PRELIMINARY ENGINEERING REPORT

WATER STUDY

PREPARED FOR

BOARD OF PUBLIC WORKS
FAIRBURY, NEBRASKA

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E-12625
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TABLE OF CONTENTS

TABLE OF CONTENTS CONT'D.

TABLE OF CONTENTS CONT'D.

TABLE OF CONTENTS CONT'D.

Abbreviations: abbreviations used in the report are as follows:

AWWA ....American Water Works Association
BCR ....Benefit Cost Ratio
BFE ....Base Flood Elevation
$CACO_3$ ....Calcium Carbonate
CCL ....Contaminant Candidate List
CDBG ....Community Development Block Grant
CT ....Contract Times
DED ....Department of Economic Development
DBP ....Disinfection ByProducts
DIP ....Ductile Iron Pipe
DWSRF ....Drinking Water State Revolving Fund
E Coli ....Escherichia Coli
EDR ....Electrodialysis Reversal
FEMA ....Federal Emergency Management Agency
FIRM ....Flood Insurance Rate Map
GIS ....Geographical Information System
GWR ....Groundwater Rule
GWUDI ....Groundwater Under the Direct Influence
HAA5 ....Haloacetic Acids
I/O ....Input/Output
IOC ....Inorganic Chemicals
ISO ....Insurance Service Office
IUP ....Intended Use Plan
IX ....Ion Exchange
LBNRD ....Little Blue NRD
LI ....Langelier Saturation Index
MBfR ....Membrane Biofilm Reactors
MCL ....Maximum Containment Level
NAC ....Nebraska Administrative Code
NBFU ....National Board of Fire Underwriters
NDEQ ....Nebraska Department of Environmental Quality
NDHHS ....Nebraska Department of Health and Human Services
NeDED ....Nebraska Department of Economic Development
NOM ....Naturally Organic Matter
NPDES ....National Pollutant Discharge Elimination System
LBNRD ....Little Blue Natural Resource District
O&M ....Operation and Maintenance
NRD ....Natural Resource District
PLC ....Programmable Logic Controller
PVC ....Polyvinyl Chloride
POE ....Point-of-Entry
PWS ....Public Water System
RDD ....Rural Development Division
RO ....Reverse Osmosis
ROW ....Right-of-Way
RTU ....Radio Telemetry Units
RWD ....Rural Water District
SBA ....Strong Base Anion
SCADA ....**Supervisory Control And Data Acquisition**.
SMCL ....Secondary Maximum Contaminant Level
SMI ....Sulfur Modified Iron
SWTR ....Surface Water Treatment Rate
TDH ....Total Dynamic Head
TDS ....Total Dissolved Solids
USEPA ....United States Environmental Protection Agency
UV ....Ultraviolet
VFD ....Variable Frequency Drives
WBA ....Weak Base Anion
WWAC ....Water & Wastewater Advisory Committee
WWTP ....Wastewater Treatment Plant
ZUI ....Zero Valent Iron

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I. SUMMARY OF FINDINGS AND RECOMMENDATIONS

A. Findings

1. The current population of the City of Fairbury is estimated to be 3,942. For the purposes of this report, a population of 3,928 by the year 2040, will be used.

2. The average and peak quantities of water distributed by the Fairbury distribution system from 2012 through 2016 was equal to 0.995 and 2.381-million gallons per day (MGD). This calculates to an approximate average use of 258 gallons per capita per day (gpcd). Average and peak daily demands for the year 2040 are estimated to be 1.013 and 2.43 MGD, respectively.

3. Current firm pumping capacity of the City's active and usable water supply facilities is 2.16 MGD for the East Well Field. Crystal Springs has a firm pumping capacity of 1.08 MGD, which feeds into the existing underground reservoir. However, due to concerns with the existing transmission main, is only running at approximately 0.8 MGD. The high service pumps, connected to the underground reservoir, have a firm pumping capacity of 1.584 MGD. The total combined available capacity is 3.744 MGD, or 2,542 gpm. Total capacity of the water supply system is 6.62 MGD (4,600 gpm).

   The current pumping capacity is sufficient to handle the City's current and projected future demands. However, concerns over the viability of the existing transmission main, nitrates, and the associated loss(es) of supply are very real.

4. The water treatment design (finish) flow rate will be sized to come from the Crystal Springs facility only. The finish flow rate from the selected treatment process will be 2.16 MGD (1,500 gpm), or total pumping capacity. Additional pumping capacity may be needed to account for water loss, or waste, from the selected treatment process.

5. The primary issues of concern stem from exceeding the Maximum Contaminant Limits (MCL) for nitrates, which is 10 mg/L. The MCL has been exceeded 2 times since 2004 at the Reservoir high service pumps and Crystal Springs facility. Well #3 shows an increasing nitrate concentration trend.

6. A previous article in the American Water Works Association (AWWA) *Journal* publication (March 2011) referenced the consideration of the United States Environmental Protection Agency (US EPA) of “revising the current 10 mg/L nitrate MCL to 5 mg/L.” The current treatment approach recommended will include provisions to treat below 5 mg/L.

7. The evaluation considered treatment locations at the Crystal Springs facility, East Well Field, or relocating the point of entry from the East Well Field to the underground reservoir for blending with treatment located at the Crystal Springs facility.

8. Nitrate monitoring completed by the Little Blue Natural Resources District (LBNRD) confirms that the nitrate levels in and around the Fairbury area are increasing over time. With this information, the option of locating a new water supply well field that is unaffected by nitrates and has an adequate supply of clean water in an area close enough to Fairbury to be cost effective, is not feasible.

9. The City of Fairbury and the LBNRD worked together to develop revised Wellhead Protection Area management rules that have worked to protect the City’s drinking water supply. The proposed new rules included restrictions on the timing and rate of nitrate applications unless nitrate stabilizers are used, nitrogen application training, and the promotion of best management practices regarding nitrogen and manure applications. Based on the nitrate concentrations at the Crystal Springs facility, it would appear that these BMPs are working since implementation in 2012 to 2013.

10. The City has approximately 3.5-million gallons of water storage between the 1.0-million gallon elevated water reservoir north along Highway 15 and the 2.5-million gallon underground water reservoir near the power plant. The future average plus residential or fire demands, as well as the peak daily demands were all less than the City’s available storage, as summarized below.
    - Projected average day plus residential fire demand: 1.19 MGD
    - Projected average day plus commercial fire demand: 2.09 MGD
    - Projected peak day demand: 2.874 MGD

    The reserve capacity, or contingency available to the City, is approximately 18% (i.e., 2.874/3.5).

11. Distribution System
The existing distribution system has piping ranging from 4 to 16-inches in diameter. Water age and static pressures within the distribution system are in the desired range. Of primary concern are water mains less than 4-inches in diameter. Several locations throughout the system were not able to provide the desired residential fire flows, based on the hydraulic model review.

12. Treatment Options Evaluated
   a. Blending
   Water from the City's Crystal Springs water supply could be blended with water supplied from the existing wells east of town in order to achieve a finished water nitrate concentration below the MCL. Blending will vary based on the nitrate levels in the City's water supply. It was determined that blending would not sufficiently reduce nitrate concentrations from Crystal Springs. However, blending of the wells from the East Well Field could be completed to reduce overall nitrate from that source.

   b. Reverse Osmosis (RO)
   RO is a pressure driven desalting process. Pressure drives water though a semi-permeable membrane leaving the salts behind. The treated water is then blended with a bypass stream to achieve an acceptable level of minerals and constituents in the finish water. Waste solution is routed to a nearby waterway or the Wastewater Treatment Plant (WWTP).

   c. Ion Exchange (IX)
   IX uses a resin to exchange undesirable ions for more desirable ions. Dissolved salts in water are either cations (positive) electrically charged ions or anions (negative) charged particles. Salt or sodium chloride becomes sodium cations and chloride anions.

   Waste solution has to go to either an on-site unit or to the WWTP if sufficient capacity is available. A modification from the 2011 study allows for a much lower (i.e. 4 gpm) waste rate, which may make this treatment option viable for the City.

d. Electrodialysis Reversal (EDR)
Water passes through a vertical stack of membranes with electrodes on both the top and bottom. The membranes are coated with IX resin, alternating cation with anion resin coated membranes. DC current is applied across the stack and cations pass through the cation membranes into concentrate spacers while anions pass through anion membranes into concentrate spacers.
The desalted water stays in the feed spacer and the salted water is in the concentration spacers and is disposed of. The polarity is reversed 3-5 times an hour so the feed spacers become concentrate spacers and the concentrate spacers become feed spacers to prevent scale. The waste solution is routed to a nearby waterway or to the WWTP.

e. Biological Treatment
General information regarding the option for biological treatment was provided for reference. For this to be a viable treatment alternative, coordination with Nebraska regulatory agencies will be required as this has yet to be proven within the state.

13. Treatment Cost Option Summary, presented in Table I-1.

Table I-1: Cost Option Summary

Treatment Option Evaluated	Total Annual Cost
Reverse Osmosis	$659,098
Ion Exchange	$554,012
Electrodialysis Reversal	$825,867

B. Recommendations

The City should improve the water system components following the recommendations in the report to serve the existing and projected population and to satisfy existing and future fire flow requirements.

1. Several water distribution system improvements were identified, ranging in size from 6 to 16 inches in diameter, for an approximate total length of approximately 65,000 linear feet of water main to be replaced, including the transmission main from Crystal Springs into town. The stated length is approximately 30-percent of the City’s distribution system. This can either be replaced as part of a larger single project, or divided into 4 or 5, or more, staged projects. This means that between 20 and 25 percent of the system would be replaced over an estimated timeline (e.g. 20-25 years). The timeline can be modified by the City based on their strategic planning, as needed. The prioritization and project timeframe will allow for a more accurate capital improvement plan (CIP) for the City.

Water distribution system replacements should be coordinated with the City's street study and replacement program to capitalize on both efforts. Replacement of the Crystal Springs transmission mains would allow for an immediate increase in water supply due to running the system to full capacity of between 150 to 250 gpm.

2. It is recommended that a new water supply well be investigated further in the vicinity of the existing East Well Field. This will require that existing private wells be decommissioned, and these individuals connected to the City's distribution system.

3. Based on the current nitrate levels, no immediate action is needed by the City to move towards the treatment option. However, it is there if future nitrate levels increase to a point where treatment is required. It is recommended that the City continue to work in partnership with the LBNRD to implement other wellhead protection measures to reduce the nitrate effects to the Crystal Springs and East Well Field systems. The recommended location of the proposed water treatment system is west of the City's existing reservoir. Approximately 1.0 acres of land will be required. The City has acquired, or is in the process of acquiring, property in this area.

   It is recommended that the City be prepared to proceed with the design and construction of a water treatment facility to remove nitrates, when appropriate. It is not necessary to initiate this effort until the nitrate MCL is exceeded consistently, or an Administrative Order is issued by Nebraska Department of Health and Human Services (NDHHS).

4. The prioritization and implementation of the CIP will require that the City determine the necessary funding for the recommended improvements. The funding recommendations will require a combination of increased water rates and either public or private funding sources. It is recommended that the City approach state and federal funding sources to determine what additional steps would be necessary to qualify.

II. INTRODUCTION

The purpose of this report is to review and evaluate the City's existing water supply, treatment, and distribution system. The document will also review and revise previously provided additional water production and/or construction of nitrate water treatment facility costs. This report predicts future growth in population and resulting increases in system demands. By determining these increases, the existing distribution system can then be evaluated to determine how well it performs under present and future conditions. The evaluation of these systems allows suggestions to improve or correct existing deficiencies and to plan for future development. This will be used by the City in conjunction with their current CIP to plan for funding and construction of the proposed improvements.

