve the percent of nodes passing under the max daily demand plus 3500gpm Commercial fire flow, with no nodes passing.

3.3.7.1.5. Scenario 6 – Fire Flow Results

Out of the six (6) scenarios, Scenario 6 has the best water system performance for fire flows, and is the only scenario to meet the Commercial fire flow required at the intersection of the Kenai Spur Highway and Bridge Access Rd. The scenario obtains the highest performance by increasing distribution pumping capacity at wellfield 2 and adding a new pumping station at Seward Ave., in addition to the 6 miles of distribution main between mile 14 and mile 20 of the Kenai Spur Highway. Scenario 6 increases the current fire flow performance of the existing City of Kenai Water System even when considering future increases in water demands.

3.3.8. Discussion of Reservoir #1 Filling Scenarios

3.3.8.1. Existing System Reservoir Fill Scenario Discussion

The sequentially numbered Reservoir #1 filling scenarios began with a model of the existing water system configuration with the 3 million gallon reservoir pumps offline and one (1) Well House #2 pump online to pressurize the system and fill the tank. This scenario was based on information provided by the city and was used to ensure the model was accurate.

3.3.8.2. Reservoir Fill Scenario #1 Discussion

Scenario 1 models the maximum performance expected while running two existing pumps at Well House #2 during the filling cycle when applying a night time factor for the future 2025 demand. For the purposes of this study, the conditions represented in Scenario 1 were used as the baseline for comparison for subsequent scenarios. With a Base Demand of 592gpm, the pumps in this scenario can fill Reservoir 1 at a rate of 700gpm while maintaining a minimum 45psi system pressure.

3.3.8.3. Reservoir Fill Scenario #2 Discussion

Scenario 2 introduces the water main extension and the 250gpm construction demand for the AGDC LNG site. With the nighttime Base Demand increased to 842gpm, the fill rate decreases to 260gpm while maintaining a minimum of 45psi system pressure, making this scenario an unsuitable option.

3.3.8.4. Reservoir Fill Scenario #3 Discussion

Scenario 3 is also an unsuitable option with the increased demand throughout the area north of Kenai along the new water main. In this scenario, the nighttime Base Demand increased to 993gpm, thereby decreasing the maximum Reservoir 11 fill rate to just 84gpm.

3.3.8.5. Reservoir Fill Scenario #4 Discussion

Scenario 4 includes the same nighttime Base Demand as Scenario 3 (993gpm), but includes upgrades to the Well House #2. With this scenario, the Reservoir 1 fill rate increases from Scenario 3 to 333gpm. Although an improvement from Scenario 3, the fill rate is still less than half of Scenario 1.

3.3.8.6. Reservoir Fill Scenario #5 Discussion

Scenario 5 includes the same nighttime Base Demand as Scenario 3 (993gpm), but includes a virtual pumping station at the start of the new AGDC main, near Seward Ave. The addition of the virtual pumping station improves the Reservoir 1 fill rate to 269gpm from Scenario 3. Again, although this is an improvement from Scenario 3, the fill rate is less than half of Scenario 1 and also less than Scenario 4.

3.3.8.7. Reservoir Fill Scenario #6 Discussion

As with the Fire Flow Scenarios, Scenario 6 provides the best performance for the fill rate at Reservoir 1 with the North Kenai distribution main extension in place. However, the estimated fill rate for scenario #6 (665gpm) is less than that for scenario #1 (700 GMP), indicating a slight loss in reservoir filling performance during the AGDC LNG Plant construction.

3.3.8.8. Reservoir #1 Turnover Rate Evaluation

The AWWA report, Maintaining Water Quality in Finished Water Storage Facilities, recommends water storage tanks be turned over about every 2.5 days (40% tank volume per day) to minimize water age and maximize water quality. The current 3 million gallon reservoir is not currently able to meet the AWWA recommended turnover rate, and instead operates at about a 19-day turnover rate (~5% of tank volume per day). Because of this reduced turnover rate the water operators closely monitor the chlorine residual in the water flowing out of the reservoir. A chlorine residual is always observed in the output water even with the reduced turnover rate likely due to mixing from the velocity of the inlet water and the cold temperature of the reservoir. The scenarios presented in this report will all reduce the current turnover rate for Reservoir #1 from the current rate, thereby increasing the age of the water within the tank before it is distributed throughout the water system. However, it should be noted that with the improvements in scenario 6, the reservoir 1 fill rate is increased 79% over the historical fill rate utilized by the operators as seen in the existing conditions scenario.

Reducing the reservoir fill rate also reduces the ability of the water operators to completely refill the reservoir during periods of peak usage. During a day of peak use or a large fire event, enough water is used from the reservoir that it may not be possible to refill the reservoir during the limited nighttime fill cycle. If this happens for an extended time period, the level in reservoir 1 is reduced and subsequently its ability to respond to a large fire event could be compromised. As recently as 2013, water use for outdoor washing and watering lawns was restricted in order to allow the reservoir to refill. The water shortage was mainly due to well production which has since been remedied by the drilling of more wells at wellfield 2. Also, the construction of Reservoir 2 has allowed nighttime fill rates to be increased because the distribution pumps speed can be increased during fill times to push out more water than is instantaneously produced by the wellfield.

3.3.8.9. Options for Increased Reservoir Filling Performance

The loss in reservoir 1 filling performance with the development in North Kenai is caused by the size of distribution lines between wellfield 2 and reservoir 1. As the flow between east and west Kenai is increased due to the increased demand from the North Kenai Area, the frictional resistance in the existing water mains increases. With a 100psi pressure threshold at wellfield 2 and no further water sources identified in West Kenai the only way to further increase the flow to west Kenai is to increase Main Capacity. The capacity of the mains can be increased by: increasing the size of the existing distribution mains, adding another distribution main, or adding another dedicated transmission main from wellfield 2 to reservoir 1. In the past, the city has explored an additional distribution main along Beaver Loop Rd and a dedicated transmission line from east to west Kenai but these improvements have not been constructed.

Constructing a dedicated transmission line from wellfield 2 to Reservoir 1 would result in a new water line approximately six (6) miles long from Wellfield 2 to Reservoir 1. In order to turn over 1.2mgd (833gpm) in Reservoir #1 in one (1) day, the dedicated water line would need to have the capacity to carry this amount of water each day. A 14in SDR11 HDPE pipe would have the capacity to carry the water with approximately 22psi pressure loss over the six (6) miles. It is important to consider that the average daily water use over the whole year for the city is currently less than 800,000 gallons per day, therefore even if all the water used by the city was distributed from reservoir #1 the tank is too large to meet the recommended turnover rate. At projected 2025 water use levels with the North Kenai water usage and LNG Plant construction usage the average daily demand would be 1.58mgd, resulting in over 75% of the city's water needing to be passed through reservoir 1 to meet the recommended 2.5 day turnover rate.

Because the performance of Scenario 6 and Scenario 1 are similar, these additional improvements for reservoir filling were not included as a recommendation in section 4.0.

3.3.9. Water Distribution Summary and Recommendation

3.3.9.1. Summary

A study on the City of Kenai Water system was performed to determine the effect of a 6 Mile long water main addition from mile 14 to mile 20 of the Kenai Spur Highway, and the resulting additional water demand from the AGDC LNG Plant and new services along the water line. Infrastructure improvements such as a new pump station at Seward Ave (mile 14 of the Kenai Spur Hwy) and distribution pumping improvements at Wellfield 2 were considered in the 6 different scenarios presented.

All of the scenarios with the Additional Water Demand from the LNG plant analyzed for the study show a decrease in performance relative to the existing City of Kenai water distribution system. The overall best performance of the scenarios tested was Scenario 6 with the distribution pumping improvements at wellfield 2 and the virtual pumping Station at Seward Ave. Although Scenario 6 provided a boost in fire flow performance throughout the City, the capacity of the system to fill Reservoir 1 was reduced by 5% relative to the capacity of the existing system. The other scenarios analyzed reduced the fire flows throughout the system and/or reduced the capacity of the system to fill Reservoir 1.

One option introduced in the study to increase Reservoir 1 fill performance was to construct a six (6) mile long 16in SDR11 HDPE dedicated water line from Wellfield 2 to Reservoir 1. The dedicated line could fill the reservoir throughout the day, eliminating the need to shut down the Reservoir #1 pumps to fill the tank during the night-time. The dedicated line would also allow an increase in the turnover rate of water cycling through the reservoir, thereby increasing water quality throughout the water system.

3.3.9.2. Recommendations

In order for the City of Kenai to distribute water to the AGDC LNG Plant and the North Kenai Service Area without a reduction in performance for the existing city users it is recommended to upgrade the distribution pumping at wellfield 2 and construct an inline pumping station at Seward Ave.

The distribution pumping upgrades at wellfield 2 include the construction of a new aboveground pumphouse with 230hp pumping capacity and the replacement if up to 500ft of transmission main.

These improvements were designed and bid ready construction documents were produced as a part of the reservoir 2 construction project in 2016. The improvements were not constructed at that time due to a lack of funds.

The pumping station at Seward Ave would likely take the form of a new aboveground building with max pumping capacity of 140hp. This pump station would act as a booster station to boost pressure in the new distribution line as the water flows north to the LNG plant site.

It is not anticipated at this time that the additional demands of the LNG facility and the North Kenai Service area would require the construction of a dedicated fill line for reservoir 2.

4. RECOMMENDED IMPROVEMENTS AND COST ESTIMATES

4.1. Recommended Improvements

The recommended improvements to the city of Kenai water system to accommodate providing water to the ADGC LNG facility include:

Water Production: Complete (2) new 12in diameter Wells, and yard piping at the wellfield 2 site.

Water Treatment: Expand Existing Treatment Plant Capacity from 1.5mg per day to 2.5mg per day. Plant capacity increase may not be required if a pilot test determines the existing filters could handle the projected flowrates. Arsenic treatment may be required in the event elevated arsenic levels are observed due to increased water production.

Water Distribution: Construct new distribution pumphouse and replace 500ft of distribution piping at Wellfield 2. Construct new pumphouse at Seward Ave. Construct 6.1 miles of new 16in HDPE distribution main connecting the west end of the existing city of Kenai system with the AGDC LNG Plant.

4.2. Concept Level Cost Estimate

The concept level cost estimate for the recommended improvements in section 4.1 are shown in Figure

8. This cost estimate total includes the construction cost as well as Engineering, Construction Inspection, City Administration, and a 10% Contingency.

Figure 8. Concept Level Cost Estimate for Improvements to the City of Kenai Water System for AGDC

Item	Unit Cost	Quantity	Extension
AGDC Water Main Extension	$250	32112	$8,028,000
Wellfield 2 Dist. Pumphouse Improvements	$1,200,000	1	$1,200,000
Seward Ave Pumping Station	$700,000	1	$700,000
12" Dia. Production Well and Yard Piping	$800,000	2	$1,600,000
Water Treatment Plant Capacity Upgrades[1]	$3,000,000	1	$3,000,000
		Construction Total	$14,528,000
Engineering. Design & Construction Inspection @15%			$2,179,200
City Admininstration @ 2%			$290,560
Contingency @ 10%			$1,699,776
		Total	$18,697,536

[1] Water Treatment Plant Capacity Upgrades may not be required if pilot study shows filters are adequate for additional flow.

Treatment for Arsenic is not currently required but may be required if higher pumping rates result in higher arsenic in the water at wellfield 2. Planning for future arsenic treatment should be completed as a contingency in the event elevated arsenic levels are observed. The planning should include the cost for an initial capital investment as well as O&M costs. Initial investment is anticipated to be as much as $4M and the O&M costs are anticipated to be approximately $400k per year.

5. REFERENCES

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Tonka Water. 2011. City of Kenai Water Treatment Facility O&M Manual. Process Memo Equipment Description.

Wang, Lili and Chen, Abraham S.C. 2011. Costs of arsenic removal technologies for small water systems: U.S. EPA arsenic removal technology demonstration program, epa/600/r-11/090: 69-77.

APPENDIX A

Graphical Representation of Junctions throughout the City of Kenai that Meet Desired Flows

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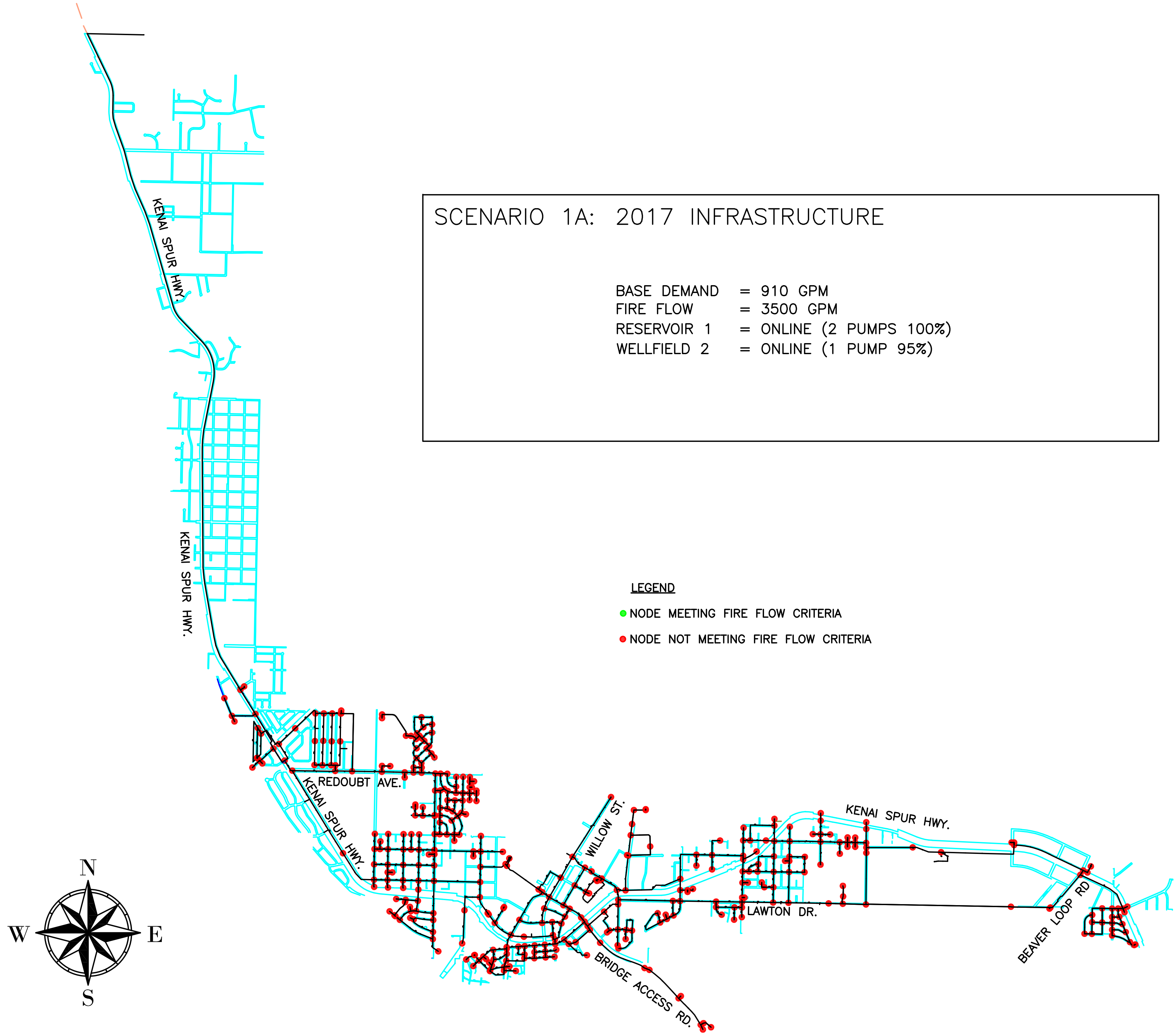