To allow for future water supply for the community, the public facilities must also be maintained or improved to handle the ongoing stress to the system. Difficulty in treating and supplying water due to an aging distribution system and treatment facilities are key factors in providing an ample supply of quality water to the citizens of Fairbury.

III. PROJECT PLANNING

In order to provide the desired planning document for the City, several different factors need to be considered. The proposed project location, environmental resources, population trends, and community involvement will be discussed in this Section.

A. Location

The proposed project or projects are anticipated to be limited to the City of Fairbury. Several figures showing the City of Fairbury, including an aerial map, topographical map, and existing City boundaries are shown in Figures III-1 to III-4.

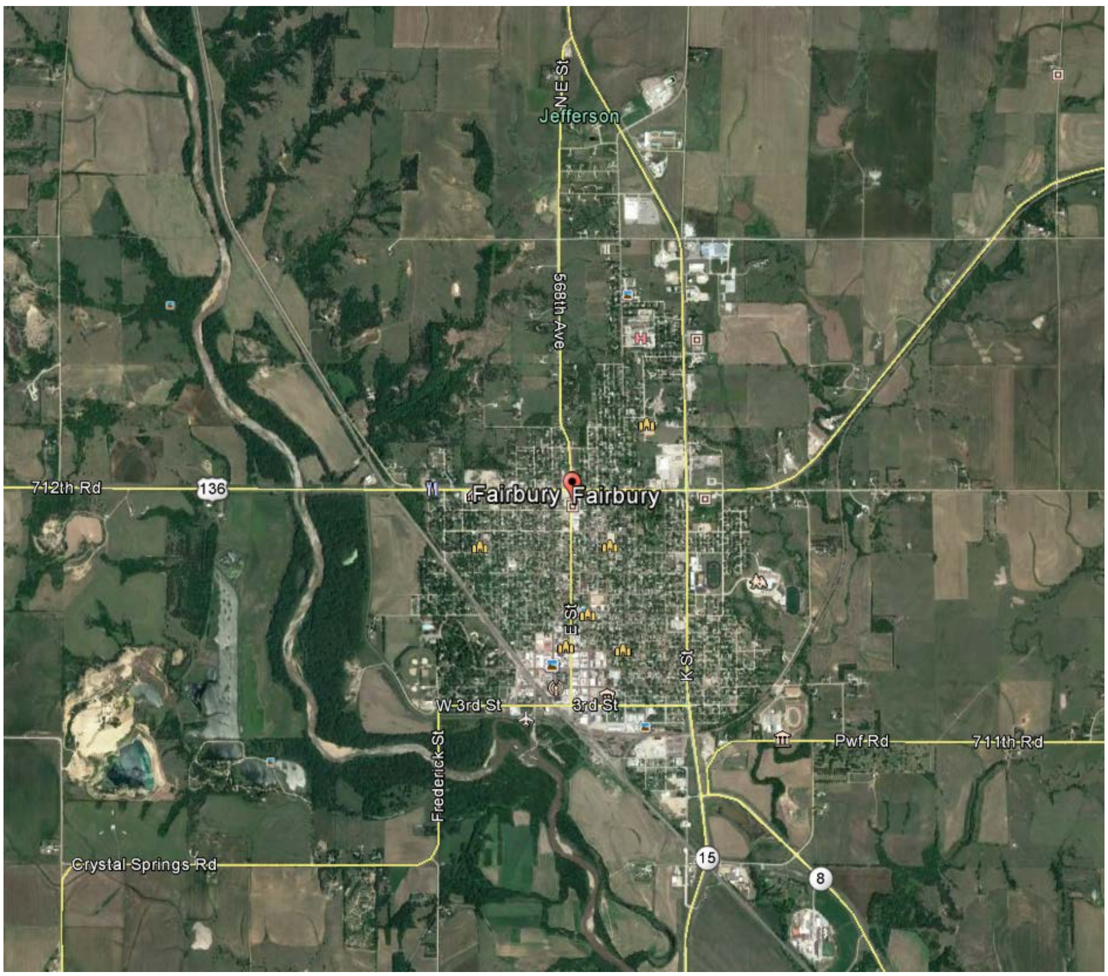


Figure III-1: Aerial Map (Google©2014: Image Landsat) – City of Fairbury, NE

The City is located at the intersection of Highways 8, 15, and 136, and a Union Pacific main rail line that is located in the southwest portion of the City. The Fairbury topoquad map, last revised in 1970, shows the City layout, topographical contours, and nearby natural features.

Figure III-2: Quadrangle Map (USGS – Fairbury, 1960 (photo revised in 1980) – City of Fairbury, NE

The City Limit Map was obtained using a map developed by the Nebraska Department of Roads, and available at http://www.transportation.nebraska.gov/maps/city/pdf/Fairbury.pdf. Another version of the City Limits map is available from the City of Fairbury map section of their website (http://fairburyne.org/maps/). Both of these maps are provided as Figures III-3 and III-4.

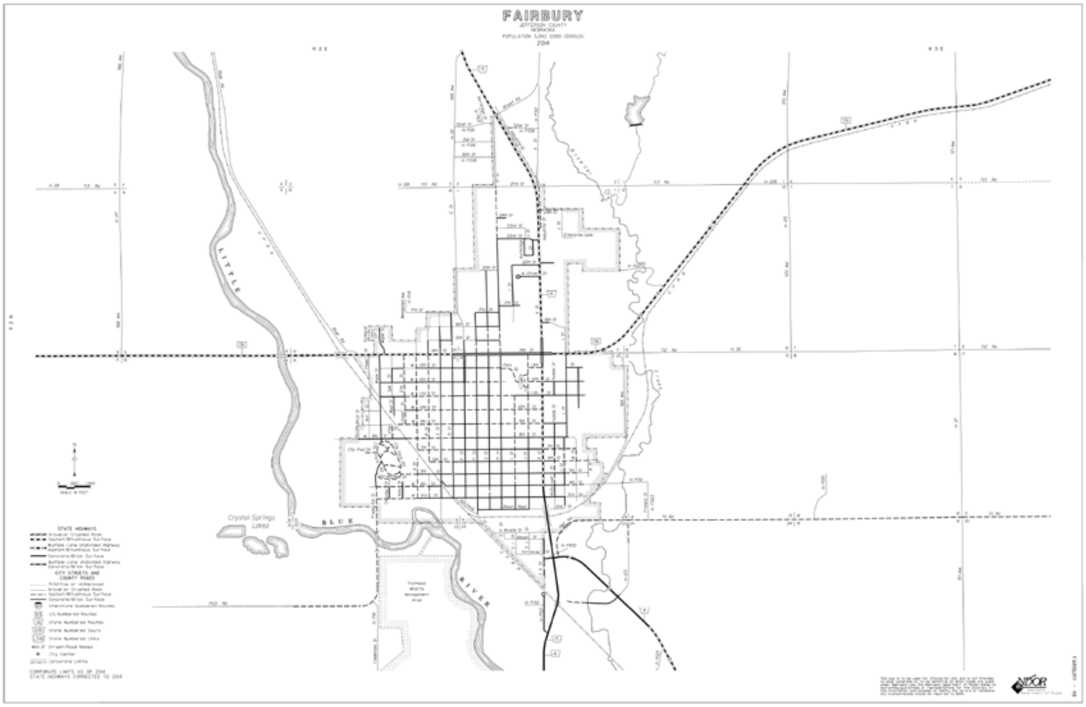


Figure III-3: City Limits (NDOR – Fairbury, 2009) – City of Fairbury, NE

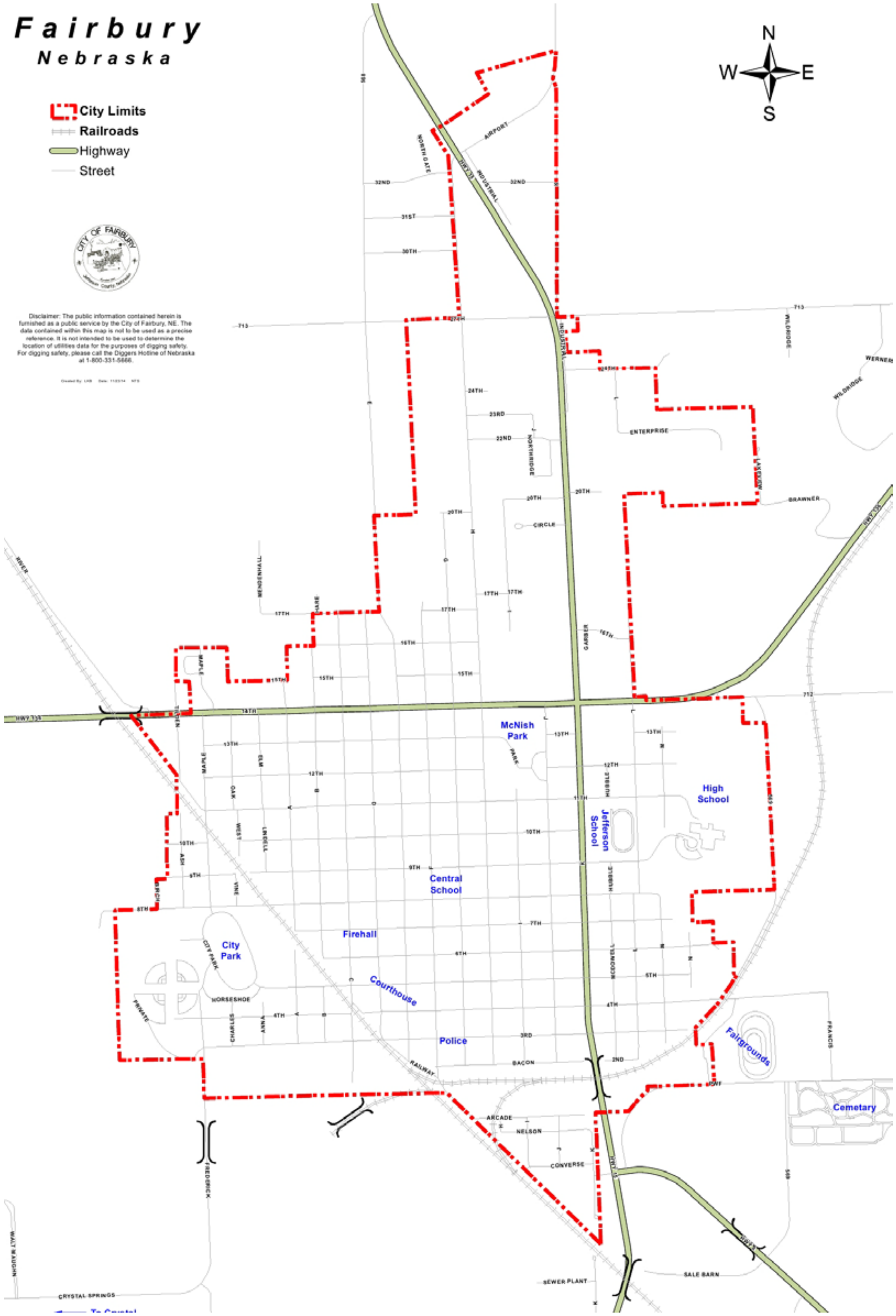


Figure III-4: City Limits – City of Fairbury, NE

B. Environmental Resources Present

Environmental features within close proximity to the City include the Little Blue River and Crystal Springs both of which are located southwest of town. To date, no information from State or Federal agencies has been requested regarding the proposed project or projects. This information is anticipated to be requested upon development and selection of the proposed project(s). A Burlington Northern Railroad and a Union Pacific Railroad parallels Highway 8, to the south of the City.

C. Population Trends

Table III-1 below shows the historical population for the City of Fairbury. The population figures are based on US Census data and information obtained from the Nebraska Department of Economic Development (NeDED).

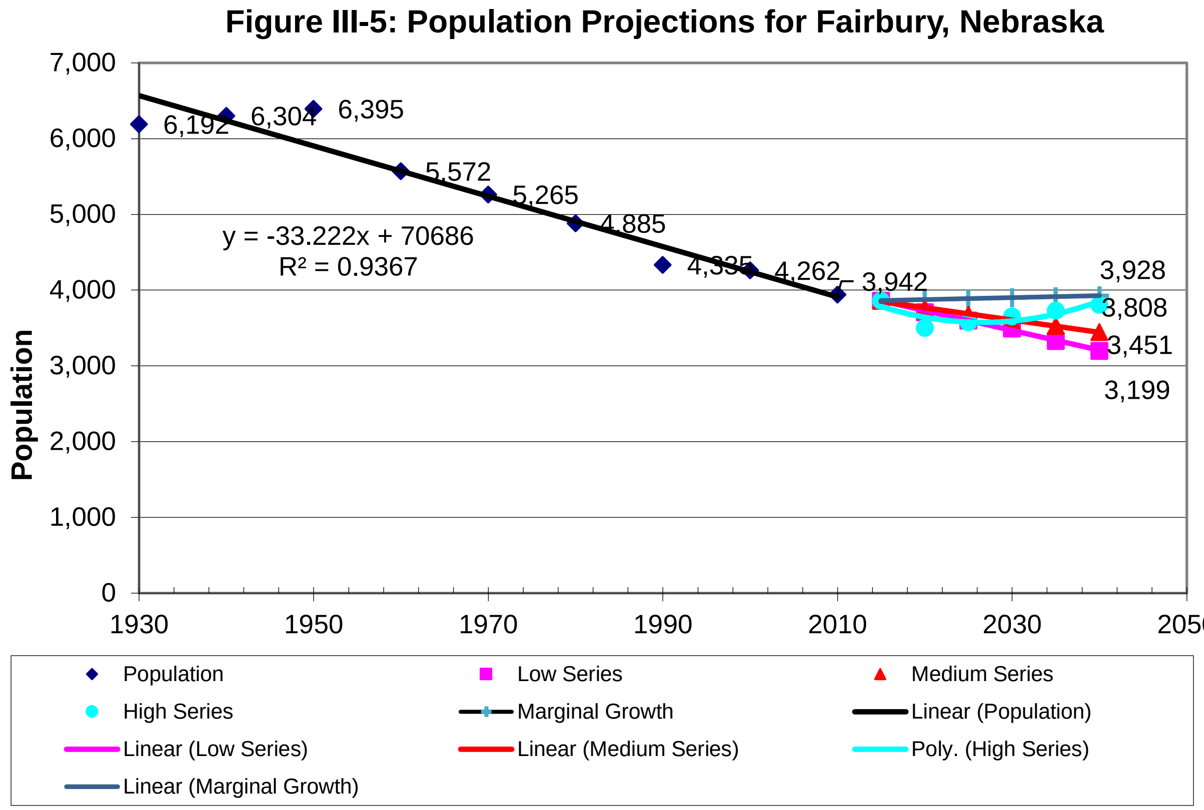
Table III-1: Historical Population

Year	Population	Percent Change Over Previous Period
1930	6,192	-
1940	6,304	1.8%
1950	6,395	1.4%
1960	5,572	-12.9%
1970	5,265	-5.5%
1980	4,885	-7.2%
1990	4,335	-11.3%
2000	4,262	-1.7%
2010	3,942	-7.5%
2012*	3,934	-0.2%
2013*	3,927	-0.2%
2015**	3,863	-1.6%

*Estimated population from NeDED.
**Estimated population from 2011-2015 American Community Survey 5-Year Estimates (US Census)

Historical records can be used to determine existing system needs and improvements, but future system demands must also be considered to prepare the system for future growth in Fairbury. Population trends from 1930 to 2010 US Census data can be used to project population growth to the year 2040. These projections were obtained from a linear regression of the above data.

Figure III-5 shows the population trends and projected population using data from Table III-1, as well as the population trends, projected population, and possible growth scenarios used to determine future population. Current population projections are available from the NeDED, which information is available at http://neded.org/files/research/stathand/bsect5c.htm.



Fairbury's projected population for the year 2030, using information from the 2013 Comprehensive Plan, would decline to between 3,494 and 3,655. However, it is beneficial to plan for some growth within the community for planning purposes. A marginal growth estimate was provided in the following table. Also provided are additional population projections obtained from the draft version of the Comprehensive Plan updates. The Low series is based upon a 1960 to 2010 trend line. The Medium series is based upon a 1990 to 2010 trend line. The High series is based upon Cohort survival analysis, which is based on population by different age groups and gender. Projecting the Marginal Growth Series, the population in Fairbury would be 3,928 in 2040. This population will be used to evaluate water treatment needs.

Table III-2 – Projected Population (2015 to 2040)

Year	Low Series	Medium Series	High Series	Marginal Growth
2015	3,863	3,863	3,863	3,863
2020	3,711	3,763	3,502	3,876
2025	3,603	3,678	3,579	3,889
2030	3,494	3,593	3,655	3,902
2035*	3,332	3,530	3,732	3,915
2040*	3,199	3,451	3,808	3,928

*Estimated from 2030 Projections from the 2013 Comprehensive Plan

D. Community Engagement

The City has utilized their existing City Council and Board of Public Works (BPW) meetings as a way to engage the community. As part of the report process, the results will be reviewed with the community, and the responses received incorporated herein. It is anticipated that this will occur as part of a regularly scheduled City Council meeting. The information to be shared will include strengths and limitations of the existing system, as well as the opportunities for expanded service, and other system improvements.

IV. EXISTING FACILITIES

The Fairbury water system consists of groundwater supply, storage and distribution facilities. The City's Public Water System (PWS) registration number is NE3109507. The City uses cartridge filtration for their Crystal Springs Water Supply Facilities. Chlorination occurs at the underground reservoir. These and other components will be addressed in this Section. The system is a Class II system, as designated in Nebraska Administrative Code (NAC) Title 179. This type of system serves between 2,000 and 15,000 person and includes filtration as a treatment technology. The system is further described in this Section.

The requirements for the water supply system generally include:

- Meeting demands of the high use (peak day) periods with a minimum of 30 psi throughout the system.
- Providing fire protection for the City by having enough well capacity, storage, and water main capacity and strength to deliver the required quantity of water with a minimum system pressure of 20 psi during a fire.
- Providing water quality that meets or exceeds the regulations for public health and acceptable standards for aesthetics.

A. Location Map

A site layout of the water supply and treatment facilities in relation to the City of Fairbury is shown in Figure IV-1. A water system flow schematic is included in Figure IV-2. Photos of the existing facilities are provided in Appendix "A."

B. History and Description

Fairbury's municipal water supply system currently consists of 2 separate water sources; Crystal Springs and an East Well Field, an underground water storage reservoir, high service or booster pumps, a distribution system, and an elevated water storage reservoir. The water system components are located throughout the community.

1. Crystal Springs Water Supply Facilities

   The Crystal Springs Water Supply Facilities consists of 3 wells/siphon wells connected to an infiltration gallery/storage reservoir and booster pumps. The Crystal Springs Water Supply is located southwest of the City. Existing supply capacities for this location are provided in Table IV-1. The City uses the Crystal Springs facility as their primary water supply, with supplemental flow provided from the East Well Field.

Table IV-1: Existing Crystal Springs Well Capacities

Well No.	Reg. No.	Year	Casing Diameter . (in)	Total Depth (ft)	Flow Rate (gpm)	Flow Rate (MGD)
Other Well	A-10553A	1957	18	176	200	0.288
Feeder Well and Siphon Well #1	A-10553D A-10553C	Unknown	18	36	400	0.576
Feeder Well and Siphon Well #2	A-10553E A-10553F	Unknown	18	36	350	0.504
Feeder Well and Siphon Well #3	A-10553G A-10553B	Unknown	18	36	600	0.864
Infiltration Gallery	A-10553H	Unknown	NA	13	750 (gravity feed)	1.08
Total*					2,100	3.024

*Total does not include other Well A-10553A.

Figure IV-3: Crystal Springs Treatment Facility

A cartridge filtration plant was constructed at this location in the early 2000's, and is discussed in more detail in subsequent sections of this document. Two (2) 750 gpm booster pumps at, 70 feet of Total Dynamic Head (TDH) transfer the finished water from the Crystal Springs Water Supply via 2 parallel 12-inch transmission mains directly to the 2,500,000-gallon underground storage reservoir. Chlorine and fluoride are added prior to entering the reservoir.

Figure IV-4: Underground Storage Reservoir

Figure IV-5: Chemical Feed to Underground Storage Reservoir

A 2,500 gpm booster pump can also transfer water from the infiltration gallery at Crystal Springs directly to the underground storage reservoir, if needed, during emergencies

Figure IV-6: High Service or Booster Pumps from the Underground Reservoir

2. East Well Field

The East Well Field is located approximately 0.5 miles east of town on PFD (711th) Road. The wells pump directly into the system via a 14-inch transmission main. A maximum flow rate of 2,500 gpm can be provided from this system. Information regarding the wells is provided in Table IV-2.

Table IV-2 – East Well Capacity and Well Data

Well No.	Reg. No.	Year Constructed	Casing Diameter (in)	Motor Size (HP)	Total Depth (ft)	Flow Rate (gpm)	Flow Rate (MGD)
1	G-032647	1970	18	100	110	1,000	1.44
2	G-068253	1982	16	100	138	1,000	1.44
3	G-096478	1997	16	50	92	500	0.72
Total Pumping Capacity						2,500	3.60
Firm Pumping Capacity (with 1 Pump Out-of-Service)						1,500	2.16

Figure IV-7: East Well #1

Figure IV-8: East Well #2

Figure IV-9: East Well #3

The City generally only operates 1 of the 1,000 gpm wells at a time. This operational structure yields a firm pumping capacity of 1,500 gpm, or 2.16 MGD from the East Well Field. The wells have chlorine and fluoride feed systems at each well house. The wells pump directly to the distribution system.
Well registration information for each of the existing wells, both at the Crystal Springs and East Well Field locations, is provided in Appendix "B." Well drawdown information is also provided for reference. A summary of the East wells drawdown information from 2010 through 2016 is provided in the following table. Within the table, SWL stands for static water level, PWL stands for pumping water level, and DD stands for drawdown.

Table IV-3: East Well Drawdown Summary (2010-2016)

Parameter	East Well #1			East Well #2			East Well #3		
	SWL (ft)	PWL (ft)	DD (ft)	SWL (ft)	PWL (ft)	DD (ft)	SWL (ft)	PWL (ft)	DD (ft)
Average	64.3	72.3	8.1	91.2	101.4	10.2	39.5	46.9	7.3
Maximum	66.0	76.5	11.5	93.0	103.0	11.5	42.0	49.0	9.5
Minimum	62.0	70.0	6.0	89.0	99.0	8.5	35.5	44.0	6.5

Overall, there has been very little fluctuation in static water level, pumping water level, or drawdown for the 3 East wellfield wells. To quantify this, the difference in maximum to minimum static or pumping water levels for each well does not vary by more than 5 feet. It should be noted that measurements are not taken every day, but every 2-3 months.