SCENARIO 1A: 2017 INFRASTRUCTURE

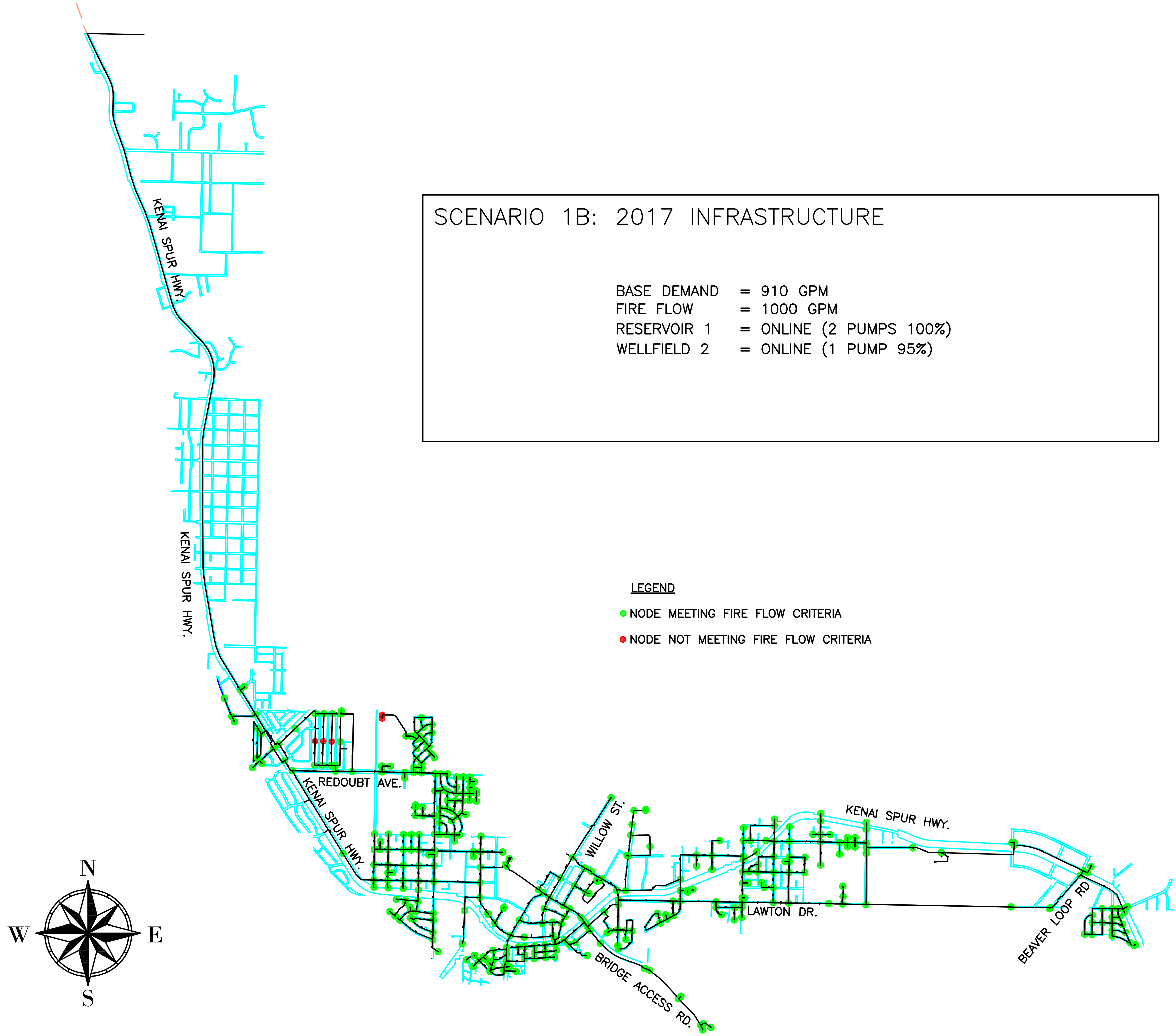
BASE DEMAND = 910 GPM
FIRE FLOW = 3500 GPM
RESERVOIR 1 = ONLINE (2 PUMPS 100%)
WELLFIELD 2 = ONLINE (1 PUMP 95%)

LEGEND

- NODE MEETING FIRE FLOW CRITERIA
- NODE NOT MEETING FIRE FLOW CRITERIA

SCENARIO 1B: 2017 INFRASTRUCTURE

BASE DEMAND = 910 GPM
FIRE FLOW = 1000 GPM
RESERVOIR 1 = ONLINE (2 PUMPS 100%)
WELLFIELD 2 = ONLINE (1 PUMP 95%)

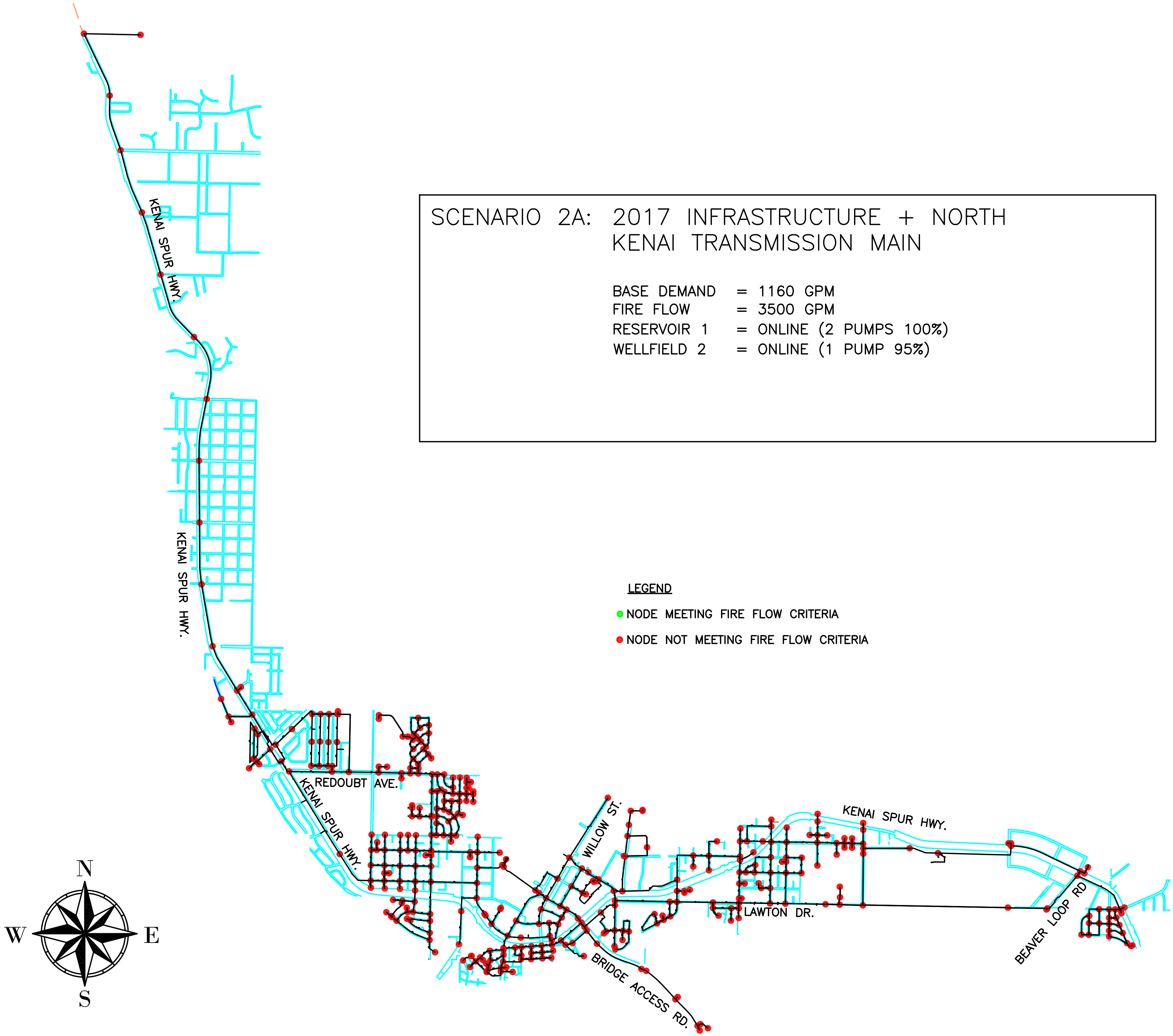


LEGEND

- NODE MEETING FIRE FLOW CRITERIA
- NODE NOT MEETING FIRE FLOW CRITERIA

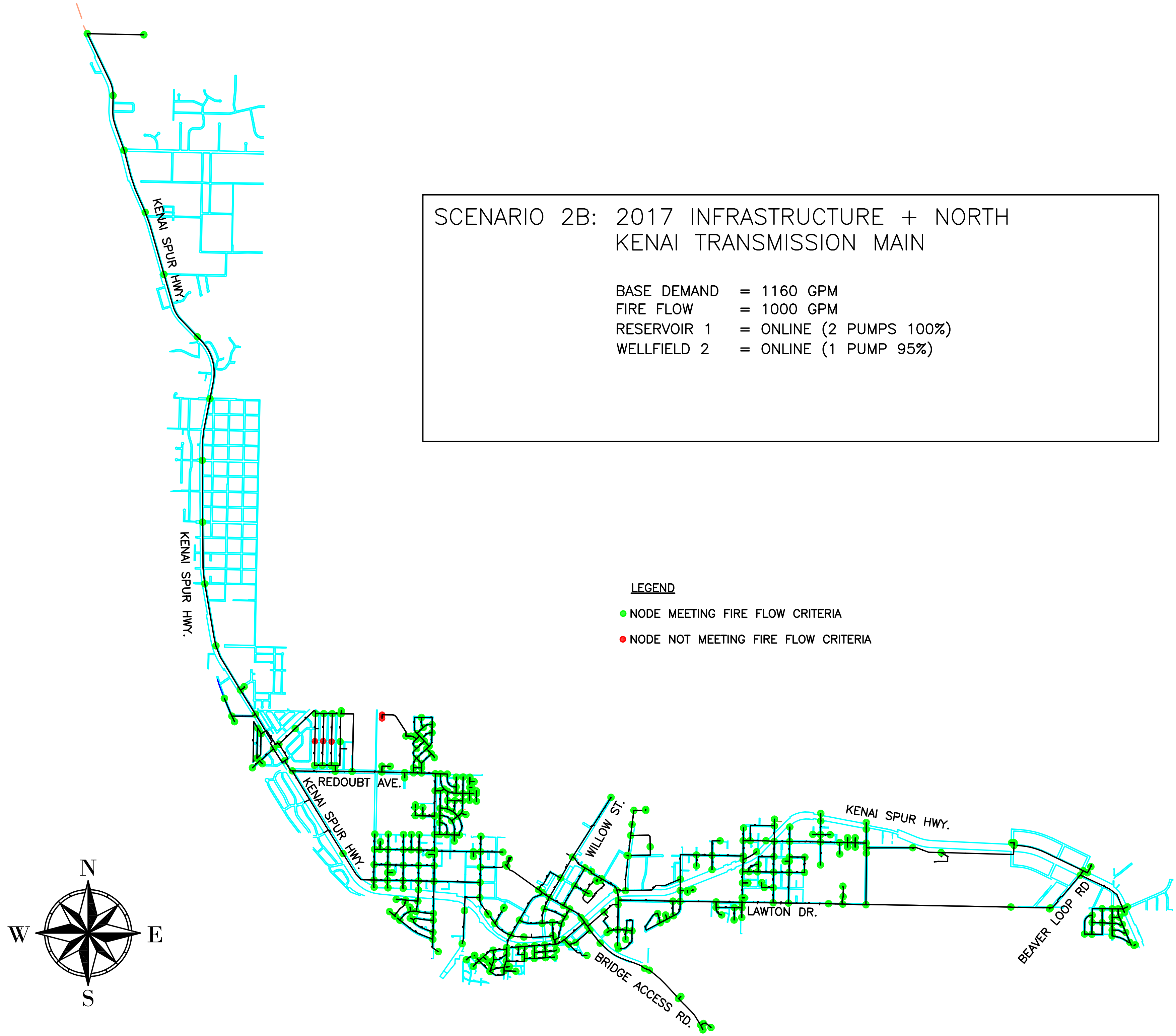
SCENARIO 2A: 2017 INFRASTRUCTURE + NORTH KENAI TRANSMISSION MAIN

BASE DEMAND = 1160 GPM
FIRE FLOW = 3500 GPM
RESERVOIR 1 = ONLINE (2 PUMPS 100%)
WELLFIELD 2 = ONLINE (1 PUMP 95%)



SCENARIO 2B: 2017 INFRASTRUCTURE + NORTH KENAI TRANSMISSION MAIN

BASE DEMAND = 1160 GPM
FIRE FLOW = 1000 GPM
RESERVOIR 1 = ONLINE (2 PUMPS 100%)
WELLFIELD 2 = ONLINE (1 PUMP 95%)



SCENARIO 3A: 2017 INFRASTRUCTURE + NORTH KENAI DISTRIBUTION MAIN

BASE DEMAND = 1392 GPM
FIRE FLOW = 3500 GPM
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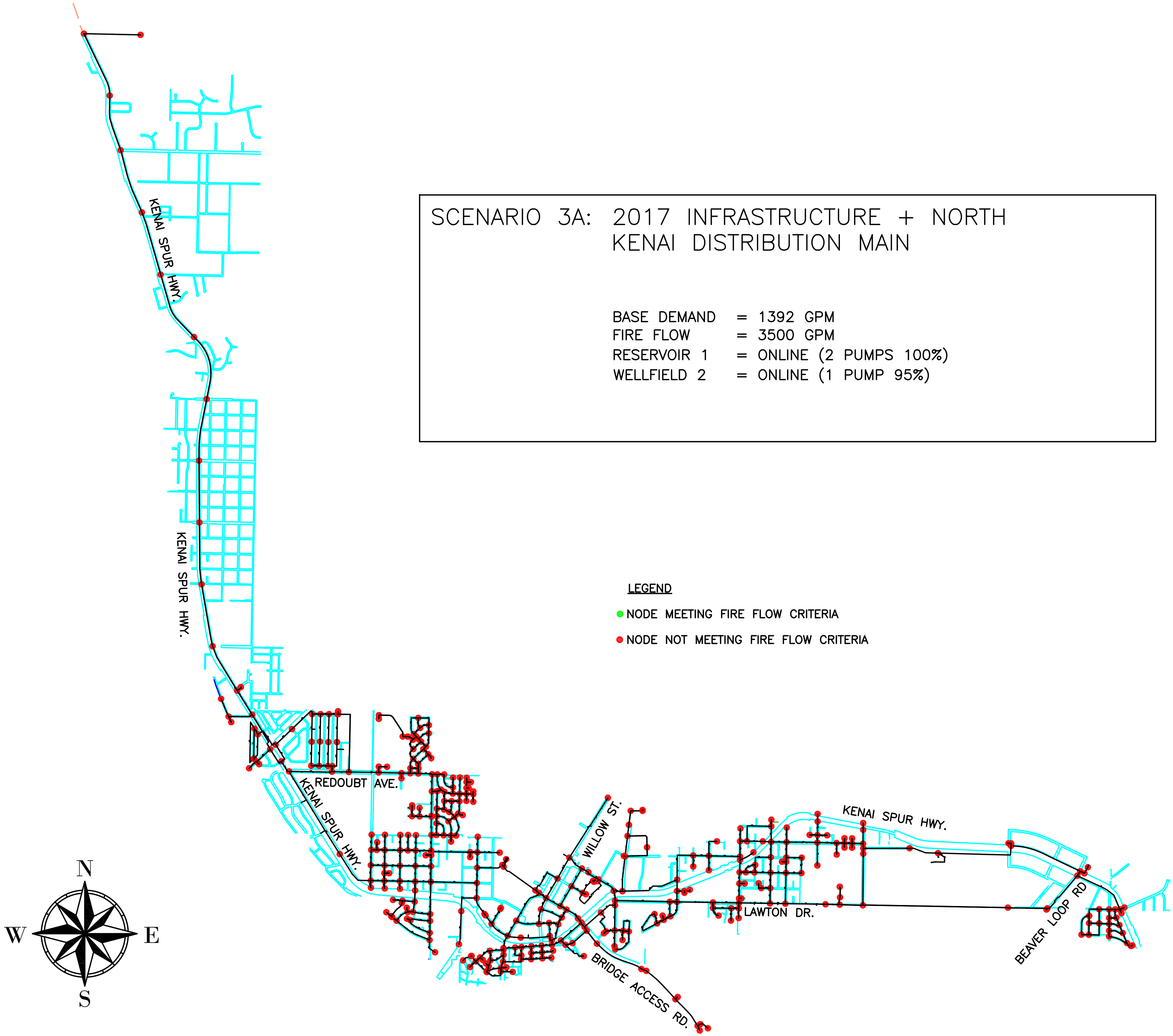
WELLFIELD 2 = ONLINE (1 PUMP 95%)