3. <u>Water System Controls</u>
The City water system is controlled by a software based Supervisory Control and Data Acquisition (SCADA) system. Based on conversations with the City's control system integrator, HOA Solutions out of Lincoln, NE, the control software has been recently upgraded. A master Programmable Logic Controller (PLC) and SCADA computer are located at the power plant. Radio Telemetry Units (RTUs) are used to communicate between the elevated water storage reservoir, the East Well Field (3 wells), the Crystal Springs treatment facility and wells. The system also includes a remote Input/Output (I/O) connections at the reservoir building via fiber optic cables. The high service pump and East wellfield operation is controlled via tower level. The Crystal Springs wells operate based on the water level in the underground water reservoir.

The existing elevated water storage reservoir was built in 1963. The listed capacity is 1-million gallons. The operating height is 123.5 feet from existing grade.

The underground reservoir, with a stated capacity of 2,500,000 gallons was built in the 1950's.

The current distribution system consists of a network of pipe ranging in size from 2 to 14 inches in diameter. The majority of the City water system is constructed of cast iron or Ductile Iron Pipe (DIP), and is at least 50 to 70 years old, or older. Newer additions and upgrades to the system are believed to have been constructed of more modern pipe materials such as Polyvinyl Chloride (PVC) or DIP. City personnel would characterize the condition of the City water system to be in fair condition. A main concern for the City is the 12-inch pipes between Crystal Springs and the underground water storage reservoir near the power plant. A small percentage of other pipe materials were also used, including HDPE and copper pipe, mainly for services. As a point of reference, the WWTP site is located south of town, west of the intersection of S. K Street and 569th Avenue.

Figure IV-10: Elevated Water Storage Reservoir

C. Condition of Existing Facilities

Historical water usage data was collected from the City and summarized to determine average water usage per utility connection. Background information regarding water use and pumping records are contained in Appendix "C." No asset management plan is currently available, but is under development via the City's Geographical Information System (GIS). Each of the system components appears to be in sufficient condition to warrant continued use, with a few exceptions, which are noted within this section.

D. Average Daily Demands

The average water usage compiled from data collected from January 1, 2012 to December 31, 2016 was 995,195 gpd, or 691 gpm over a 24-hour period. This is less than the per capita usage of 285 gpcd calculated in 2011. The average daily per capita demand is 258 gpcd, using the 2015 population estimate. This number decreases of 207 gpcd when the LBNRD's rural water system's calculated population of 952 persons is used, for a total population of 4,815. The per capita usage is higher than the national average of 100 gpcd, most likely due to watering of livestock and irrigation. In addition to average day demands, peak day, and future demands must also be considered to determine necessary water storage and well field capacity.

E. Peak Daily Demands

Peak daily demands occur during the summer months (June – August) and are primarily due to lawn irrigation. From the water records gathered, the peak daily water consumption for the community was 2,381,100 gpd, or 1,653 gpm over a 24-hour period, or 2,480 gpm over a 16-hour period. By comparing the peak water usage for the community and reviewing past reports of Fairbury's water system, a peak day to average day demand factor was determined to be 2.39 times greater than the average daily demand (2,381,100 gal/995,195 gal), which will be rounded to 2.4 to be conservative.

F. Peak Hourly Demands

Peak demands on a community's water supply system occur for short periods of time, normally 1 to 4 hours in duration. This condition generally occurs after working hours when people start lawn and garden watering during the summer. These short periods of high demand, referred to as peak hourly demands, impose critical demands on various elements of the water system. The combination of well pumping and flow from storage must supply these high demand rates. The distribution mains must be adequate to deliver water throughout the entire system without excessive loss in pressure.

Peak hour demands are generally based on population, housing density, and a variety of other factors. In general, small communities are affected more by peak demands than larger communities, and thus have larger peaking factors.

An equation used to determine the peak hourly demand is as follows:

Equation 1

$Q_{\text{peak hour}}$ = (3.34 * Number of Dwelling units) + (2.02 * $Q_{\text{peak day}}$)

The 2010 US Census indicated 2,211 total housing or dwelling units in Fairbury (https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=CF). Using the equation indicated above, the peak hourly demand is as follows: $Q_{\text{peak hour}}$ = (3.34 * 2,211) + (2.02 * 2,381,000 gallons/day) = 4,817,005 gallons/day.

Based upon the calculation above, the ratio of peak hour to peak daily demands (4,817,005 gpd/2,381,000 gpd) is 2.02. Therefore, a peak hour to peak daily demand factor of 2.0 will be used for the City of Fairbury.

G. Peak Daily Demand Plus Fire Flow

The required flow for firefighting purposes depends upon a number of different factors. Fire demand can be calculated using the following empirical formula based on population suggested by the National Board of Fire Underwriters (NBFU) for communities having populations less than 200,000, and referenced in Clark et al (1971, pg. 111):

Equation 2

Q = [1020(P)^.5][1-0.01(P)^.5]   Where: Q = required fire flow, gpm
P = population, thousands

Using the equation indicated above and the 2015 US Census Community Survey estimate information, the calculated fire demand is as follows:

Q = [1020(3.863)^.5][1-0.01(3.863)^.5] = 1,965 gpm

The fire demand in the year 2040 using the population estimate and Equation 2 is as follows:

Q = [1020(3.928)^.5][1-0.01(3.928)^.5] = 1,981 gpm ≈ 2,000 gpm

In areas of town where large structures or warehouses may be present, the fire flow will exceed the calculated flow based on population. For this reason, residential and commercial fire flows need to be considered separately.

The following is an empirical formula suggested by the Insurance Service Office (ISO, 2008) based on the square footage of the structure, construction type, and occupancy:

Equation 3

Q = 18F(A)^0.5 Where: Q = required flow, gpm
A = total floor area excluding basement ft^2

F = coefficient: 1.5 for wood frame construction (Class 1), 1.0 for ordinary construction (Class 2), 0.8 for noncombustible construction (Classes 3 and 4), and 0.6 for fire-resistant construction (Classes 5 and 6).

For the second equation, flow should not exceed 6,000 gpm for a single story, 8,000 gpm for a single building, or 12,000 gpm for a single fire. Flow should not be less than 500 gpm. After calculating the required fire flow for a community, it was necessary to determine how long the flow must be maintained in order to determine the size of water storage facilities. The American Water Works Association (AWWA) Manual of Water Supply Practices M32 (2005) states that required durations to sustain fire flows of 2,500 gpm or less should be 2 hours, fire flows of 3,000 to 3,500 gpm should be 3 hours, and fire flows of 4,000 to 12,000 gpm should be 4 hours. For the purpose of this study, and to remain conservative, a 3-hour duration was used for fire flows.

The most recent ISO report was completed in April 2016. The report states that a maximum of 4,500 gpm was needed for commercial fires. A flow rate of 1,000 gpm was referenced for fire flows in residential areas. However, the calculated fire rate was nearly double this amount. A residential flow rate of 1,500 gpm is typical, and is the average between the calculated and ISO testing results. A copy of the report is provided in the Appendices for reference.

For the purposes of this study, fire flows of 1,500 gpm (residential) or 4,500 gpm (commercial), will be used. In general, system pressures between 35 psi and 90 psi (20 psi minimum) are recommended.

H. Description of Water Users

The City of Fairbury has a large water user structure, which includes both residential and commercial customers and meter sizes ranging from ¾-inch to 6-inches. The total number of customers is described in Table IV-4. The designation ‘NCL’ applies to customers who do not live within City limits. Appendix “C” contains information provided by the City regarding their current number of customers and rates.

Table IV-4: City Water User and Meter Size Summary

Type	Meter Size	# of Regular Customers	# of NCL Customers	# of Customers (including NCL)	%
Residential	3/4"	1,522	21	1,543	79.87%
Residential	1"	75	36	111	5.75%
Residential	1 1/4"	0	0	0	0.00%
Residential	1 1/2"	3	0	3	0.16%
Residential	2"	1	1	2	0.10%
Commercial	3/4"	155	7	162	8.39%
Commercial	1"	49	5	54	2.80%
Commercial	1 1/4"	1	0	1	0.05%
Commercial	1 1/2"	18	0	18	0.93%
Commercial	2"	25	4	29	1.50%
Commercial	3"	3	1	4	0.21%
Commercial	4"	2	2	4	0.21%
Commercial	6"	1	0	1	0.05%
Total		1,855	77	1,932	100%

Based on a comparison of the residential versus commercial users, the breakdown is as shown in Table IV-5.

Table IV-5: City Residential and Commercial Water User Summary

Type	# of Regular Customers	# of NCL Customers	# of Customers (including NCL)	%
Residential	1,601	58	1,659	85.87%
Commercial	254	19	273	14.13%

The residential customers make up nearly 87% of the total number of customers. For the purposes of analyzing the impact of the various treatment options when calculating the effect on rate payers, the total number of 1,995 customers will be used, as shown in Table III-4. The results will indicate that most of the cost will be borne by the residential customers. Actual costs will be allocated through updated rates, which analysis will be conducted separately from this study.

In addition, the City of Fairbury has several water users that consume larger quantities of water. A summary of annual water use from 2012 to 2016 is provided in the Appendices. A list of the top 10 users includes the LBNRD rural water system, Fairbury Foods, Jefferson County Health Center (Hospital), Farmer's CO-OP, Fairbury Steaks, Cedarwood (Senior Living Facility connected to the Hospital), Consolidated Sand and Gravel, City Swimming Pool, and the Softball Association (for underground sprinklers at City ballfields. The total water usage of these eight users is approximately 200,000 gallons per day, from the 2011 report, which is approximately 20% of the current average daily demand (approx. 1.0 MGD). More recent information was not readily available for review.

I. Little Blue Natural Resources District Rural Water System

The LBNRD's rural water system is supplied by the City of Fairbury, and is also included. Per their website (http://www.littlebluenrd.org/rural_water_projects.html), the Rural Water District (RWD) serves more than 284 domestic, livestock, and business hook-ups in their northern district, as well as more than 145 customers in their southern district. A map of the system is included in the Appendices. The RWD's north pump house contains pumps with a 150 gpm capacity, though they currently only use 50 to 75 gpm. The RWD's west pump house contains 100 gpm pumps. The west pumps would be upsized to 150 or 200 gpm, if possible.

Currently, the rural water system is not able to connect any other customers due to the water demand required. Using the information provided by the District on their website, there are a total of 429 service connections. By using the 2010 US Census information for Jefferson County, Nebraska, it states an average household size of 2.22 persons. The total calculated population served by the RWD is 953 persons. This is the equivalent of approximately 24% of the population of the City of Fairbury, using the 2010 US Census population. The RWD calculates an approximate population of 1,250 persons, per their survey to NDHHS.

Approximately 30 service connections prior to the west pumping station are supplied from the City's water tower, and are not included in the RWD's daily usage calculations. Based on phone and email conversations with Kevin Orvis, the projects manager for the RWD, they have a current demand limit of 200 gpm. When asked about future water needs, an instantaneous demand of 250 gpm was requested. Recent water use information is summarized below. Per capita water use was calculated based on the calculated population of 953 persons. The gpm water use calculations were determined based on a 24-hour period. 2012 was a drier year, and resulted in higher water use. The water use provided by the RWD represents the most recent peak use, for consideration.