LEGEND

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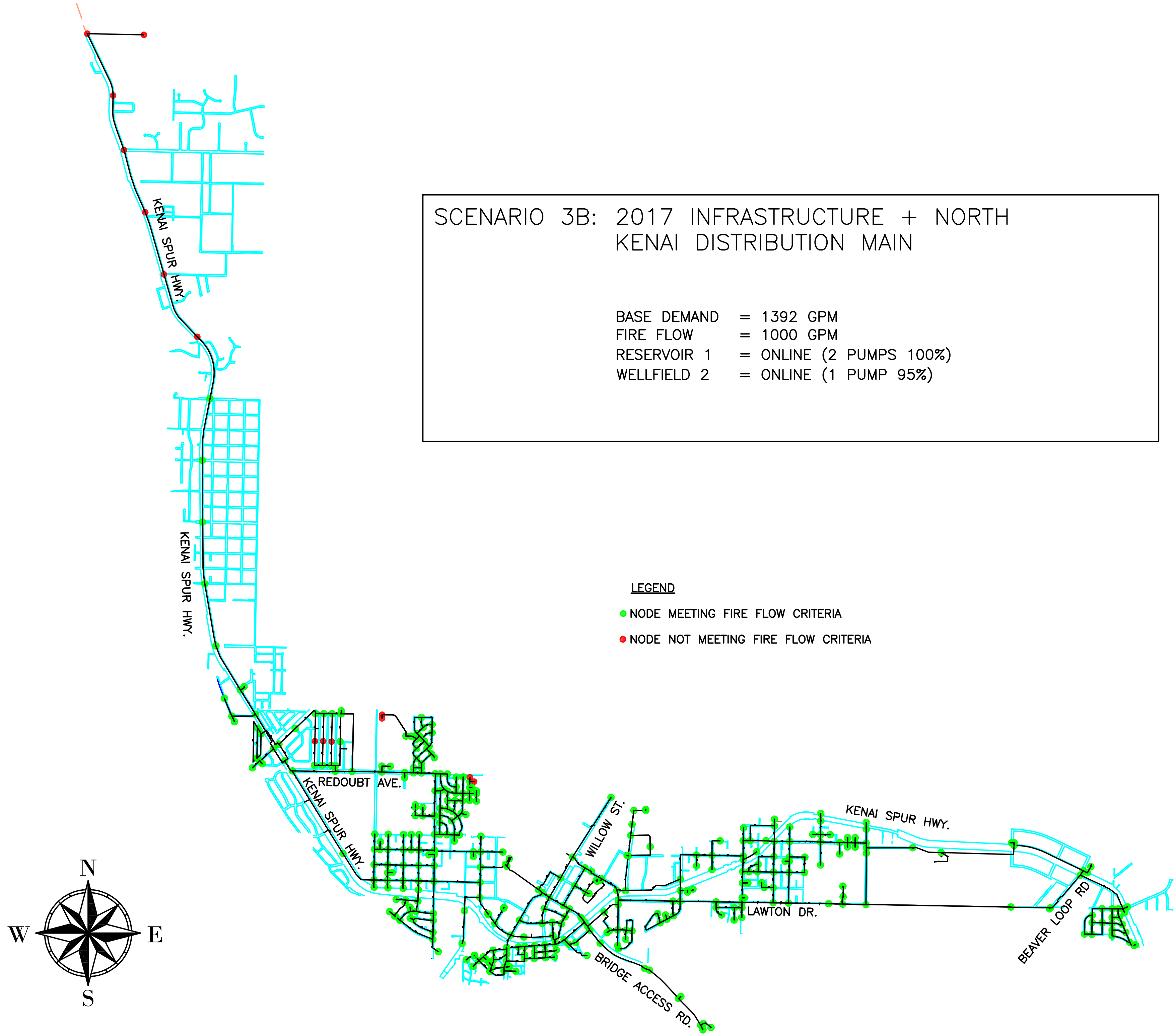
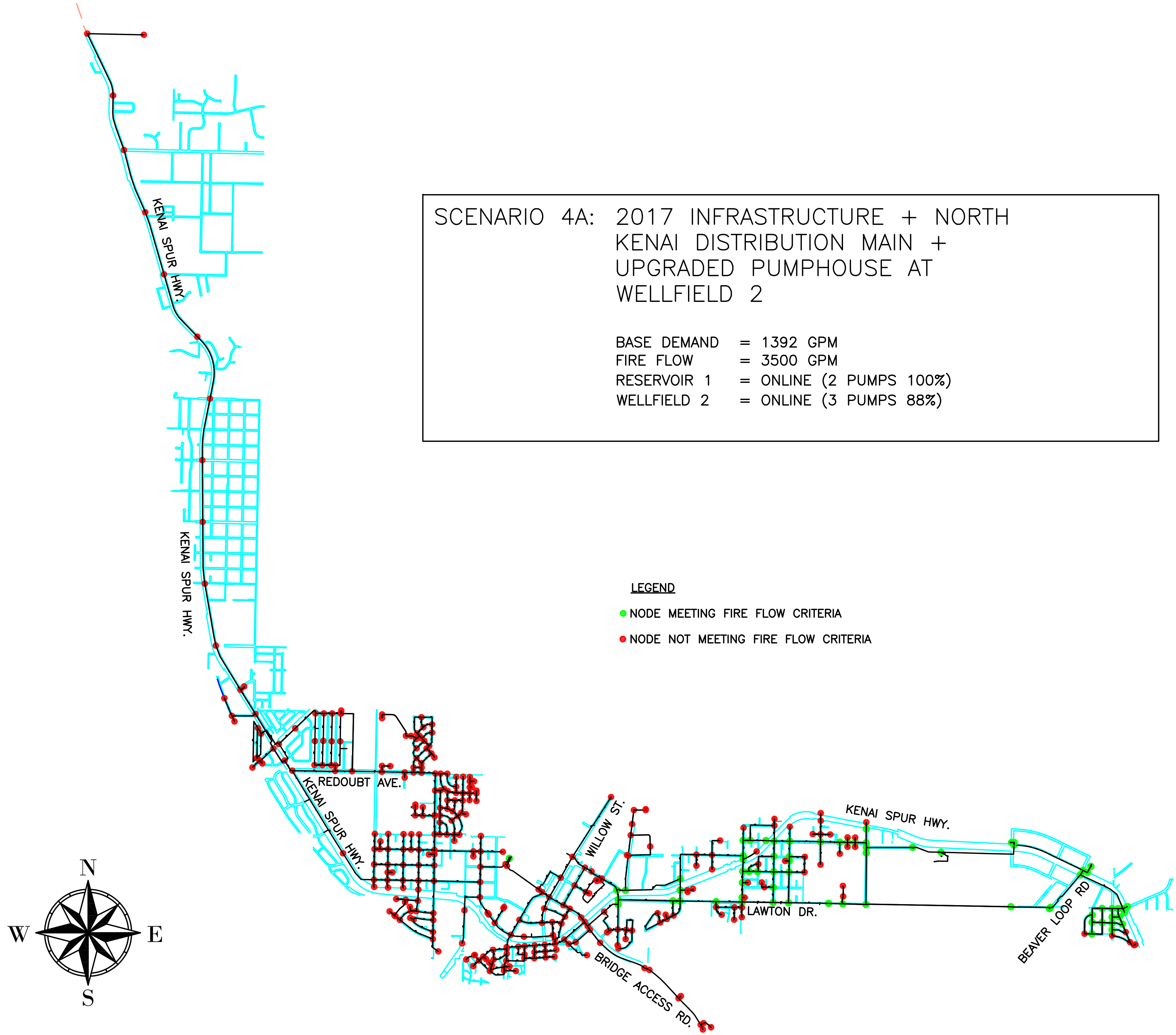
SCENARIO 3B: 2017 INFRASTRUCTURE + NORTH KENAI DISTRIBUTION MAIN

BASE DEMAND = 1392 GPM
FIRE FLOW = 1000 GPM
RESERVOIR 1 = ONLINE (2 PUMPS 100%)
WELLFIELD 2 = ONLINE (1 PUMP 95%)





SCENARIO 4A: 2017 INFRASTRUCTURE + NORTH KENAI DISTRIBUTION MAIN + UPGRADED PUMPHOUSE AT WELLFIELD 2

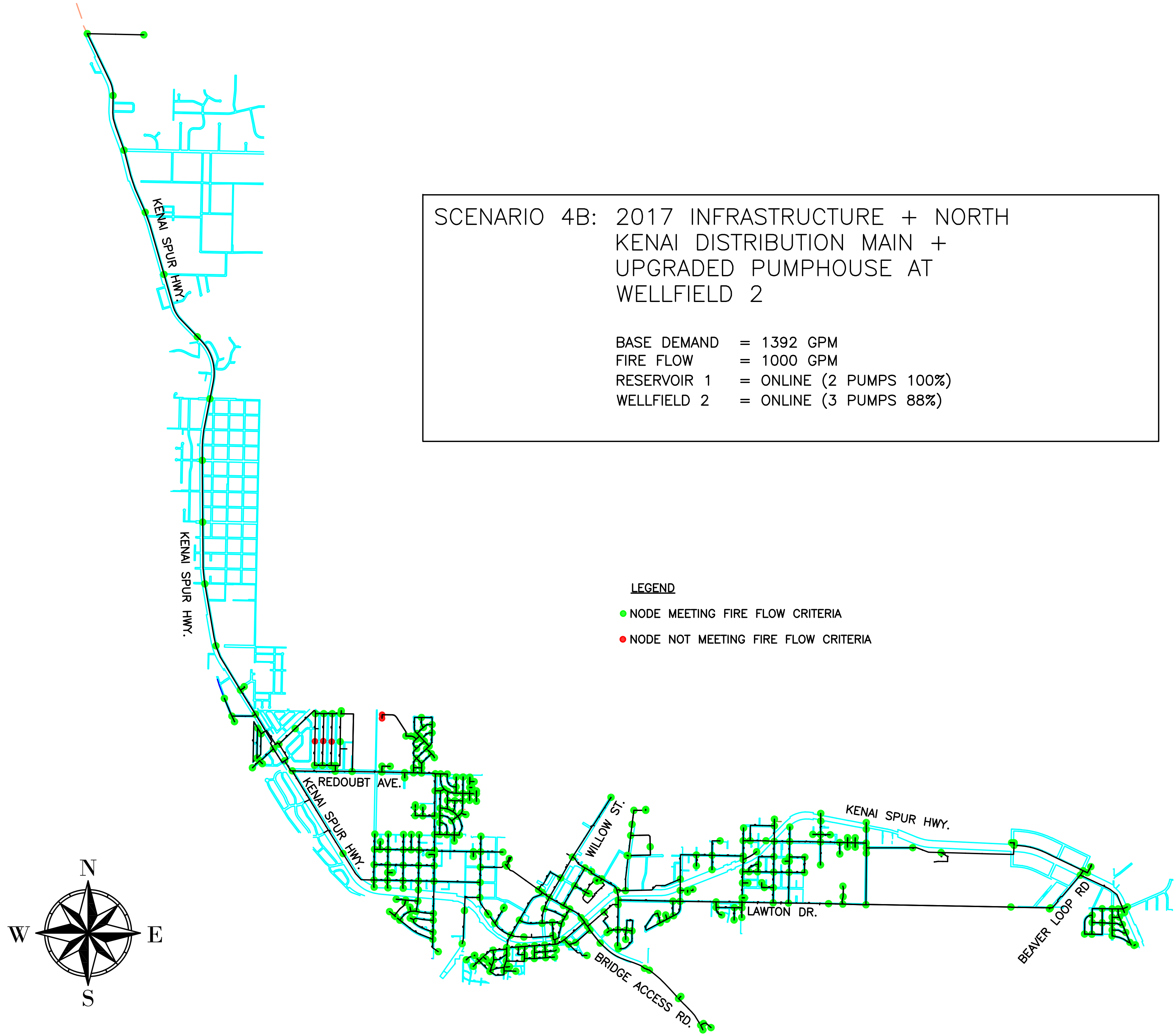
BASE DEMAND = 1392 GPM
FIRE FLOW = 3500 GPM
RESERVOIR 1 = ONLINE (2 PUMPS 100%)
WELLFIELD 2 = ONLINE (3 PUMPS 88%)

LEGEND

- NODE MEETING FIRE FLOW CRITERIA
- NODE NOT MEETING FIRE FLOW CRITERIA

SCENARIO 4B: 2017 INFRASTRUCTURE + NORTH KENAI DISTRIBUTION MAIN + UPGRADED PUMPHOUSE AT WELLFIELD 2

BASE DEMAND = 1392 GPM
FIRE FLOW = 1000 GPM
RESERVOIR 1 = ONLINE (2 PUMPS 100%)
WELLFIELD 2 = ONLINE (3 PUMPS 88%)