IV-6: LBNRD RWD Historical Water Use

Description	Water Use (gpd)	Water Use (gpm)	Per Capita Water Use
2012 Average Daily Water Use	201,199	139.7	211
2012 Peak Daily Water Use (June 4-11)	275,517	191.3	289
2012 Peak Daily Water Use (July 16-23)	276,280	191.9	290
2016 Average Daily Water Use	157,451	109.3	165
2016 Peak Daily Water Use (June 6-13)	215,257	149.5	226

The water service agreement between the City of Fairbury and the RWD was initiated on September 2, 1997, and effective on January 1, 1998. The agreement includes provisions for review every 5 years. Section 4 outlines the quantity of water to be provided by the City to the RWD. The contract limits are a daily maximum of 38,500 cu. ft., or 288,000 gallons, per day, at a maximum rate of 26.74

cu. ft., or 200 gallons, per minute. Amounts used over the contract amount is billed at 20 times the current purchase rate. The RWD has requested an increase to 250 or 300 gpm, or a daily maximum rate of either 360,000 or 432,000 gallons per day, respectively. The amount requested represents a 25 or 50% increase, and will require a modification to the existing service agreement. It should be noted that the average daily water use of the RWD alone ranges from 15.75 to 20.1-percent of the City's average daily water use. These percentages were based on the 2012 (peak) and 2016 (average). Of the top water users in the community, which has been shown to be 20-percent collectively. This calculates to be nearly 80-percent on the lower end of the scale, using 2016 usage information.

J. Future Design Factors and Demands

Table IV-7 summarizes existing and estimated future system demands.

Table IV-7: Population Projections and Water System Demands

Estimated Demands	2010	2015	2020	2025	2030	2035	2040
Population Projection	3,942	3,863	3,876	3,889	3,902	3,915	3,928
Per Capita Demand (gpcd)	258	258	258	258	258	258	258
Average Daily Demand (MGD)	1.017	0.997	1.000	1.003	1.007	1.010	1.013
Average Daily Demand (gpm); 24 hour	706	692	694	697	699	701	704
Peak Day/Average Day Ratio (1)	2.40	2.40	2.40	2.40	2.40	2.40	2.40
Peak Hour/Peak Day Ratio (2)	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Peak Day Demand (MGD)	2.441	2.392	2.400	2.408	2.416	2.424	2.432
Peak Day Demand (gpm); 24 hr	1,695	1,661	1,667	1,672	1,678	1,683	1,689
Peak Day Demand (gpm); 16 hr	2,543	2,492	2,500	2,508	2,517	2,525	2,534
Peak Hour Demand (gpm)	3,390	3,322	3,333	3,345	3,356	3,367	3,378
Residential Fire Demand (gpm), calculated	1,985	1,965	1,969	1,972	1,975	1,978	1,981
Residential Fire Demand plus Peak Day Demand (gpm); 24 hr	3,680	3,626	3,635	3,644	3,653	3,662	3,671
Residential Fire Demand (gpm), minimum	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Residential Fire Demand plus Peak Day Demand (gpm); 24 hr	3,195	3,161	3,167	3,172	3,178	3,183	3,189
Average Day plus Residential Fire Storage Requirements (1,500 gpm for 2 hours), million gallons (calculated), minimum	1.197	1.177	1.180	1.183	1.187	1.190	1.193
Commercial Fire Demand (gpm), calculated	4,500	4,500	4,500	4,500	4,500	4,500	4,500
Commercial Fire Demand plus Peak Day Demand (gpm); 24 hr	6,195	6,161	6,167	6,172	6,178	6,183	6,189
Average Day plus Commercial Fire Storage Requirements (4,500 gpm for 3 hours), million gallons (calculated), minimum	1.827	1.807	1.810	1.813	1.817	1.820	1.823

(1) From City Records
(2) ASCE Glossary Definition (Section IV-C)

These demand rates serve as the basis for recommending improvements to the major components of the water system which will serve Fairbury's water system demands until the year 2040. It was decided to only use the City's population, and not the NRD calculated population. The per capita rate was calculated using the City's population.

The current pumping capacity is sufficient to handle the City's current and projected future demands. However, concerns over nitrates and the associated loss of supply are very real. The City's past approach has been to use the East Well Field as their system limitation, which includes a firm pumping capacity of 2.16 MGD, or 1,500 gpm. In this case, the projected peak water use (2.432 MGD) is over the capacity of the East Well Field by nearly 13%, or 0.272 MGD.

The RWD has requested an increase of 50 to 100 gpm, or an additional 72,000 to 144,000 gpd to their allotment. We have also been informed that Westin Foods desires to increase their water use over the next 20 years. Their currently anticipated projected daily water use is as follows: Current – 40,000 gpd; 5 years (2022) – 80,000 gpd; 10 years (2027) – 120,000 gpd; 20 years (2037) – 160,000 gpd. The City has also requested that additional capacity be reserved for economic development, and has selected 25%, or approximately 0.250 MGD. The information presented in the previous table is provided below, and combined with the current water requests mentioned.

Table IV-8: Projected Water System Demands

Estimated Demands	2010	2015	2020	2025	2030	2035	2040
Average Daily Demand (MGD)	1.017	0.997	1.000	1.003	1.007	1.010	1.013
Average Daily Demand (gpm); 24 hour	706	692	694	697	699	701	704
Peak Day Demand (MGD)	2.441	2.392	2.400	2.408	2.416	2.424	2.432
Peak Day Demand (gpm); 24 hr	1,695	1,661	1,667	1,672	1,678	1,683	1,689
RWD Additional Use, MGD	-	0.072	0.072	0.072	0.072	0.072	0.072
Westin Foods Additional Use, MGD	-	-	0.040	0.080	0.080	0.120	0.120
City Economic Development Use	-	-	0.25	0.25	0.25	0.25	0.25
Total Avg. Daily Demand, MGD	-	-	1.362	1.405	1.409	1.452	1.455
Total, gpm (24 hour)	-	-	946	976	978	1,008	1,011
Total Peak Daily Demand, MGD	-	-	2.762	2.810	2.818	2.866	2.874
Total, gpm (24 hour)	-	-	1,918	1,951	1,957	1,990	1,996

K. Wells and Pumps

Fairbury's water supply system currently consists of an infiltration gallery with feeder and siphon wells at Crystal Springs and the East Well Field, which consists of 3 active wells. The Crystal Springs water supply pumps through the cartridge filters and into the underground water storage reservoir at the power plant via twin 12-inch diameter transmission mains. The East wellfield wells pump directly to the distribution system and elevated water storage reservoir.

Pump capacities can change over the years due to pump repair and replacement. The apparent total capacity of the water supply and distribution system is shown in Tables IV-9 through 11. A total of 3 Reservoir High Service Pumps are located in the basement of the power plant.
Variable Frequency Drives (VFD's) were installed on 2 of the high service pumps within the last few years. Only 2 of the pumps are used at this time. The pumps operate at a head of between 300 and 323 feet (130 to 140 psi). Data on these pumps was not readily available. Fairbanks-Morse, the pump manufacturer was contacted to research pump information. The nameplate reads 6-inch, 5814NE, Serial No. 292947. The pumps are 6-inch, split-case style, installed in 1936 (shipped May 28). The pumps are rated for 1,200 gpm at 300 feet TDH. A performance curve was provided, and is included in Appendix "G."

Table IV-9: Pumping Capacity – Crystal Springs Supply

Pumping Location	Flow Capacity (gpm)	Flow Capacity (MGD)
Crystal Springs Supply-Cartridge Filtration Capacity	1,500	2.16
Crystal Springs High Service Pump Firm Capacity (2 pumps)	750	1.08
Reservoir High Service Pump #1	1,100	1.58
Reservoir High Service Pump #2	1,050	1.51
Total Pumping Capacity	2,100	3.02
Firm Pumping Capacity (with 1 Pump Out-of-Service)	750	1.08

As noted in Table IV-9, High Service Pumps #1 and #2 are separate from the pumps at the Crystal Springs facility, hence the total pumping capacity is not additive. Since the Crystal Springs are the limiting factor, the facility is limited to a pumping rate of 750 gpm, or 1.08 MGD. The City has attempted to run both pumps in the past, but have ruptured the existing 12-inch transmission mains. This limits their potential capacity.

Table IV-10: Pumping Capacity – East Well Field Supply

Pumping Location	Flow Capacity (gpm)	Flow Capacity (MGD)
Well #1	1,000	1.44
Well #2	1,000	1.44
Well #3	500	0.72
Total Pumping Capacity	2,500	3.60
Firm Pumping Capacity (with the Largest Pump Out-of-Service)	1,500	2.16

Table IV-11: Total Pumping Capacities

	Crystal Springs (GWUDI)		East Well Field (Groundwater)	
	gpm	MGD	gpm	MGD
Total Pumping Capacity	2,100	3.02	-	-
Total Treatment Capacity	1,500	2.16	2,500	3.60
Firm Pumping Capacity (Crystal Springs Pumps)	750	1.08	1,500	2.16
Firm Pumping Capacity (Crystal Springs Pumps)	1,050	1.512	-	-
Treatment Design Capacity	750	1.08	1,500	2.16
Current Operational Capacity	600	0.864	Same	Same

The City's total firm pumping capacity between the Crystal Springs high service pumps and the East wellfield is 2,250 gpm, or 3.24 MGD. This is 75% of the future peak daily demand of 2.43 MGD.

The additional demands (2.874 MGD) presented in Table IV-8 can be accommodated by the City's firm pumping capacity, which is nearly 89% of the calculated capacity. However, using only the East Well Field capacity, the projected peak water use is exceeded by 133%, or 0.714 MGD (496 gpm). It is anticipated that additional capacity requests will require financial commitments for system capacity and expansion. Adding the firm pumping capacity of Crystal Springs (750 gpm or 1.08 MGD) increases the City's firm pumping capacity to 3.24 MGD.

The system is controlled automatically based on the water level in the tower. High service pumps #1 and #2 are on a rotating start-up basis. This occurs when the water tower reaches 40 feet. The pump(s) shut-off when the tower water level reaches 44 feet. The East well combinations need to be started manually. The City currently doesn't run Wells #1 or #2 at the same time due to concern with the existing water transmission main. Either well can be used on its own or in combination with Well #3. The East wells are used to avoid low water supply from the underground reservoir.

The wells are currently tested and maintained by Sargent Drilling, of Geneva, Nebraska. The high service pumps have not been test pumped due to the lack of blow-off. It is recommended that the manufacturer or another company be retained to maintain and test pump these pumps to compare the current performance with the original pump capacities. The local pump representative, Bert Gurney, mentioned that the Fairbanks Pump Services Group could be contacted to do some on-site flow testing and compare the pumps to the original operating curve. Limited on-site visual inspection can also be conducted on the inside components, volute, and impeller of the split-case pumps. It is anticipated that this could occur at the same time as the flow testing.

For a more detailed inspection, such as detailed measurements of components to compare to original specifications, the pumps would have to be pulled and sent to the factory in Kansas City. Factory testing is also available to confirm the re-built pump meets the original specifications. Since the pumps are an older model, it is anticipated that similar pump models are in very limited production, so replacement would be necessary. Pump replacement would also mean additional piping modifications would be required to connect to the existing piping.

The last 3 years' worth of information regarding well service or condition assessment was provided by Sargent Drilling for review. These results are summarized in the following table.

Table IV-12: East Well Field Testing Results

Test Year	Well Test	Well #1	Well #2	Well #3
2014	Efficiency	77%	65%	81%
	Drawdown (gpm/foot)	106	84	76
2015	Efficiency	81%	64%	81%
	Drawdown (gpm/foot)	107	92	79
2016	Efficiency	69%	69%	83%
	Drawdown (gpm/foot)	106	89	79

A review of the information in Table IV-7 shows that for the most part, the wells in the East Well Field are maintaining their integrity. Well #1 seems to be decreasing in efficiency. Based on the results of the 2017 pump test, it may be time to consider performing maintenance on the pump, motor, and well screen. Some ideas and tips on maintaining water wells from the October 2005 and 2013 issues of Opflow; a publication by American Water Works Association (AWWA), are contained in Appendix "H."