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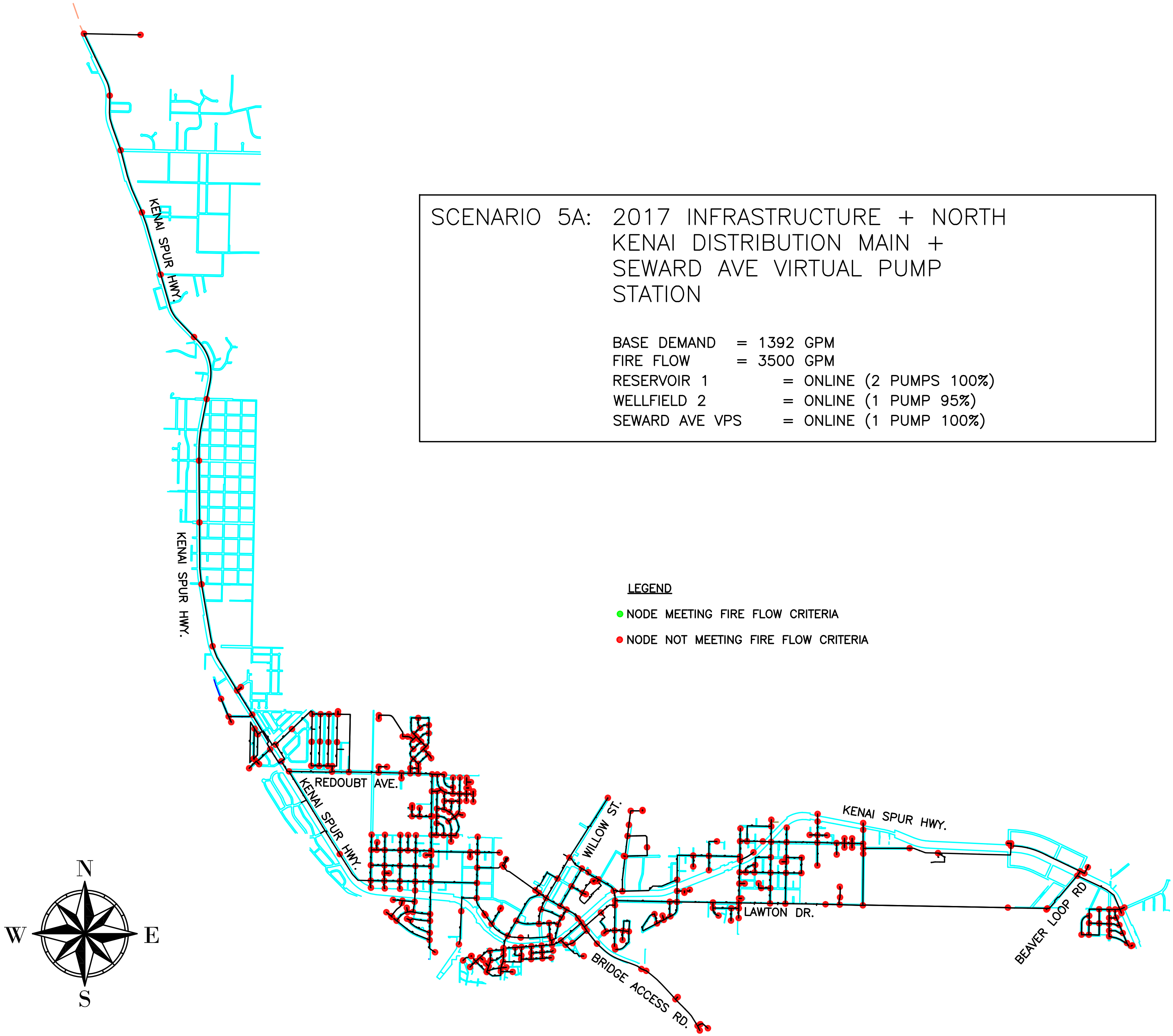
SCENARIO 5A: 2017 INFRASTRUCTURE + NORTH KENAI DISTRIBUTION MAIN + SEWARD AVE VIRTUAL PUMP STATION

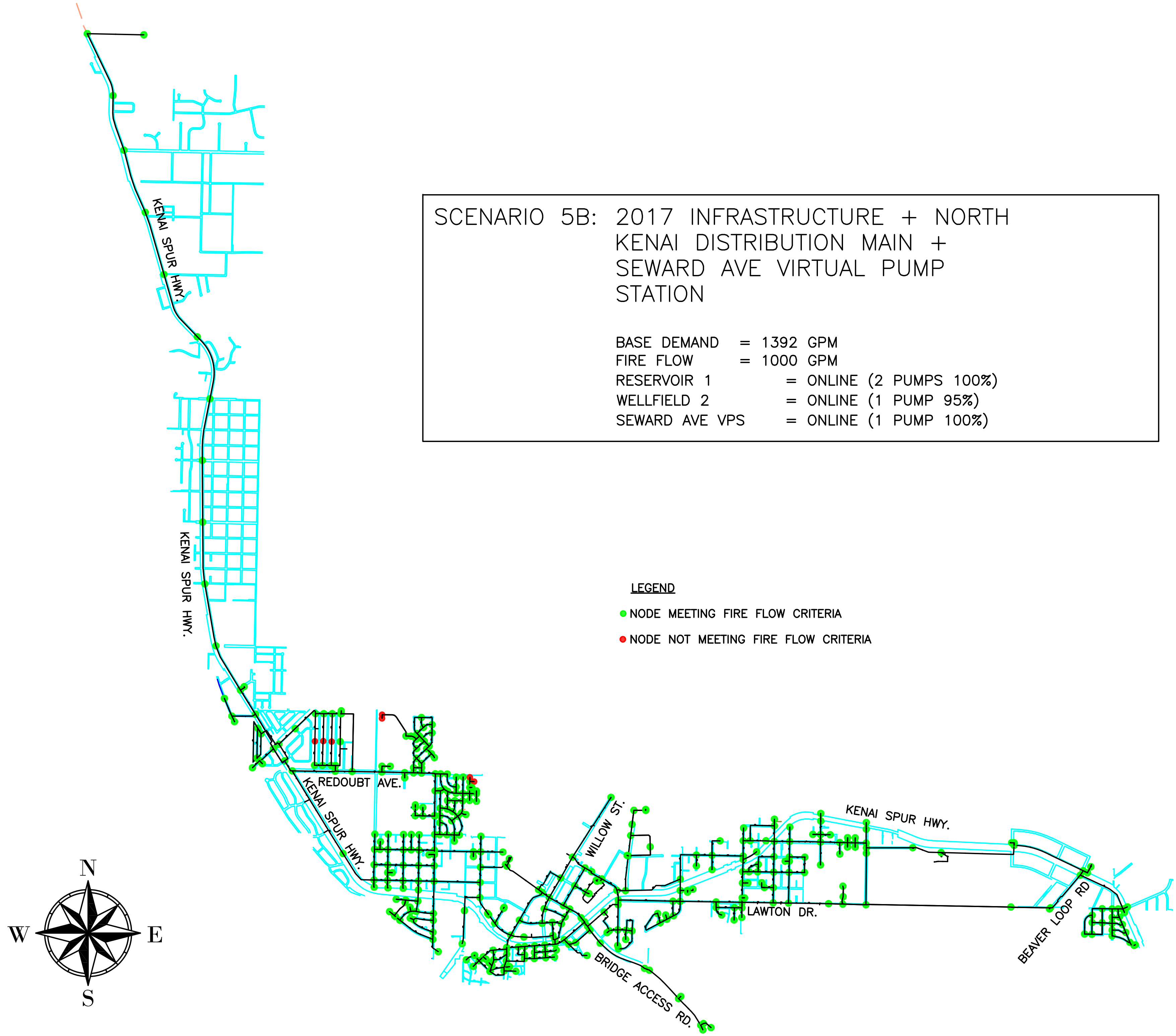
BASE DEMAND = 1392 GPM
FIRE FLOW = 3500 GPM
RESERVOIR 1 = ONLINE (2 PUMPS 100%)
WELLFIELD 2 = ONLINE (1 PUMP 95%)
SEWARD AVE VPS = ONLINE (1 PUMP 100%)

LEGEND

NODE MEETING FIRE FLOW CRITERIA

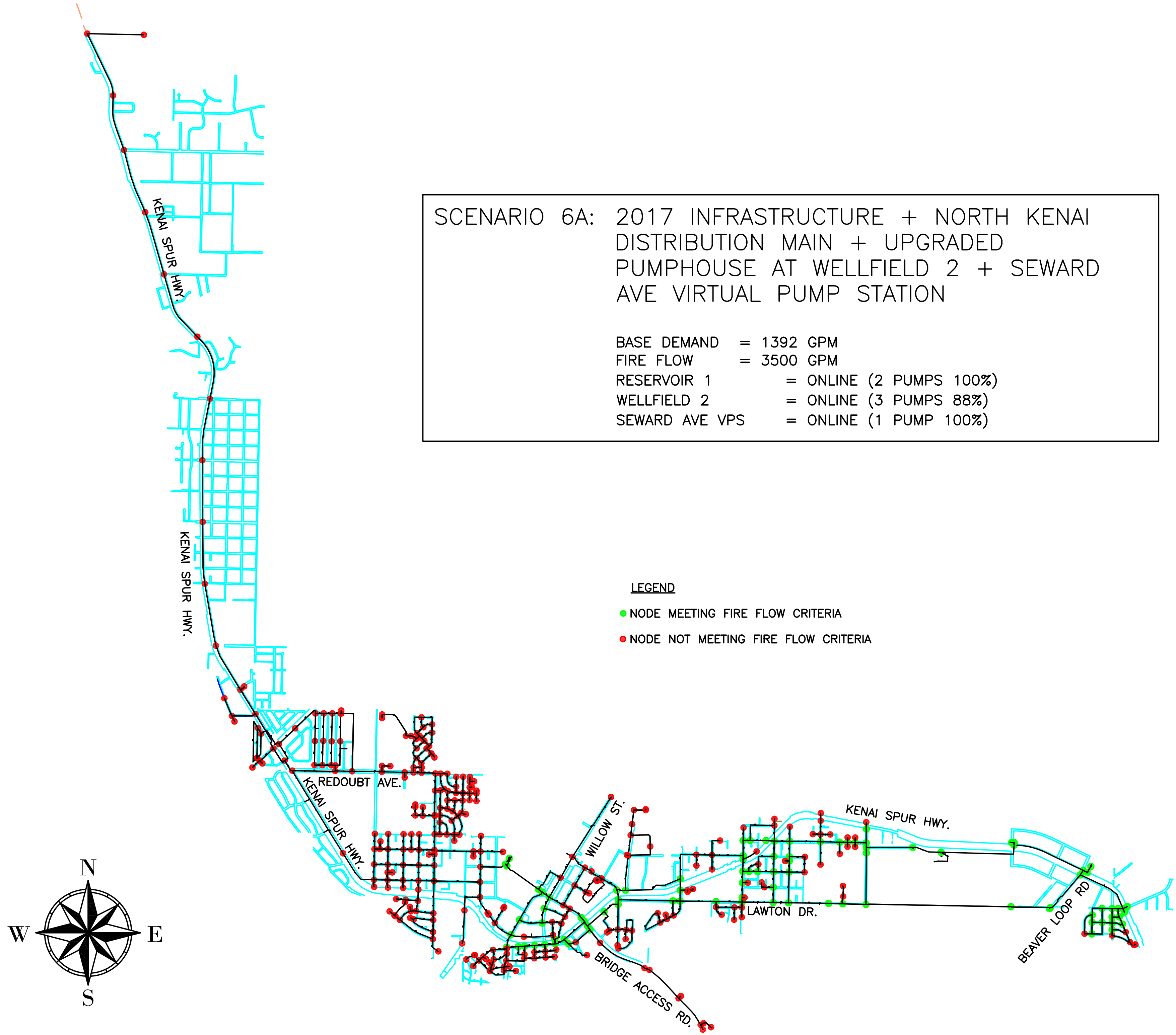
NODE NOT MEETING FIRE FLOW CRITERIA

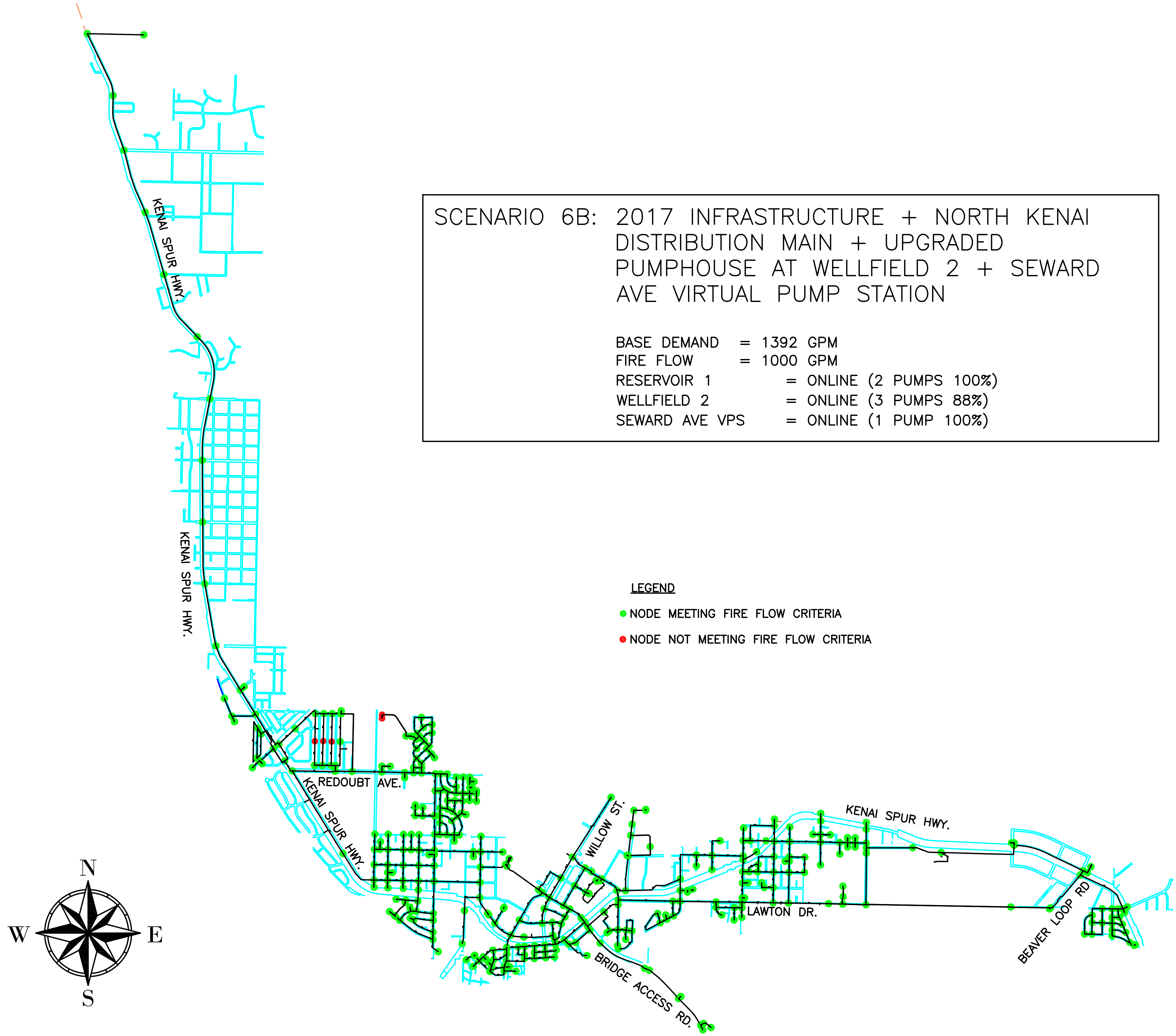



SCENARIO 5B: 2017 INFRASTRUCTURE + NORTH KENAI DISTRIBUTION MAIN + SEWARD AVE VIRTUAL PUMP STATION
BASE DEMAND = 1392 GPM
FIRE FLOW = 1000 GPM
RESERVOIR 1 = ONLINE (2 PUMPS 100%)
WELLFIELD 2 = ONLINE (1 PUMP 95%)
SEWARD AVE VPS = ONLINE (1 PUMP 100%)
LEGEND
NODE MEETING FIRE FLOW CRITERIA
NODE NOT MEETING FIRE FLOW CRITERIA
KENAI SPUR HWY.
KENAI SPUR HWY.
REDOUBT AVE.
KENAI SPUR HWY.
WILLOW ST.
KENAI SPUR HWY.
LAWTON DR.
BRIDGE ACCESS RD.
BEAVER LOOP RD
N
W
E
S

SCENARIO 6A: 2017 INFRASTRUCTURE + NORTH KENAI DISTRIBUTION MAIN + UPGRADED PUMPHOUSE AT WELLFIELD 2 + SEWARD AVE VIRTUAL PUMP STATION

BASE DEMAND = 1392 GPM
FIRE FLOW = 3500 GPM
RESERVOIR 1 = ONLINE (2 PUMPS 100%)
WELLFIELD 2 = ONLINE (3 PUMPS 88%)
SEWARD AVE VPS = ONLINE (1 PUMP 100%)





SCENARIO 6B: 2017 INFRASTRUCTURE + NORTH KENAI DISTRIBUTION MAIN + UPGRADED PUMPHOUSE AT WELLFIELD 2 + SEWARD AVE VIRTUAL PUMP STATION

BASE DEMAND = 1392 GPM
FIRE FLOW = 1000 GPM
RESERVOIR 1 = ONLINE (2 PUMPS 100%)
WELLFIELD 2 = ONLINE (3 PUMPS 88%)
SEWARD AVE VPS = ONLINE (1 PUMP 100%)

LEGEND

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- NODE NOT MEETING FIRE FLOW CRITERIA

APPENDIX B

Graphs of Pressure vs. Line Distance of each Secnario

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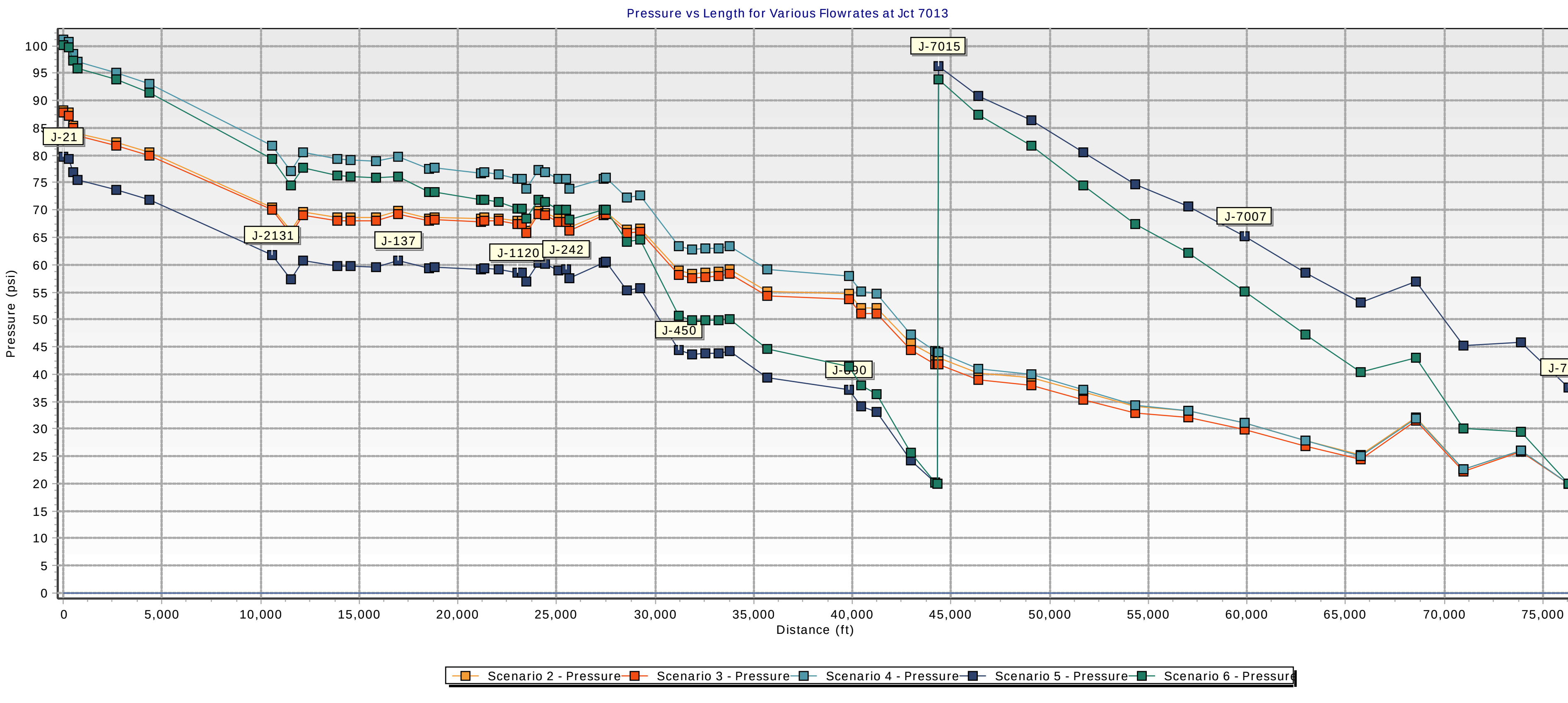
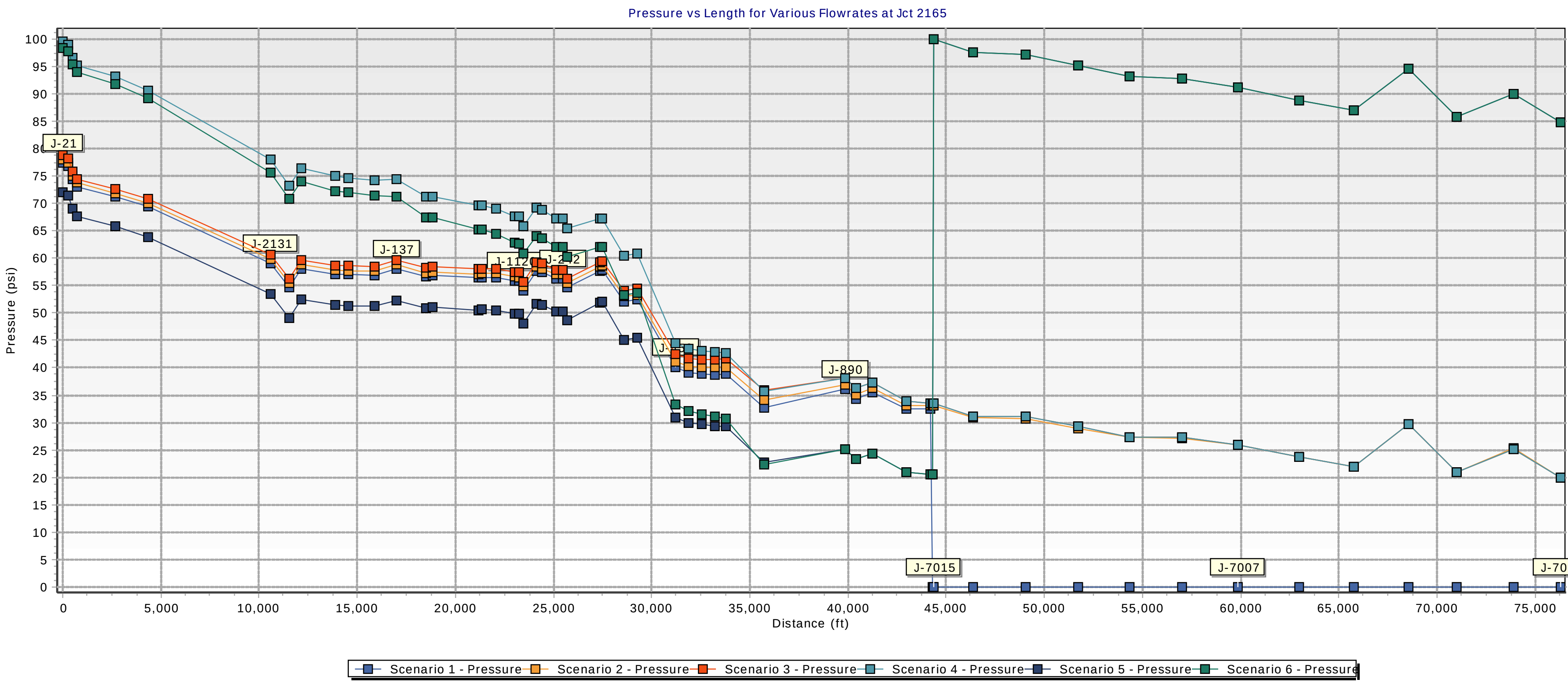


Pressure vs Length for Various Flowrates at Jct 7013
Pressure (psi)
Distance (ft)
J-21
J-2131
J-137
J-1120
J-242
J-450
J-690
J-7015
J-7007
J-7013
Scenario 2 - Pressure
Scenario 3 - Pressure
Scenario 4 - Pressure
Scenario 5 - Pressure
Scenario 6 - Pressure



Pressure vs Length for Various Flowrates at Jct 2165
Pressure (psi)
Distance (ft)
J-21
J-2131
J-137
J-890
J-7015
J-7007
J-7013
Scenario 1 - Pressure
Scenario 2 - Pressure
Scenario 3 - Pressure
Scenario 4 - Pressure
Scenario 5 - Pressure
Scenario 6 - Pressure

APPENDIX C

City of Kenai Water System Map / Graphical Model

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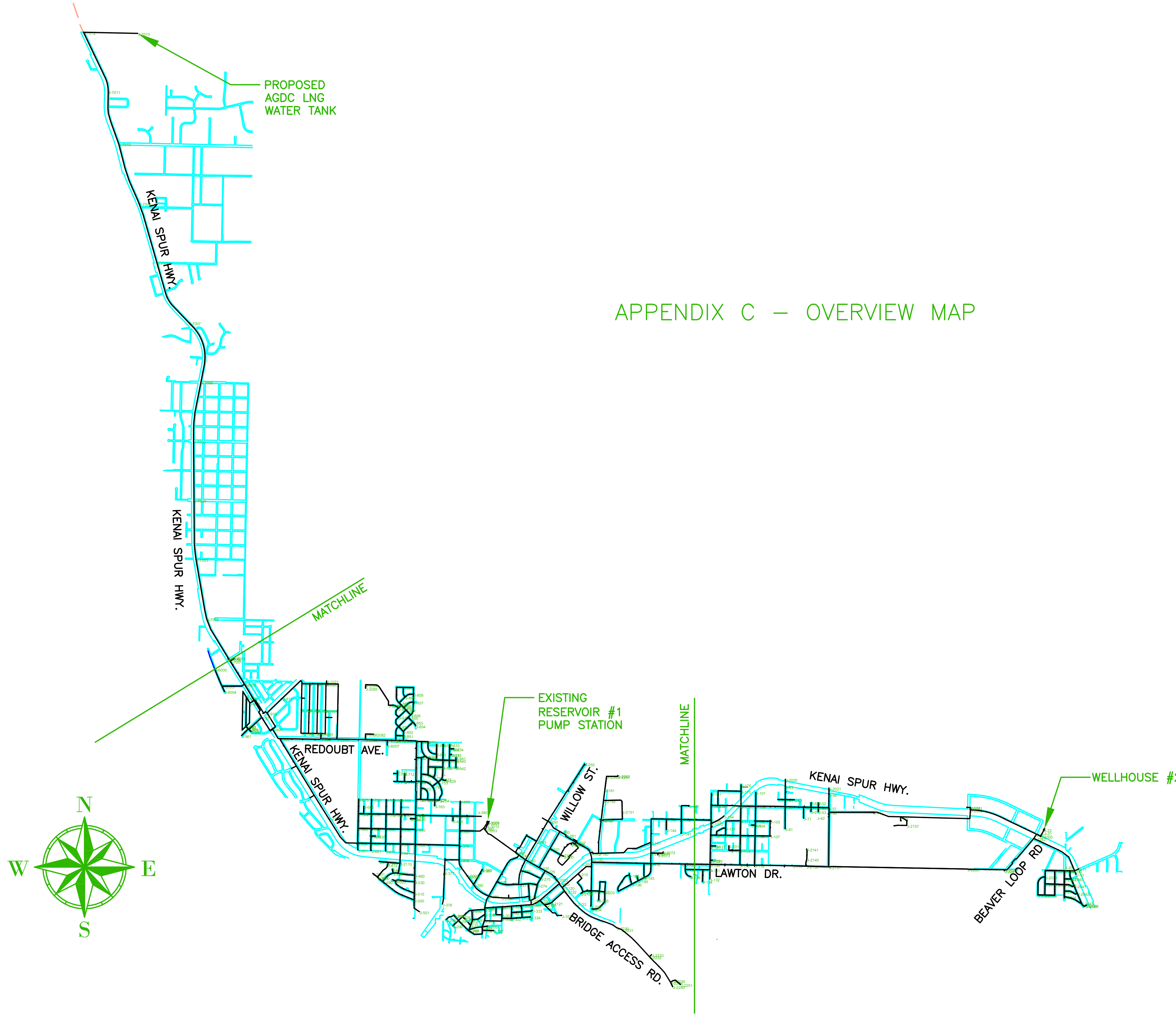
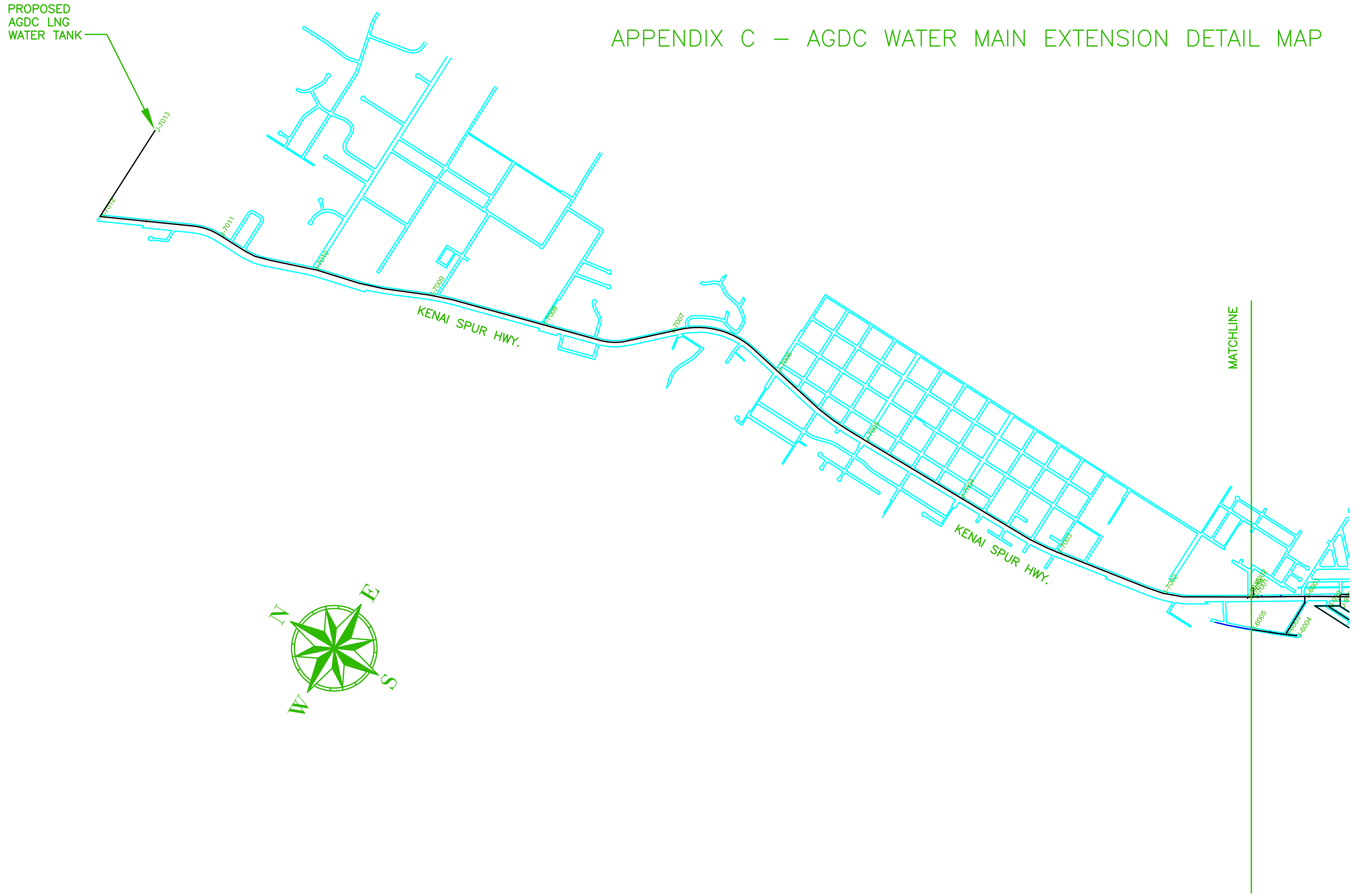
APPENDIX C — OVERVIEW MAP