L. Transmission and Distribution System

The current distribution system consists of a network of pipe ranging in size from 4 to 16-inches in diameter, as stated previously. The distribution system layout is provided previously in Figure IV-1. The approximate pipe totals in the system, taken from the City's existing system maps, are provided in Table IV-13.

Table IV-13: Transmission/Distribution System Pipe Summary Table

Diameter (inch)	Pipe Material(s)	Length of Pipe (feet)	Length of Pipe (miles)	Volume (gallons)	% of Total
4	Various	82,135	15.6	53,618	36.2%
6	Various	48,170	9.1	70,752	21.2%
8	Various	37,690	7.1	98,416	16.6%
10	Various	13,500	2.6	55,080	6.0%
12	Various	29,130	5.5	171,144	12.8%
14	Various	14,635	2.8	117,033	6.5%
16	Various	1,460	0.3	15,249	0.6%
Total		**225,210**	**42.7**	**581,292**	**100%**

The volume calculated includes the nominal volume for purposes of water age approximation. Using the previously calculated and projected average day demand, (1,013,000 MGD) the nominal water age of water within the distribution system is 0.57 days (581,292 gallons volume/1,013,000 gpd), not including storage volume. When the storage volume is included (an additional 3.5 MG), the nominal, or average, water age within the storage and distribution system increases to just over 4 days.

Water age, or system residence time, can be defined as the time from when the water is treated to when it reaches the customer, or the residence time of water in the system. Water age is of concern within water distribution systems as it can affect the water quality observed by system users. These effects range from aesthetic concerns such as corrosion within the system, taste, odor, smell, to health concerns such as Disinfection Byproducts (DBPs) formation (with full-time disinfection or chlorination), nitrification, microbial growth, to name a few.
Water age is a function of system operation, system design, and water demands. It should be noted that some documents reference smaller systems having historically higher water ages.

An indicator of water age is low chlorine concentrations of less than 0.2 mg/L. It is unknown as to how long this takes to occur. One (1) reference stated that "disinfectant residual levels begin to decrease within 200 hours, or about 8.3 days" (http://midwestwatergroup.com/downloads/Opflow%20-%20November%202011%20-%20Dead%20End%20Danger%20Zones.pdf), from the AWWA November 2011 *Opflow* publication, pgs 20-21. The article went on to state that "depending on initial disinfectant levels, water may become unsafe within 30 days or less." Additional commentary in the article discussed a 7-day water age recommendation for dead-end water mains. The City's current calculated nominal water age was shown to be less than 1-day, which is not a concern. A review of the hydraulic model may show pockets of higher water age in dead end or low use areas. These locations will be identified and discussed later in this document.

The City's transmission mains from Crystal Springs are 1 of their greatest concerns due to the age of the pipe and lack of information about pipe materials, bury depth, and other similar information. The ability to accurately ascertain pipe condition in an in-situ or minimally invasive manner are expensive and/or difficult to manage, but they are possible. This option was discussed with one service provider, Aquam, who can send the probe through a lower pressure line. The head conditions at the Crystal Springs WTP are 100-feet TDH, or a maximum of 43 psi, which decreases as the transmission main progresses towards the underground reservoir. A few of the pipeline condition investigation services require a minimum of 30 psi. A 2-inch minimum access point (i.e. service tap) every 0.5 miles (2,640 feet) is required. Over the 6,500 length of each 12-inch transmission main, this would require 3 taps per pipe. The initial price quoted was in the range of $12,000 to $15,000 per site, not including the new service tap to perform a visual inspection and pipe profile along the line. A more detailed cost will need to be confirmed, but the City would need to budget nearly $100,000 to video inspect the existing pipes plus additional services (engineering, 2-inch service taps, monitoring stations, etc).

As a comparison, the replacement cost of the 2 transmission mains (12-inch) from Crystal Springs to the underground reservoir have been calculated, and presented later on in this document.

It was discussed that it is not possible to flush the transmission mains at the underground reservoir. Flushing occurs at hydrants located at Crystal Springs, which results in an out and back flushing effort via the 2 Transmission mains. It is recommended that fire hydrants be installed prior to the water entering the underground reservoir, with appropriate valving to shut-off water flow to the reservoir. This modification may be done by the City, outside of a larger project.

M. Fire Hydrants

The City of Fairbury provides fire protection throughout the entire distribution system via 320 fire hydrants, according to the City's GIS. Ten States Standards (Section 8.4, 2012 Edition) indicate that hydrants should be a maximum of 350 feet apart to ensure adequate fire protection. A 350 feet buffer was applied to the fire hydrants in the GIS system to identify potential gaps in the City's fire hydrant coverage. This is displayed in Figure IV-11 of the report. As indicated in the Figure, there are presently a few gaps in the City's hydrant coverage based on their current distribution system configuration. Most of these are in sparsely populated areas. However, there are a few areas west of the hospital, on the north side of Hwy 136 near the shopping area, as well as the industrial area south of the railroad tracks and west of Highway 15 that could use additional fire hydrants.

N. Valves

The Fairbury GIS System indicates that there are presently 374 valves in the distribution system. Ten States Standards (Section 8.3, 2012) indicates that a water system should have adequate valves to minimize inconvenience and sanitary hazards during repairs. The standard recommends that valves not be placed more than 500-feet intervals in commercial districts, and not more than or 800-feet intervals in other districts. In locations where future development is not expected and users are scattered, valves should be placed at 1-mile intervals or less.

The valve locations from the City's GIS were used to analyze the system's valve coverage. A 500-foot buffer was applied to each of the valves in the GIS to determine any potential gaps in the valve coverage of the water system, displayed in Figure IV-12. As indicated in the figure, the City's distribution system generally has adequate valve coverage in town, though there are areas where valves should be added, as indicated by the figure. In addition, there are some long stretches of transmission main on the outskirts of the system with gaps in the valve coverage.

O. Water Storage Facilities

Water storage provides increased reliability for equalizing peak demands and emergencies during power outages. The amount of storage required depends on water demand and the capacity of the well supply. The distribution system pressure is regulated by a 1-million gallon elevated water storage reservoir. The tank has a nominal exterior diameter bowl of 64.5 feet and an 8 feet diameter riser. The base elevation is approximately 1440, with a height to water level of 103-feet. The tank is located southeast of the intersection of 24th Street and Highway 15.

In addition, the City's water storage also include an underground water storage tank with a capacity of approximately 2,500,000 gallons. The nominal interior reservoir dimensions are 188.5 feet (east to west) and 93.5 feet (north to south), with 18.75 feet to water surface, based on the 2005 record drawings. Part of the previous project was to install baffles between the reservoir columns to reduce water short circuiting and assure the necessary chlorine contact time in the basin. It should be noted that the reservoir isn't exactly square (1 corner is angled. The reservoir is located west of the City's power plant, near 3rd and A Streets. Water enters the reservoir in the southwest corner, where chlorine is injected. Water is also conveyed from this point to the northwest corner to work through the baffles to the outlet point. The outlet point is the center of the east reservoir wall. Two (2) high service pumps, located in the basement of the City's power plant, transfer the water from the reservoir to the distribution system and 1-million gallon elevated water storage tank. These water storage locations are shown in a previous figure.

The water level in the elevated tank controls the operation of the water supply wells or high service pumps. The current settings are to initiate the high service pumps when the water tower level is at 40 feet, and shut-off at 44 feet. The operating level may need to be increased to allow for more frequent turnover of water within the tower, and to reduce the impact of thermal stratification. Information regarding drawdown recommendations were requested of a water tank mixing company. The recommendations are provided for review/consideration in the Appendices. The assumptions were a 1,000 gpm peak fill rate and 2,000 gpm peak withdrawal rate. With the installation of a tank mixer, the drawdown of 4-feet is sufficient. However, there is another portion of the recommendation that lists a fill time, and associated drawdown, to achieve complete mixing. The calculated recommendation for this is 23 feet. EPA recommends a 20 to 30-percent daily tank turnover to meet the 3 to 5 day water age or residence time, discussed previously. The City may wish to adjust their tank fill time, volume, or consider the installation of a static mixer. The cost for a mixer of this type is in the $55,000 to $65,000 range. This could be installed as part of the City's subsequent tank maintenance cycle, if desired.

System pressures at the base of the elevated tank fluctuate depending on the system demands. Normal operating pressures range throughout the distribution system from 50 to 110 pounds per square inch (psi). Total available water storage is approximately 3.5-million gallons. However, the City has stated that the full storage may not be available due to the pumping configuration and flows into and out of the reservoir.

The City had an inspection performed on the pressure tank on August 5, 2013 by Liquid Engineering Corporation of Billings, MT. A copy of the inspection report is available in Appendix "J". The results of the underground reservoir inspection included statements of no health or safety concerns. It was stated that the tank was listed to be in excellent condition, though it was noted that there is some interior and exterior leaking. There is not a perimeter fence around this location.

The results of the elevated tank inspection included the recommendation to provide paint repairs, primarily in the upper walls of the tank. These repairs were completed a year later (August 14, 2014). It was noted that the tank was listed to be in fair to good condition. Tank and reservoir cleaning was recommended to be performed every 3 to 5 years for both locations.

Each storage facility should have enough storage to meet the domestic water requirements within its area of influence. The area of influence is a function of area water consumption demands and distribution piping. Fairbury has 2 storage facilities; therefore, enough water storage should be provided to handle average and peak water consumption for the entire City, as well as firefighting capacity.

The minimum firefighting requirements are shown in the City's most recent ISO report. However, firefighting storage for maximum fire capacity are sometimes not financially possible. For example, a firefighting storage volume of 4,500 gallons at a duration of 4 hours to handle a commercial fire would be 1,080,000 gallons. A similar calculation for a residential fire demand of 1,500 gpm at a duration of 2 hours results in a firefighting volume of 180,000 gallons. Larger volumes are more difficult to manage from a water age consideration. The future (2040) greatest average day demand of nearly 1,013,000 gallons was calculated previously.
The minimum recommended water storage volume is then calculated to be 1,193,000 gallons, which includes average day plus residential firefighting volume. The closest standard water tower size is 1,250,000 gallons.
If commercial fire demands are used, then the average daily demand plus fire storage equals 2,093,000, or nearly 2.1-million gallons.

If either the largest well, or a single high service pump, each with a capacity of approximately 1,000 gpm, is included with the calculation, this reduces the required residential fire flow to 500 gpm. Then the required storage volume would also reduce to 1,073,000 gallons, which results in the same nominal standard tank volume, when rounding up. The future (2040) greatest peak day demand of nearly 2,846,000 gpd, or 2.846 MGD, was also calculated previously. This is greater than the average day plus residential or commercial fire demands. Therefore, it is recommended that the City use the larger of the calculated volumes. It should be noted that the future projected peak day demand is less than the total available storage of 3.5-million gallons, or approximately 81% of the total volume.

In regards to water age calculations, the existing reservoirs are calculated to empty between every 4.31 to 1.23 days, using a projected average (0.813 MGD) and peak (2.846 MGD) daily water use, respectively, if the entire available storage volume is considered. This calculation excludes the volume of the transmission or distribution systems.

P. Water Quality

Water quality samples were obtained as part of this study from each of the active wells and from the point of entry to the distribution system, post-treatment. The point of entry samples included blending of both of the wells in the detention tank. The results of the water quality data are summarized in Table IV-4. Refer to Appendix "J" for water quality sampling results.