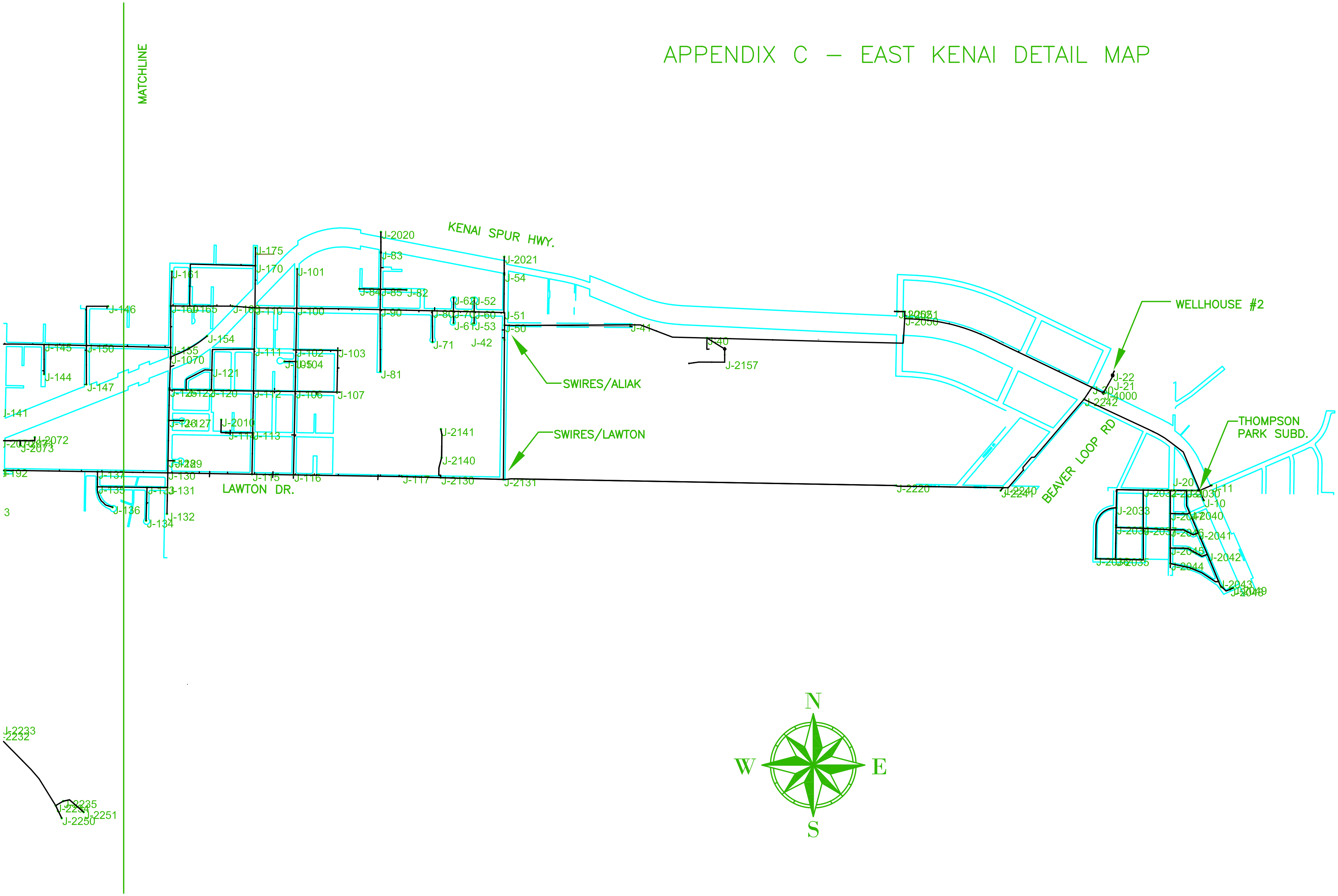


APPENDIX C – AGDC WATER MAIN EXTENSION DETAIL MAP



APPENDIX C – WEST KENAI DETAIL MAP

APPENDIX C — EAST KENAI DETAIL MAP



APPENDIX D

Water Source Evaluation – City of Kenai Well Field 2

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Public

Water Source Evaluation – City of Kenai Well Field 2

December 28, 2017

AKLNG-4030-OOO-RTA-DOC-00003

Alaska LNG
3201 C Street, Suite 200
Anchorage, Alaska 99503
T: 907-330-6300
www.alaska-lng.com

REVISION HISTORY

Rev	Date	Description	Originator	Reviewer	Approver
0	Dec 28, 2017	For Use	Nelson Engineering – J.A. Munter Consulting Inc.		Fritz Krusen
Approver Signature*					

*This signature approves the most recent version of this document.

MODIFICATION HISTORY

Rev	Section	Modification

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ACRONYMS AND ABBREVIATIONS

ft .... foot / feet
gpm .... gallons per minute of water
LNG................................ Liquefied Natural Gas
MCL .... Maximum Contaminant Level
µg/L .... micrograms/Liter
MGD .... Million Gallons per Day of water
TDS. .... Total Dissolved Solids

EXECUTIVE SUMMARY

This reconnaissance-level evaluation of the City of Kenai Well Field 2 found that additional development of the water resources at Well Field 2 to supply water for the proposed LNG facility and associated additional demand in the area appears to be feasible. This includes projected population and water-use growth in the existing and future City of Kenai water service area. While it is unlikely that expanded water production would draw in significant amounts of salt water or human-caused contamination from surrounding areas, an increase in concentrations of naturally-occurring arsenic to levels above the maximum containment level (MCL) is a risk considering the common presence of arsenic in surrounding areas.

Also, some surrounding private wells could be adversely affected by the increased withdrawal at distances up to a few miles away. These adverse effects could result either from a reduced ability to pump water from existing private wells or from worse quality of water either from existing, deepened, or new wells. To some extent, however, increases in future pumping at Well Field 2 to meet City water demands, even without development of the LNG facility, could result in increased arsenic in City wells or adverse effects on surrounding wells.

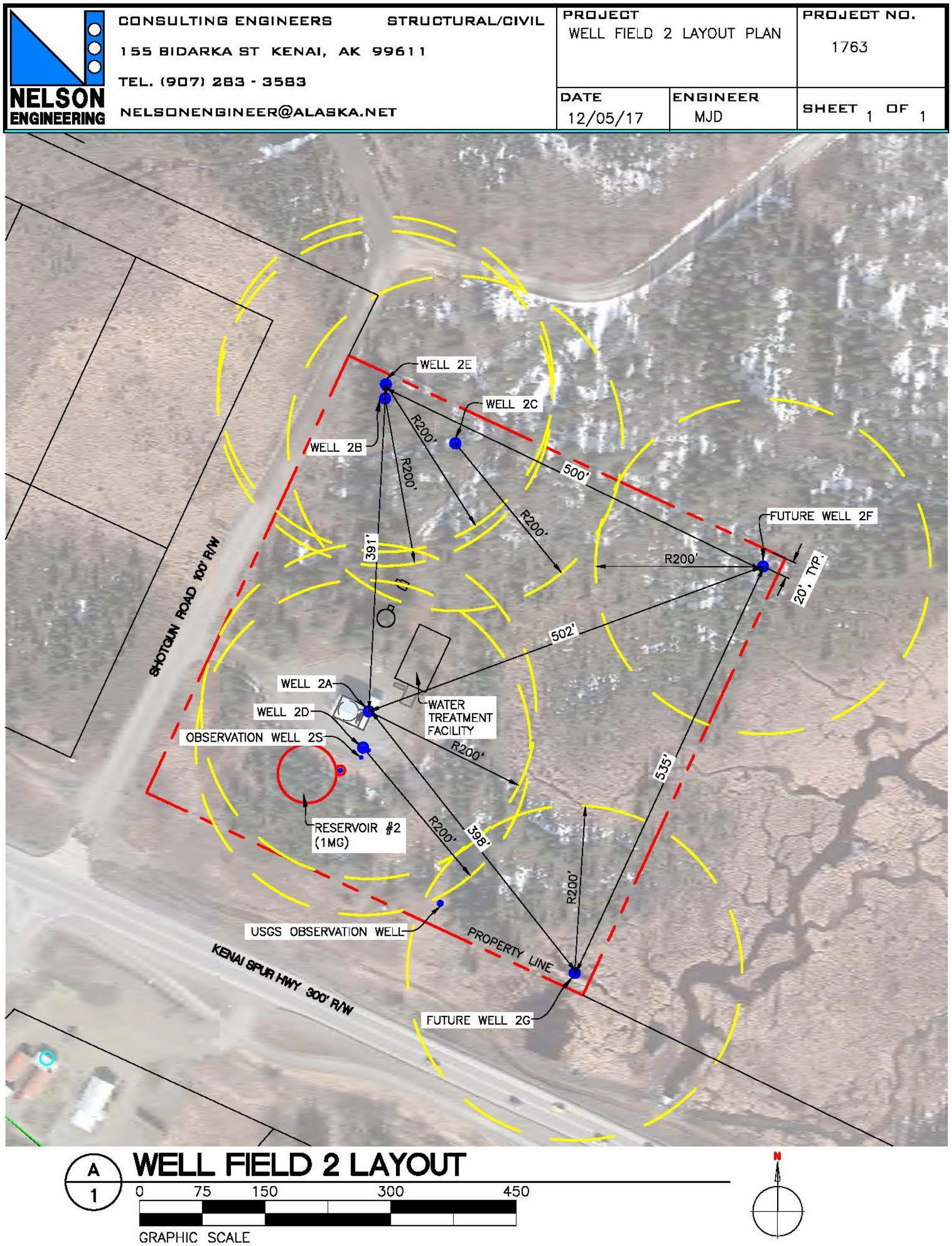
Additional baseline data collection and analysis, facility maintenance and capital improvements, establishment of long-term monitoring networks, and planning for mitigative actions are suggested for consideration should water use from Well Field 2 increase as proposed.

1. INTRODUCTION

1.1. Background and Objectives

The City of Kenai obtains all of its water under normal operating conditions from a well field (Well Field located near the junction of the Kenai Spur Highway and Beaver Creek (Figure 1). Other City of Kenai wells exceed water-quality criteria (primarily arsenic) and are not routinely used. This report presents a reconnaissance-level evaluation of the capacity of the main well field to supply additional water required for the development of the proposed LNG facility, including projected population and water use growth in the existing and future City of Kenai water service area. Additionally, potential impacts on surrounding private well owners and potential water quality impairments from contaminated sites, naturally-occurring arsenic, salt-water intrusion and upconing are addressed. Finally, initial considerations regarding further data collection and analysis, design, maintenance, monitoring and mitigation are provided for preliminary planning purposes.

Figure 1. Well Field 2 Layout



2. WELL FIELD 2

2.1. Hydrogeologic Setting

Well Field 2 obtains water from an unconsolidated confined sand and gravel aquifer. Glass (1996) reports that the composition and hydrologic properties of unconsolidated aquifers in this area differ greatly over short horizontal and vertical distances. Thus, depths, yields, water levels, and water quality of closely spaced wells are commonly dissimilar. The depth to bedrock is estimated to be approximately 500 feet in the vicinity of Well Field 2, and little is known about deeper aquifers at the site of Well Field 2.

2.2. Well and Aquifer Characteristics

Well Field 2 consists of 12-inch diameter production wells 2A and 2E and six-inch diameter production wells 2D and 2C. Other wells at the site include wells 2S, 2B, and the USGS observation well (see Figure 1). All wells tap a confined sand and gravel aquifer generally found at a depth interval of approximately 120 to 225 feet below ground surface. There are silty semi-confining layers within the aquifer at various depth levels that separate the aquifer into upper and lower productive water-bearing zones. The first well drilled at the site, the USGS well, encountered flowing artesian conditions with a water level reportedly 29 feet above land surface. The well was tested at a flow rate of 1100 gallons per minute (Anderson, 1971). An aquifer test conducted in 2010 using Well 2A as the pumping well resulted in the estimation of aquifer transmissivity of 13,500gpd/ft^2 and storativity of 0.0022 (J. A. Munter Consulting, Inc., 2010). An aquifer test conducted at the USGS well resulted in a calculated transmissivity of 73,500gpd/ft^2 assuming that the aquifer was non-leaky (Anderson, 1971). Aquifer testing at another test well further downstream in the Beaver Creek valley (Anderson and Jones, 1972) indicated that the confined aquifer should be considered a leaky confined aquifer and the resulting transmissivity estimate should be lower than that calculated assuming a non-leaky aquifer. A review of the pumping and water-level data collected since Well 2E began pumping shows that the well has a specific capacity of approximately

30 gallons per minute of water (gpm)/ft of drawdown, suggesting that the transmissivity of the aquifer at that site could be approximately 60,000gpd/ft^2, using a method described by Sterrett (2007). The available data suggest that the aquifer transmissivity may be somewhat larger than that estimated by the 2010 test. Also, under long-term pumping, the aquifer may best be characterized as a leaky aquifer (i.e. water leaks into the aquifer from adjacent semi-permeable confining beds).

2.3. Current Conditions

Currently, water is pumped intermittently from all four production wells. Figure 2 presents a summary of total well field pumping for the twelve-month period from August 2016 through July 2017. Water- level readings are made daily in both pumping and non-pumping wells. Figure 3 shows selected water- level data from non-pumping wells in the well field. These data show that the potentiometric surface in the well field at non-pumping wells 2D and 2E is approximately 29 feet above sea level, compared to the pre-development potentiometric surface of approximately 70 feet above sea level, suggesting that water development has caused approximately 41 feet of historical water-level decline. A modest increase in water levels attributable to spring recharge is noted.

Figure 2. Total Reported Pumpage at Well Field 2 between August 2016 and July 2017

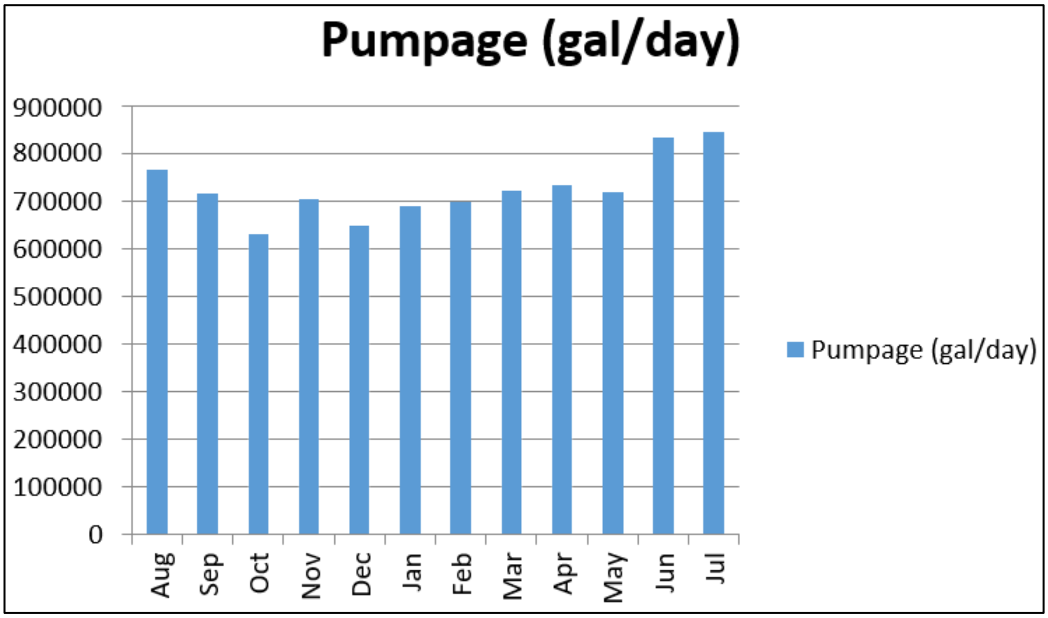
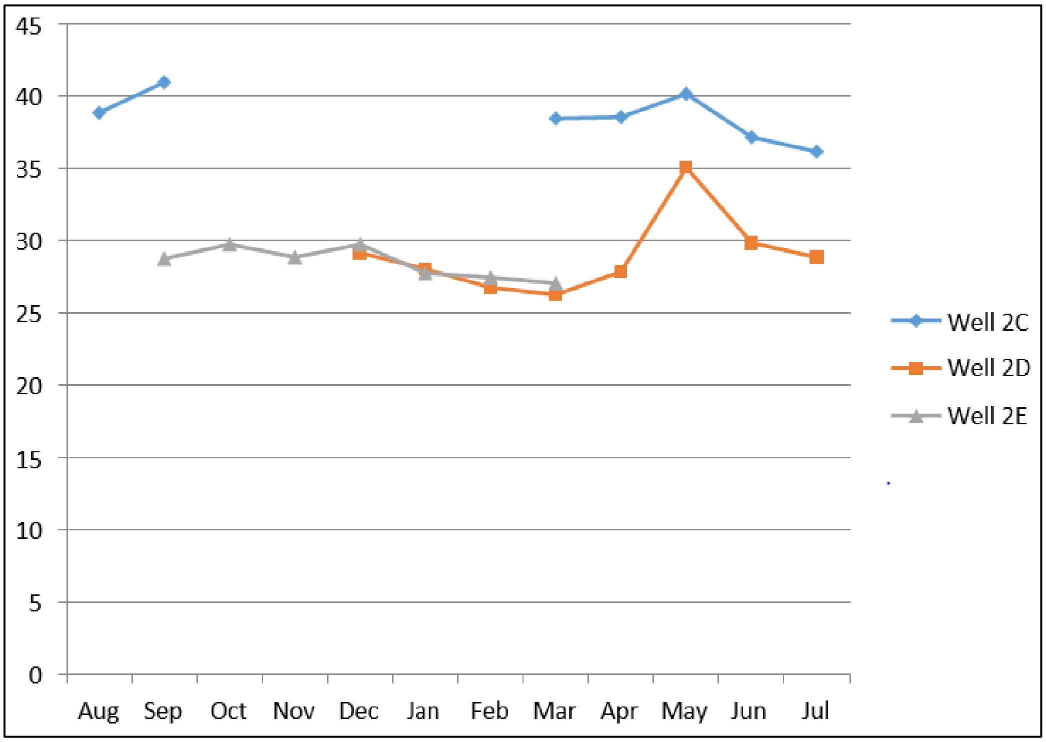


Figure 3. Reported Monthly-Average Water Level Elevations in Non-pumping Wells from August 2016 - July 2017



(In feet above mean sea level)

2.4. Evaluation of Historic Pumping and Drawdown

Water use data has been compiled since 2011 for Well Field 2, and shows a gradual decline of average annual production from 0.96 million of gallons per day of water (mgd) to 0.73mgd (M. Dura, written communication, 2017). Average production during this period has been 0.845mgd. The method of Theis (1935) can be used to compare actual drawdown observed at Well Field 2 with model projections of what would be expected, considering the aquifer characteristics determined from the 2010 aquifer test described above and the reported historic pumping. Assuming that pumping began at the beginning of 2011, the Theis (1935) method predicts 58 feet of drawdown in the well field at a distance of 200 feet away from a single well pumping at an average rate of 0.845mgd. This is somewhat larger than the observed drawdown in the well field, suggesting that the method is somewhat overly conservative (i.e. somewhat over-predicts drawdown) in its long-term projections. This will be addressed more fully later in this report. A simulation of one year of pumping at a flow rate closer to current pumping, 0.73mgd, results in 42 feet of calculated drawdown, which is close to what has been observed. The reason for the over-prediction of drawdown is likely caused by the aquifer having a higher transmissivity than estimated; the aquifer receives recharge, the confining beds act as leaky confining beds, or some combination of these factors. Overall, however, this analysis of historical pumping and water level data supports the concept that the Theis (1935) methodology is applicable to a reconnaissance analysis of the response of the aquifer to pumping at Well Field 2.

3. CURRENT AND PROJECTED WATER USE

3.1. City of Kenai Water Use

3.1.1. Current City Water Use

Current annual average City of Kenai reported water use for the period August 2016 to July 2017 is approximately 726,000 gallons per day (gpd) (Figure 2), with average summer demand of 814,000gpd, a 17 percent increase over non-summertime use. Considering the three-year period between 2014-2017, the peak monthly average use was 900,000gpd and the estimated maximum daily demand was 1.22mgd (M. Dura, Written Communication, 2017).

3.1.2. Projected City Water Use

Population growth in the City of Kenai is expected to result in a 7% increase in water use in 2025 compared to 2015 demand levels and a 13.3% increase in water use in 2045 compared to 2015 demand levels (M. Dura, Written Communication, 2017). Extension of water mains and new service connections in the future North Kenai service area could add an average of approximately 208,000gpd beginning after a service line is constructed through the area. (M. Dura, Oral Communication, 2017).

3.2. Projected LNG Water Use

During the construction phase of the LNG facility, which is expected to last approximately eight years from 2019 to 2027, an average of 250gpm (360,000gpd) would be needed for the construction camp. After construction, operational water use for the LNG facility would average approximately 150gpm (216,000gpd).

3.3. Projected Total City of Kenai and LNG Water Use

This analysis requires that assumptions be made about the rates and durations of future pumping from Well Field 2. These assumptions include projecting average annual water use for future years and estimating peak water-use periods for higher-than-average summer periods and also for peak daily use. These shorter periods of peak use can have a meaningful effect on drawdown in the well field and the ability of wells to meet typical demands.

3.3.1. Annual Average Water Use

For this analysis, it will be assumed that beginning in 2019 and for eight years thereafter, total estimated average water use would be 1.348mgd (936gpm) (780,000gpd City water use plus 360,000gpd construction camp water use plus 208,000gpd for the future North Kenai service area. After construction is complete, LNG facility water use would decline by 100gpm (14,000gpd), however population growth would gradually result in City of Kenai use increasing to approximately make up the difference. For the long-term planning purposes of this report, it will be assumed that annual average water demand would be 1.35mgd beginning in 2019 and continuing for a 30-year planning period thereafter.

3.3.2. Future Summertime Peak Demand

Population estimates through 2045 indicate that population (and therefore water use, except for LNG plant water use) would increase 13.3 percent from 2015 levels. This suggests that summertime average water demand would grow to 1.47mgd in 2045. This is rounded to 1.5mgd.

3.3.3. Future Daily Peak Demand

The ratio of current daily peak water demand to average annual water demand is 1.58. Applying this ratio to City of Kenai and future North Kenai service area demands in 2045 results in a total estimated peak daily demand at that time of 1.965mgd. This is rounded to 2mgd.

4. WELL FIELD 2 ANALYSIS

4.1. Methodology and Assumptions

Projection of the effects of future pumping of groundwater can be made using the method of Theis (1935) to mathematically simulate future pumping. Numerical calculations using this method were made using software developed by HydroAps (1992). The Theis (1935) method relies on certain simplifying assumptions. It is assumed that the aquifers are infinite in lateral extent without boundary conditions, are homogeneous and isotropic, and that recharge does not occur within the simulation time period. While these assumptions are simplifications of actual aquifer conditions, the Theis (1935) model is widely used and can provide an initial assessment of the magnitude of the likely effects of pumping.

The principal of superposition is used to simulate multiple pumping wells and multiple pumping durations and rates. The Theis (1935) model calculates theoretical drawdowns for a production well, however experience shows that actual pumping wells exhibit additional drawdown caused by well loss, which is a manifestation of head (water-level) losses caused by turbulent flow entering the well. The well efficiency is defined as the theoretical drawdown divided by the actual drawdown in a pumping well. Well-efficiency data are not clearly known for all the wells, and especially for wells not yet constructed. For this analysis it is assumed that production wells are/will be 80 percent efficient.

Available drawdown is the maximum amount of water-level drop that a production well can experience while still producing water. In Well 2A, for example, the pump is set in a section of unperforated casing set between upper and lower screened intervals in the well. The top of the uppermost screen is set at 156.5ft below land surface. Drilling records do not provide a reliable indication of what the static water level was at the time the well was drilled. The USGS well, when drilled, reported a static water level 29 feet above land surface. The land surface elevation at the well site at City Well No. 2 is approximately 9 feet above the USGS site. The recovery data collected from the deep and shallow observation wells during the 2010 test (J. A. Munter Consulting, Inc., 2010) suggests that the static water level at the site was likely in the range of 10 to 20 feet above land surface. It will be assumed for all existing and new production wells in this analysis that the static water level is 10 feet above land surface (or at an elevation of approximately 160 feet above sea level), and that water levels may be drawn down to the top of the screen setting. In Well 2A, that results in a total available drawdown of 166 feet. Assuming a well efficiency of 80% the available drawdown is 133 feet. Table 1 shows comparable amounts of total available drawdown calculated for the other wells, including a potential future well, Well 2F, whose proposed location is shown in Figure 1.

Table 1. Well Data and Simulation Results

Well	Top of Screen (feet below grade)	Total Avail-able Draw-down (ft)	Available draw- down assuming 80% efficient wells (ft)	Scenario 1 Rate of pumping (gpm)	Total calcu-lated draw-down (ft)	Scenario 2 Rate of pumping (gpm)	Total calcu-lated draw-down (ft)	Scenario 3 Rate of pumping (gpm)	Total calcu-lated draw-down (ft)
2A	156.5	166	133	300	114	321	123	390.4	141
2C	141	151	121	100	89	121	98	190.4	116
2D	203	213	170	200	108	221	118	290.4	136
2E	140	150	120	150	91	171	100	240.4	116
2F	140	150	120	187.5	91	208.5	100	277.9	114

4.2. Simulation Parameters

Simulation in this report use a value of transmissivity (T) of 13,500gpd/ft2 and value of storativity of the aquifer of 0.0022. Long-term average pumping durations are assumed to last for a period of two years. Beyond two years, it is assumed that aquifer recharge or leakage through the confining beds would offset any further water-level declines. This is considered reasonable because most of the drawdown caused by pumping would occur during the first two years and because of the influence of seasonal recharge noted in Figure 2.

4.3. Simulation Scenarios

4.3.1. Scenario 1

First, long-term average pumping at an average rate of 1.35mgd (937.5gpm) is simulated. Preliminary calculations found that the existing four producing wells were unlikely to be able to sustain this rate plus expected peak pumping periods. Thus, a new well, Well 2F, is simulated at the location shown in Figure 1. Well 2F is assumed to be constructed identical to well 2E. The amounts of simulated pumping from each well are shown in Table 1.

4.3.2. Scenario 2

Second, elevated summertime demand of 1.5mgd (1042gpm) is simulated for a three-month period during the final three months of the two-year simulation period in Scenario 1. This elevated rate of pumping is spread equally among all five wells.

4.3.3. Scenario 3

Finally, peak daily demand of 2mgd (1389gpm) is simulated during the last day of Scenario 2. This extra pumping is also spread equally among the five pumping wells.

4.4. Simulation Results

Table 1 shows the resulting calculated drawdowns for each of the simulation scenarios. These scenarios are intended to simulate the actual conditions that are expected, including higher than average summertime and peak daily use. The results show that Well 2A would slightly exceed the expected amount of available drawdown in the well (assuming it was 80% efficient) and the other wells would be close their maximum potential flow rate. Careful management of flow rates and use of system storage, would likely allow production of the required quantity of water, but there would not be very much, if any, margin of extra water to cover unexpected conditions or uncertainty in the analysis.