Reviewing the water quality information in Table IV-2 indicates that at this time the water quality areas of concern are iron and manganese concentrations in the South Well. The calculated Langelier Index is used as a measure of water stability, which is determined by the saturation percentage of calcium carbonate, using alkalinity and calcium concentrations. The calculation is made by subtracting the pH from the saturated pH (pH_s). A positive Langelier value tends to form scale within the system. A negative Langelier value tends to be corrosive. Generally, if the Langelier Saturation Index (LI) results are between 0.5 and -0.5, the water is considered to be balanced, as shown in Table IV-13. The water quality results summarized in Table IV-12 show that the water quality entering the system does not exceed the Maximum Contaminant Level (MCL) and Secondary Maximum Containment Level (SMCL) concentrations for all constituents.

Reviewing the water quality information in Table IV-14 indicates that at this time water quality is not an issue of concern for Fairbury, with the exception of nitrate concentrations. The following are comments on some of the constituents in the well water quality data summarized in the table.

1. Alkalinity is a measure of the ability of water to neutralize acids, and is measured as a Calcium Carbonate ($CaCO_3$) equivalent. The recommended range for drinking water alkalinity is 75 to 400 mg/L. All of the City's water sources fall into this range, and are below 250 mg/L.

Table IV-14: Water Quality Testing Results (May 2017)

Chemical Constituent (mg/L)	Crystal Springs	Well #1 (701)	Well #2 (801)	Well #3 (971)	MCL	SMCL	Rec. Limits
Year of Analysis	**2017**	**2017**	**2017**	**2017**	**-**	**-**	**-**
Total Alkalinity (as $CaCO_3$)	195	217	201	216	-	-	>75
Total Hardness (as gr/gal)	11.9	14.1	12.8	13.8	-	-	-
Total Hardness (as $CaCO_3$)	203.5	241	219	236	-	-	300
pH (S.U.)	7.21	7.03	7.01	7.14	-	6.5 - 8.5	-
Total Dissolved Solids	447	385	359	399	-	500	-
Conductivity (mmhos/cm)	0.688	0.592	0.553	0.614			
Sodium	68.2	31.3	29.5	39.4	-	-	20
Calcium	66.7	81.6	73.3	77.8	-	-	-
Magnesium	9.04	9.05	8.79	10.1			
Iron	<RL	<RL	<RL	<RL	-	0.3	-
Manganese	<RL	<RL	<RL	<RL	-	0.05	-
Fluoride	0.2	0.4	0.2	0.2	4.0	2.0	-
Chloride	66	14	14	15	-	250	-
Sulfate	26	31	31	36	-	250	-
Nitrate + Nitrite (as N)	8.7	8.6	8.4	**10.0**	10	-	-
Arsenic, Total (ug/L)[1]	2.3	1.0	0.9	1.1	10	-	-
Gross Alpha (pCi/L) [1]	3.25	2.89	2.98	<RL	15	-	-
Combined Radium 226 & 228 (pCi/L) [1]	0.70	1.60	1.68	1.10	5	-	-
Langelier Saturation Index	-0.326	-0.357	-0.450	-0.273	-	-	-
Total Organic Carbon (TOC)	<RL	<RL	<RL	1.0			
Ammonia – N	<RL	<RL	<RL	<RL			

All bold numbers exceed existing or proposed limits by USEPA.
<RL = Below reporting level, SU = Standard Units
1) Gross Alpha, and Combined Radium levels were obtained from Nebraska DHHS Drinking Water Branch on-line reporting (2017) for the City of Fairbury.

2. Total Hardness is a measure of the calcium and magnesium concentrations. They are the primary cause of hard water. Concentrations of the City's hardness constituents range from 204 mg/L to 241 mg/L as $CaCO_3$. Water with hardness between over 180 mg/L is considered 'very hard'. The most desirable Hardness is between 60 – 120 mg/L.

3. pH is a measure of hydrogen ion concentration (acidity). The pH for drinking water generally ranges from 6.5 to 8.5, with an ideal pH range of between 7.0 and 8.5. Lower pH values can result in corrosion and a metallic taste to water. Higher pH values result in a slippery feel, deposits, and a soda taste. All of the City's wells have acceptable pH levels.

4. The Total Dissolved Solids (TDS) test measures the total amount of dissolved minerals in the water. TDS concentrations in the City's existing sources range from 359 mg/L to 447 mg/L. These concentrations are slightly lower than the SMCL of 500 mg/L.

5. Sodium, or salt, is listed on the EPA's Contaminant Candidate List (CCL). The inclusion of sodium on the CCL allows the EPA to evaluate and revise regulations on the mineral, as needed. The sodium levels in the existing sources are above the desired concentration of 20 mg/L.

6. Iron and manganese concentrations are less than the reportable limit, and are not an issue in the City's water supply.

7. Fluoride concentrations are between 5 and 15% of the MCL of 4.0 mg/L. The optimal fluoride concentration in water is approximately 1.0 mg/L, which is lower than the concentrations in the City's supply sources. Fluoride is added.

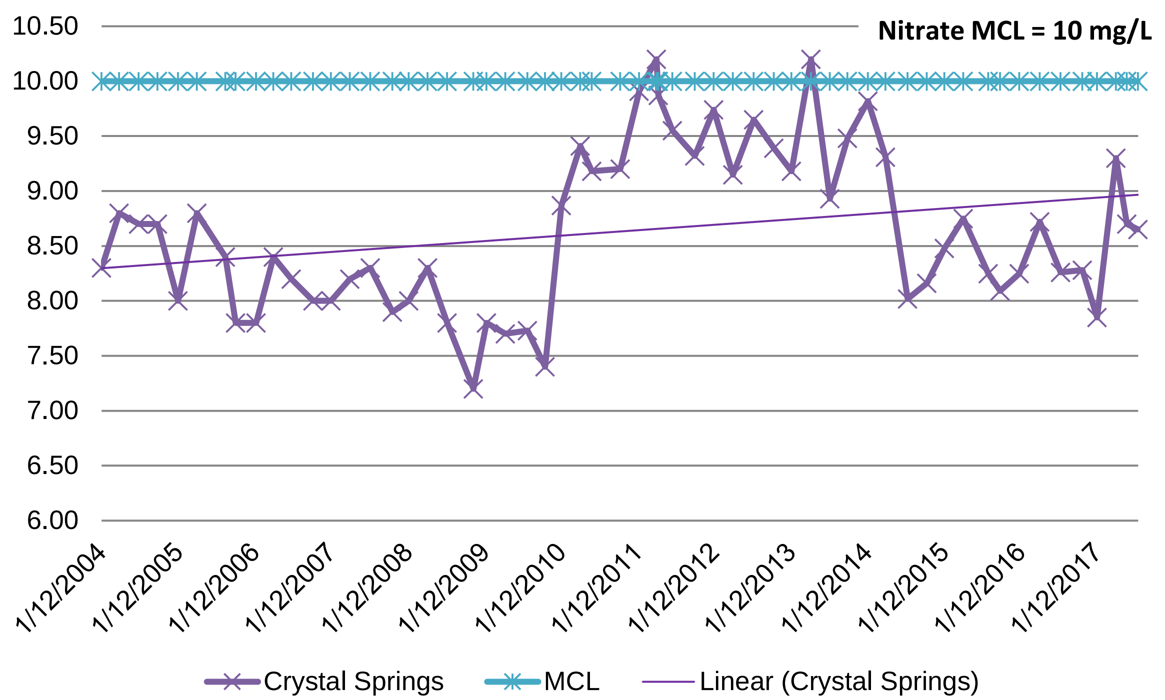
8. Chloride and Sulfate are low with concentrations well below the SMCL's of 250 mg/L, each.

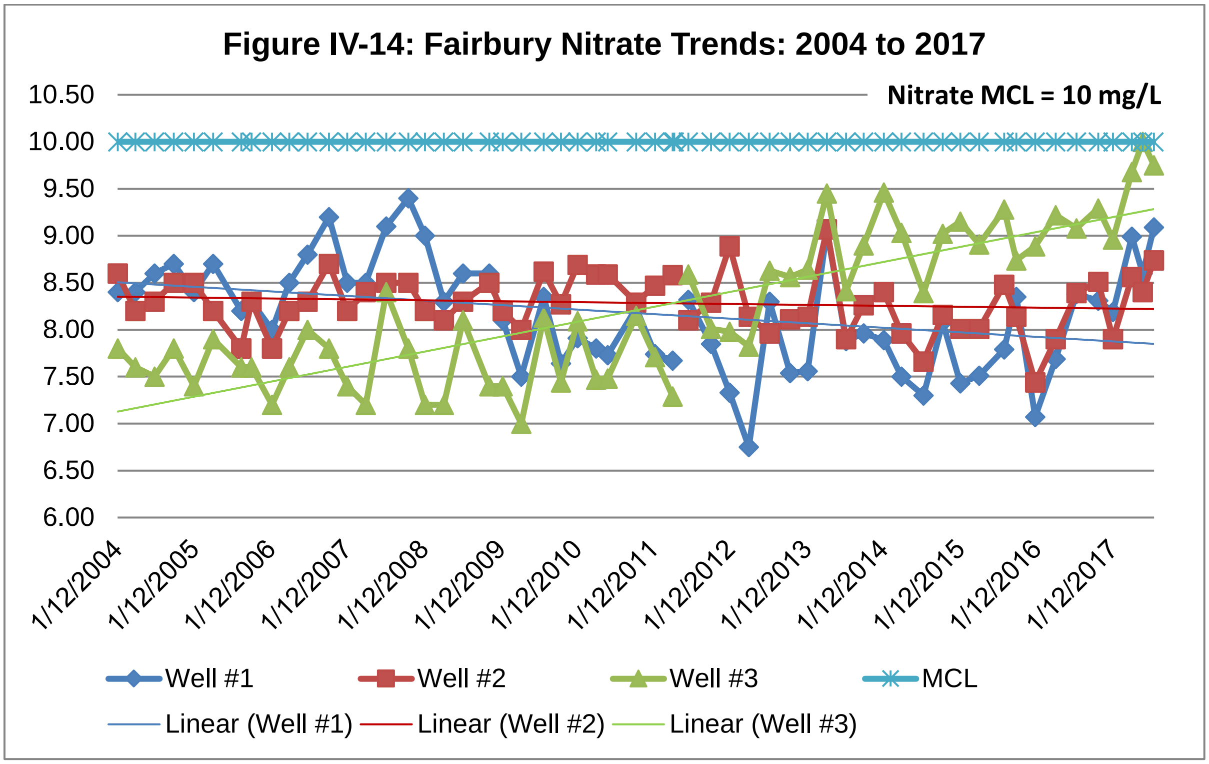
9. Nitrate (as nitrogen) levels vary among the different wells. Crystal Springs, Wells #1, #2, and #3 have reported average nitrate concentrations from 7 to over 9 mg/L using data from January 2004 to April 2017. The maximum concentrations are in the 8 to 10 mg/L range. The current MCL is 10 mg/L. Figures IV-13 and 14 show the reported nitrate concentrations from 2004 to 2017. A line illustrating the current MCL is shown on the Figure. The raw data is provided in the Appendices for review. The main item of concern is the large jump in nitrate concentrations at all of the water supply sources between January and April 2017. The increases range from 0.66 to 1.45 mg/L. The sample updates, taken prior to the July 2017 quarterly sample, have provided a glimpse into potential future nitrate concentration movement.