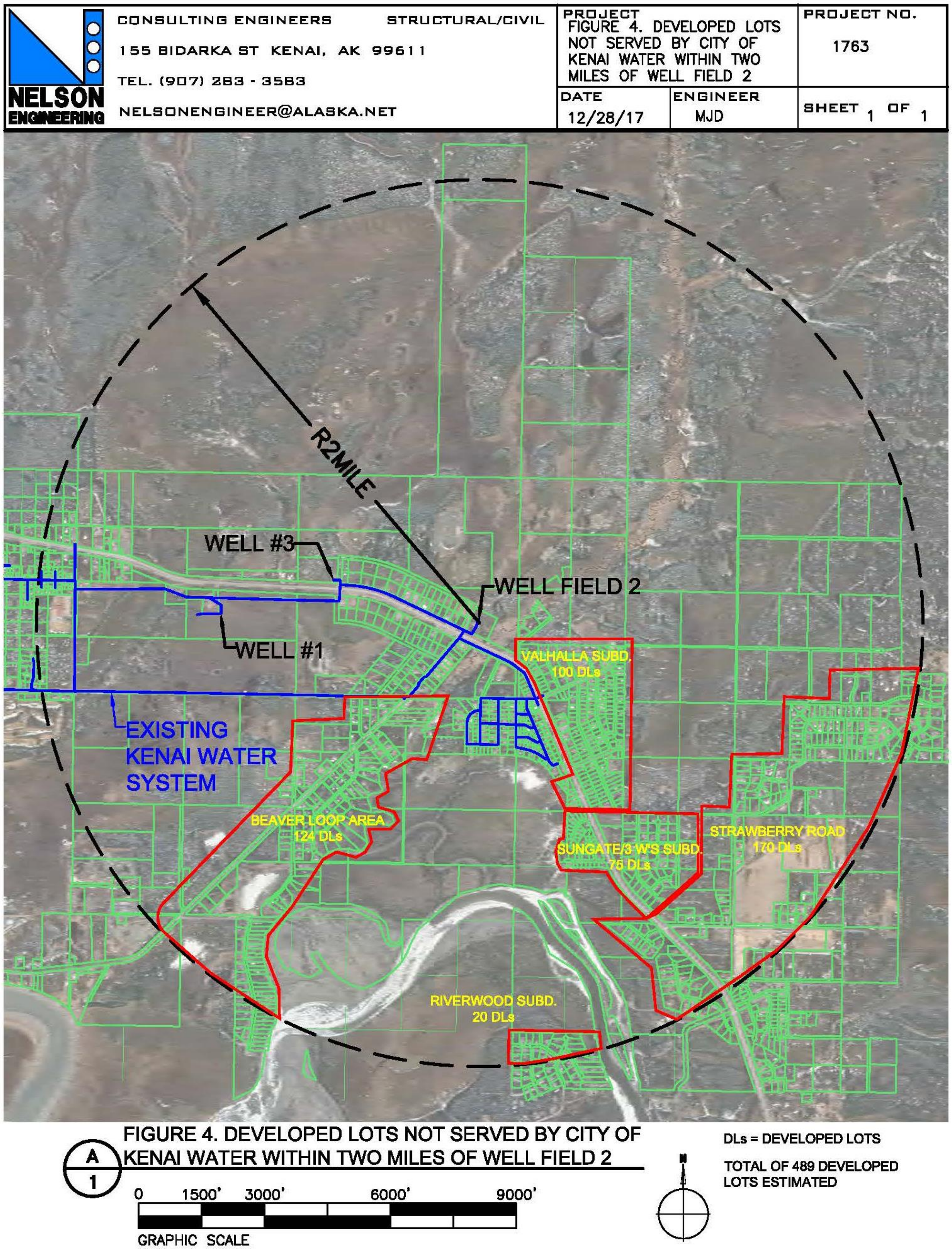
5. POTENTIAL IMPACTS OF PUMPING ON SURROUNDING WELLS

5.1. Surrounding Well Data

Glass (1996) shows the presence of numerous domestic wells within about a two-mile radius of Well Field 2. Some residential properties without City water service are located less than 1000 feet away. Local wells tap either a shallow unconfined aquifer or tap into a confined aquifer. Anderson and Jones (1972) noted that most wells in the Kenai-Soldotna area were less than 100 feet deep, which is confirmed by a limited review of well data. Shallow wells are expected to be unaffected or less affected by pumping from the confined aquifer because the silty confining beds would be expected to provide a barrier to the propagation of drawdown into the shallow aquifer.

For wells tapping a confined aquifer, Table 2 shows drawdowns that could result using the method of Theis (1935) at several distances from a pumping well. Table 2 illustrates that substantial drawdown can be expected in wells that tap the confined aquifer in surrounding neighborhoods, and that some amount of drawdown may be experienced in neighborhoods a few miles away. In order to estimate approximately how many wells are within an area that may be influenced by increased pumping at Well Field 2, Google-earth aerial photography and Kenai Peninsula Borough property records were used to estimate the number of developed lots in areas not served by the City of Kenai water system within a two-mile-radius area around Well Field 2 (Figure 4). The number of developed lots shown in Figure 4 using these criteria is 489. While it may be assumed that these properties are served by wells, it is not likely that all of these properties would be affected, or even potentially affected. Rather, these properties are identified primarily as places where further investigation could be useful. As previously indicated, most of these lots are expected to have wells that are less than 100 feet deep and are therefore less likely to be affected by pumping at Well Field 2. Other factors described below also suggest that many wells within the two-mile radius would not be adversely affected.

Figure 4. Developed Lots not Served by City of Kenai Water within Two Miles of Well Field 2



As time of pumping and distance from the pumping wells become larger, some of the assumptions of the Theis (1935) method become more uncertain. First, the method assumes no recharge, whereas in reality, over periods months to years, the aquifer is likely to receive recharge through gaps in the confining unit or as a result of leakage through the confining beds. This recharge would reduce the expected amount of drawdown calculated by the Theis (1935) method. Also, the aquifer may have boundaries that limit the spread of drawdown to surrounding neighborhoods. Aquifers and confining units have not been mapped in detail in the Kenai area, so it is difficult to assess the effects of potential aquifer boundaries. A review of a limited amount of well data in the vicinity shows that wells tap aquifers at different depths, with different thicknesses of confining units present. Also, the Kenai River is located within the two-mile radius and may be an effective aquifer boundary or hydrologic boundary that would limit the propagation of drawdown.

The effects of drawdowns such as are shown in Table 2 on surrounding wells are difficult to assess with existing information. Some wells tapping the same confined aquifer as Well Field 2 are expected to have more than 100 feet of available drawdown and would still be able to provide sufficient water for domestic purposes under the conditions described by Table 2. Other wells, however, may be shallower, have less available drawdown, or be lower yielding wells, and could still be hydraulically connected to the confined aquifer such that they would experience meaningful drawdown and could experience difficulty providing water for domestic use. In most cases, these wells could likely be deepened to provide additional water; however, adverse water quality conditions such as elevated arsenic, dissolved solids, color, or iron could be encountered. These potential effects on surrounding private wells could also occur as a result of normal increasing water usage by the City of Kenai, whether or not the LNG facility is constructed.

Table 2. Predictions of Drawdown in the Confined Aquifer at Selected Distances

Distance from the center of the well field	Calculated drawdown (ft)
500 feet	69
2000 feet	46
2 miles	20

Assumptions:
Method of Theis (1935). See text for method assumptions.
Pumping for two years at a rate of 1.35mgd from the center of the well field.

6. POTENTIAL IMPACTS OF PUMPING ON SALTWATER INTRUSION OR UPCONING

6.1. Proximity of Groundwater with Elevated Levels of Dissolved Solids

Glass (1996) shows that some water wells in coastal locations near Kenai or near the Kenai River have elevated electrical conductivity, which is correlated with elevated Total Dissolved Solids, usually caused by sodium and chloride. The highest reported values, however, are only at or marginally above the drinking water MCL of 500 mg/L total dissolved solids. Anderson and Jones (1972) also report that some wells in the Kenai area have objectionable quantities of dissolved minerals and that over-development of the aquifer could result in intrusion of salt water from Cook Inlet or from upward vertical leakage (upconing) in the aquifer. Fortunately, Well Field 2 is located in an area where Anderson and Jones (1972) considered that problems caused by "the intrusion of undesirable water should be minimized". Glass (1996) shows that wells in the vicinity of Well Field 2 have specific conductance of less than 400 microsiemens per centimeter at 25 degrees Celsius, which is generally regarded as fresh water, and supports Anderson and Jones' (1972) finding.

6.2. Salt-water Intrusion from the Coast

Pumping groundwater at coastal locations can draw water levels down below sea level and cause brackish or saline groundwater to flow horizontally through an aquifer from below the ocean towards the pumping well(s). At Well Field 2, land surface altitude is approximately 150 feet above sea level and projected drawdowns (see table 2) in the well field are not expected to drop below sea level, thus this mechanism is not expected to be a significant factor during future pumping of the aquifer at rates projected in Table 2.

6.3. Salt-water Upconing from Below

When wells pump water from an aquifer that contains deeper sources of brackish or saline groundwater, the drawdown caused by pumping can induce upward flow, known as upconing, of that brackish or saline water into the pumping well (Todd, 1980). At Well Field 2, there is no evidence to suggest that a deeper layer of salty water exists at that location. Well logs indicate that the pumped aquifer is underlain by silty sediments that would limit the upward flow of such water if it was present at greater depth. Also, after many years of pumping at the well field, there is no evidence that water quality has deteriorated as a result of the intrusion of brackish water. For all of these reasons, it is considered unlikely that brackish or saline water upconing at the well field would be a significant problem during future pumping of the aquifer.

Closer to the Kenai River, however, some wells have encountered water with elevated electrical conductivity and the propagation of drawdown from Well Field 2 could extend to those areas. This could alter the dynamic relationships in those areas such that the pumping of existing wells could cause the intrusion of brackish water from deeper parts of the aquifer into those wells. With only minimal data available, the potential for this happening is difficult to evaluate further.

7. POTENTIAL IMPAIRMENT OF WATER QUALITY FROM CONTAMINANTS OTHER THAN SALT WATER

7.1. Potential Impairment of Water Quality

A Source Water Assessment prepared for City Well No. 2 (currently called Well 2A) in 2004 described potential water quality risks from several potential sources of contamination. The study:

"Identified potential and current sources of contaminants for the City of Kenai-Well No. 2 include: large capacity septic systems, roads, residential septic systems, residential area, motor vehicle water disposal wells, construction trade areas, aircraft maintenance shop, race track and hardware store. These identified potential and existing sources of contamination are considered as sources of bacteria and viruses, nitrates and/or nitrites, volatile organic chemicals, inorganic chemicals, synthetic organic chemicals and other organic chemicals. Overall, the public water source for the City of Kenai-Well No. 2 received a vulnerability rating of Low for synthetic organic chemicals, Medium for bacteria/ viruses, nitrates/nitrites and other organic chemicals, (and) High for volatile organic chemicals and inorganic chemicals." (ADEC, 2004).

The vulnerability ratings described above are influenced by several factors including a large number of septic systems and private wells within a calculated two-year groundwater travel time distance of Well 2. Many of these wells are assumed to be ungrouted, providing a postulated potential conduit for transport of contaminants to Well 2. Examination of the report maps, however, shows that the distances between these systems and Well 2 are commonly more than 1000 feet, compared to the normal separation distance requirement for a public water supply well of 200 feet. The absence of any human-derived contaminants being observed in well water from any of the wells in the well field in the 13 years since the ADEC report was published suggests that the analysis may be overly conservative. Also, none of the potential sources of contamination identified are listed in the State's inventory of contaminated sites, suggesting that substantive groundwater contamination may not be present.

One contaminant of concern, however, bears further examination. Arsenic is identified in a sample from Well 2 (ADEC, 2004) as a naturally occurring contaminant present at 6 µg/L, which is 60% of the MCL for arsenic of 10 µg/L. A review of recent analyses for arsenic from Well Field 2 (M. Dura, written Communication, 2017) shows that the only exceedance of the MCL for arsenic occurred in water sampled from Well 2D in 2014. Subsequent testing has shown that the level has declined to levels below the MCL.

Groundwater in this part of the Kenai Peninsula is known to exceed the current MCL for arsenic in many wells (Hattenburg Dilley and Linnell, 2007; Glass, 2001). J. A. Munter Consulting, Inc. (2010) noted that pumping from existing or new wells at Well Field 2 had the potential to cause arsenic levels to increase over time. Even though additional data are now available compared to 2010, the situation is substantially unchanged, i.e. that new wells at any of the new locations proposed may result in production of water that exceeds water quality criteria at any of the wells in the well field. This could occur either at the time of development or later if lower quality water is drawn towards production wells through the aquifer in response to pumping. These effects could also occur whether or not the LNG facility is constructed.

8. ANALYSIS, MAINTENANCE, DESIGN, MONITORING, AND MITIGATION CONSIDERATIONS

8.1. Further Data Collection and Analysis

Further analysis is warranted of the potential long-term effects of source water development at Well Field 2. Assessment of the accuracy of the assumptions of the Theis (1935) analysis, for example, would benefit from a better understanding of well efficiency at the well field, variations in aquifer transmissivity in and near the well field, and better quantification of the long-term effects of pumping from a leaky aquifer. Also, there is limited information about the potential interconnections between water-bearing zones tapped by local wells and the extent to which local wells could be affected by increased pumping. A baseline water-quantity and water-quality study of surrounding wells (and possibly to include construction of new monitoring wells) designed to map local aquifers, confining units, and groundwater flow systems, establish baseline water-quality conditions, and improve predictions of the effects of the proposed pumping would be useful. In addition, performance of an aquifer test using approximately the full pumping capacity of the existing well field (which may be approximately double the existing average pumping rate) could provide additional information about the propagation of drawdown to wells in surrounding neighborhoods at higher pumping rates. Advance baseline work to identify (or drill) suitable monitoring wells in the area would be very helpful to the interpretation of such a test.

Source water assessments for wells at Well Field 2 should be prepared and updated, including a review and revaluation of the methodology for evaluating risks from nearby septic systems.

Finally, deeper exploratory drilling and testing of deeper aquifers encountered above bedrock could potentially enhance water availability at Well Field 2 and reduce or eliminate adverse effects of pumping on surrounding wells. City Well 3, for example, located 3/4 mile west of Well Field 2 (see Figure 4), is 420 feet deep and appears to tap a deeper aquifer, but pumps water that exceeds 10 µg/L of arsenic. Deeper wells, in general, present an increased likelihood of encountering higher-arsenic groundwater (HDL, 2007).

8.2. Maintenance

There is evidence, mainly from Well 2A, that wells in Well Field 2 become less efficient and gradually pump less water over time. This is a normal situation with many wells. A regular program of evaluation of this phenomenon combined with well rehabilitation, maintenance, or replacement when needed would be beneficial in maintaining high well efficiencies, which is critical to successfully sustaining long- term production at high rates.

8.3. Design

The analysis presented indicates that at least one new well will be needed in the well field to provide the required water. An additional well would also be useful to spread pumping out among more wells, provide robustness in case of temporary outage of any of the other five pumping wells, or to provide a factor of safety to compensate for the uncertainties of the analysis and the long-term nature of the predictions.

It may also be useful to plan for eventual treatment of arsenic should levels of arsenic rise at Well Field 2. Treatment facilities could potentially be used to treat water from other City of Kenai wells that pump water exceeding the MCL for arsenic.

8.4. Monitoring

Minor adjustments in the current City of Kenai data collection program would help with the analysis of well-field performance. Installation of a long-term off-site groundwater level and water quality monitoring network would assist in evaluation long-term aquifer production capacity and the effects of production on surrounding users of the aquifers.

8.5. Mitigation

Should development of the water resources result in adverse effects on other users of the resource, remedies such as deepening wells or hooking homes up to public water may be appropriate. These types of issues are typically addressed through the State of Alaska's water-rights program.

9. CONCLUSIONS

Historical pumping and water-level information were used to confirm that the Theis (1935) method is a reasonable, although perhaps somewhat conservative, method for evaluating the long-term response of the aquifer to pumping. The method was used to determine that the aquifer is likely capable of supplying sufficient water for expanded production from the well field to support projected increasing City of Kenai demand and construction and operating demand from the proposed LNG facility. Future production to meet these demands, however, would require construction of at least one additional well at the well field.

It is unlikely that expanded water production would draw in human-caused contamination from surrounding areas or salt water, however increasing levels of naturally-occurring arsenic to levels above the MCL is a risk because of the common presence of arsenic in surrounding areas. Also, some surrounding private wells could be adversely affected by the increased withdrawal at distances up to a few miles away. These adverse effects could result either from a reduced ability to pump water from existing private wells or from worsening quality of water either from existing or deepened wells. To some extent, however, increases in future pumping at Well Field 2 to meet City water demands, even without development of the LNG facility, could result in increased arsenic in City wells or adverse effects on surrounding wells.

Additional development of the water resources at Well Field 2 to supply water for the proposed LNG facility and associated additional demand in the area appears to be feasible. Additional work to explore for deeper aquifers, to understand, monitor, and mitigate potential effects on surrounding private wells, and to evaluate and perhaps treat elevated arsenic levels may be warranted.

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