With the exception of Well #3, which was right at 10.0 mg/L, the other nitrate samples have backed off. The next quarterly sample will confirm an issue with Well #3. The nitrate concentration must be below 10.4 mg/L. It may be beneficial to begin setting up a blending configuration with the East Well Field to reduce the impact from Well #3. This is outlined in a subsequent portion of this document.

A review of the data presented shows that the overall trend in nitrate concentration is downward for Wells #1 and #2. Well #3 and Crystal Springs are trending upwards over the period of record. However, it should be noted that the upward trend is primarily due to the stretch of higher nitrate concentrations from 2010 to 2014. After that time, the concentrations have been less than 9 mg/L, with the exception of the most recent (April 2017) sample.

Figure IV-13: Fairbury Nitrate Trends: 2004 to 2017





With the downward trend of nitrates in Crystal Springs, it appears that the best management practices developed and implemented as part of the 2011 study have helped to address increases in nitrate concentrations. A copy of the previous recommendations is provided in the Appendices for reference.

10. Radionuclides, including Gross Alpha, and combined radium 226 and 228 were well below MCL levels during the most recent sampling, conducted in 2017.

11. The LI is used as a measure of water stability, which is determined by the saturation percentage of calcium carbonate, using alkalinity and calcium concentrations. The calculation is made by subtracting the pH from the saturated pH (pH_s). A positive Langelier value tends to form scale within the system. A negative Langelier value tends to be corrosive. Generally, if the LI results are between 0.5 and -0.5, the water is considered to be balanced. Though some sources list a much narrower range of -0.2 or 0 to 0.2 as optimal. Using the inputs from the water quality sampling results provided, it appears that the water could be considered slightly corrosive (LI average of -0.3515). The highest LI was observed from Well #2 from the most recent sampling results.

Based on the recent results of the City's on-going lead and copper corrosion results, corrosion reducing chemical addition, such as poly or orthophosphates may be necessary in the future. This can be discussed with the City's chemical feed supplier for initial recommendations.

In conversations with NDHHS, the City had an initial lead and copper rule exceedance in early 2017. The City was required to take two large rounds of additional lead and copper samples. One round is complete, pending results. The other round is scheduled to occur in September 2017, with results anticipated in October 2017. Any additional action or follow up will be confirmed and discussed at that time.

In summary, the City's water supply quality indicates that the water supply is good quality with 1 exception. Nitrate concentrations are approaching the MCL in some wells, and surpassed the MCL in April 2011 and 2013 at the Crystal Springs facility. The overall trend in nitrate concentrations is increasing with time, as shown by the Crystal Springs trend line. The City has requested that options for nitrate removal be provided, because of this water quality issue.

Q. Water Treatment Facilities

In 2002, the NDHHS classified the Crystal Springs Water Supply Facilities as being Groundwater Under the Direct Influence (GWUDI) of surface water. In 2004, a cartridge filter plant was constructed in order to comply with the Surface Water Treatment Rule (SWTR). This effort was completed by Olsson Associates (Project No. 2003-0409). The treatment facilities were designed to provide at least 99.9% (3 log) inactivation of *Giardia lamblia* cysts and 99.99% (4-log) inactivation of viruses every day the system serves water to the public (per Title 179 NAC 2, Section 2-013.03A1) and to identify all sources of microbiological contamination within the delineated area well protection area. No sources of microbiological contamination such as lakes, abandoned septic systems, etc. can be located within the 1-year time of travel from the well or well-field (per Title 179 NAC 2, Section 2-013.02B5b).

Five (5) (pre-filter) and 1-micron cartridge filters are provided to protect consumers from Giardia lamblia, Cryptosporidium, and viruses in accordance with the Long-Term 1 Enhanced SWTR (LT1ESWTR). The cartridge filter system has a 2,100 gpm design flow rate.

Baffling of the underground storage reservoir was provided in 2004 in order to increase chlorine Contact Times (CT) for disinfection. Provisions were made in the treatment facilities to provide for UV disinfection, if required by future regulations.

R. General Information

Table IV-15 includes some suggested minimum design standards (AWWA) for distribution piping that the City should continue to use while expanding the system and making improvements. A reference article titled *Developing & Implementing a Distribution System Flushing Program*, from the July 2002 AWWA Journal is include in Appendix "H."

Regarding water quality recommendations and water system design standards, it is advantageous for a municipality of any size to provide ongoing training and education opportunities to the water system employees. National and State organizations, specifically the AWWA and the Nebraska local chapter, provide these opportunities. Educational seminars of varying degrees are provided at a reduced cost to members of the organization.
It would behoove the City to provide funding that would allow water system employees the opportunity to become involved in the AWWA. Involvement in the organization would allow the water system employees to run the City water system more efficiently and to become aware of new technology that exists to improve the overall function of the existing system. The benefits for this small expenditure would more than pay for itself with the education and experiences that are provided with membership. Membership applications are also available on-line at https://www.awwa.org/Membership/ applications.cfm. The local chapter website is http://www.awwaneb.org/.

Table IV-15: Minimum Standards for Distribution Piping

Appurtenances	Minimum Standard
Lines	
Smallest Pipes in the Network	6-inch
Smallest Branching Pipes (Dead Ends)	8-inch
Largest Spacing of 6-inch Grid (8-inch Grid Beyond this Value)	600 feet
Smallest Pipes in High-Value District	8-inch
Smallest Pipes on Principal Streets in Central District	12-inch
Valves	
Largest Spacing on Long Branches	800 feet
Largest Spacing in High-Value District	500 feet
Hydrants	
Provided with Auxiliary Valve	All Hydrants
Minimum Size	6-inch
Spacing in Congested Areas	300 feet
Spacing in Light Residential Areas	600 feet
Suggested Fire Hydrant Locations:	At Intersections, Middle of Long Blocks, Near End of Dead End Streets

S. Financial Status of Existing Facilities

Current water rates were last updated on May 1, 2014, which includes several different water rates and organizational structures. A copy of the current rates are provided in the Appendices for reference. The number of water service connections within the system was presented previously. The system is currently metered. Financial information on the City's water fund was provided for fiscal years ending April 30 for 2012 through 2016, as part of this document.
Exhibit D from the City's audit for each of the referenced years are provided for reference in the Appendices. A summary of income, expenses, and reserves for each of the fiscal years provided is shown in Table IV-16.

The income for the system comes from water rates, both within the City and from the RWD. Income and expenses have fluctuated year to year, but are relatively consistent. In order for the City to be fiscally sound, sufficient revenue should be generated to account for emergency and planned repairs and maintenance. The current reserve available to the City is approximately $2.24-million. However, these are a summary of assets, and not cash. In conversations with the City, they have approximately $750,000 of cash on-hand. The is approximately 1 years' worth of operating expense, which is their reserve goal.

Table IV-16: City Financial Summary – Water Fund

Category	2012	2013	2014	2015	2016
Operating Revenue - Total	$755,195	$835,471	$828,821	$894,916	$872,072
Operating Expenses - Total	$739,639	$788,528	$754,265	$691,643	$753,508
Operating Income (loss)	$15,556	$46,943	$74,556	$203,273	$118,564
Non-Operating Revenues (Expenses)	($14,534)	$16,171	$2,591	$9,850	$12,340
Income (loss) Before Contributions and Transfers	$1,022	$63,114	$77,147	$213,123	$130,904
Transfers Out	$0	$0	$0	$0	$0
Changes in Net Assets	$1,022	$63,114	$77,147	$213,123	$130,904
Total Net Assets - Beginning	$1,751,060	$1,752,082	$1,815,196	$1,892,343	$2,105,466
Total Net Assets - Ending	$1,752,082	$1,815,196	$1,892,343	$2,105,466	$2,236,370

The City does have a current CIP, which is posted on their website as a list of projects and the associated anticipated construction costs. Proposed water system project includes adding auxiliary valves to fire hydrants (approximately 10 per year) adding 12 blocks of 12-inch main, potential water treatment facility for nitrates, connect existing wells to the distribution system, and extend or replace existing water mains throughout the distribution system.

Repairs to the system have historically been made as problems have occurred. Anticipated capital improvement costs will be allocated through the current rate structure. It may be necessary to adjust rates in order to fund system improvement or expansion. The rate analysis would be conducted separately from this study. At a minimum the new rates should cover the current expenditures as well as the planned system improvements. In regards to the larger water users, such as the RWD, Westin Foods, and others as desired by the City, it may be beneficial to structure rates based on actual usage. That way each of these users are paying a commensurate share of their use of the City's water system resources, including capital and operational costs.

T. Water, Energy, and Waste Audits

No water, energy, or waste audits have been conducted by the City.

U. Hydrologic Review

1. Hydrogeologic Characteristics of the Well Fields

The hydrogeology of Jefferson County including the Fairbury area was described in the Nebraska Geological Survey Bulletin No. 18A (Condra, Reed and Gordon, 1950) and more recently in publications by Dr. R.M Joeckel of the University of Nebraska (Joeckel R.M. et al 2005 and Brenner, R.L., et al 2000). In the Nebraska Geological Survey report, a subsurface gravel-filled paleovalley aquifer is described that extends east to west across the south central part of Jefferson County. The paleovalley aquifer crosses the Blue River at Fairbury. This paleovalley aquifer is the major source of water for the area and both the Crystal Springs and East Well Field are located within the paleovalley aquifer. Groundwater production rates within the paleovalley aquifer are high in comparison to the areas outside the paleovalley were the aquifer is thin or absent.

Figure IV-15 illustrates the configuration of aquifers in the area. Areas where the principal aquifer is absent are identified in a stippled pattern on the map. In contrast, the areas where groundwater production rates are high are indicated on the map as areas with progressively higher transmissivity. Transmissivity is a measure of how water moves through the aquifer materials and, as shown in the previous figure, the ancient river valley (paleovalley) aquifer has the highest transmissivity values in the area.

Groundwater flow in the Fairbury area is towards the Blue River. At the East Well Field, groundwater flow is from the northeast to the southwest. In contrast, at Crystal Springs, groundwater flow is from west to east. Along with the differences in groundwater flow direction, there are also significant hydrogeologic differences between the two well fields.

At Crystal Springs, groundwater discharges at the ground surface because the water table elevation is higher than the ground surface. The three siphon wells and the infiltration gallery take advantage of this phenomenon. At the East Well Field, the water table is approximately 70 feet below the ground surface and groundwater is pumped from the three wells.

2. Water Quality Source Protection
The City of Fairbury has invested significant resources in the construction, operation, and maintenance of the two water supply well fields. The City, working with the Little Blue NRD and Nebraska Department of Environmental Quality (NDEQ) prepared Wellhead Protection Areas for Fairbury's two water sources, as part of the Wellhead Protection Program, dated 2002 (www.deq.state.ne.us). The Wellhead Protection Areas are illustrated in Figure IV-16. The maps illustrate the source areas for the two well fields for a one, two, ten, and twenty-year time period. The red line that depicts the WHPA boundary encompasses the ground that through infiltration of precipitation and groundwater flow within a 20-year period will supply groundwater to the springs and wells at the well fields. It is the intent of the City, NDEQ and the NRD that through the management of activities within the boundaries of the Wellhead Protection Area, the City's water supply will be protected from contamination.

3. Existing City Wellhead Protection Area Ordinances
The City of Fairbury, the NDEQ and Little Blue NRD have established Wellhead Protection Areas for the Crystal Springs and East Well Field. Additionally, the City of Fairbury has setback requirements for certain activities and structures that range from 50 to 1,000 feet from any municipal water well. The setback requirements are defined in the City's Wellhead Protection Area Ordinances that are a part of the City's municipal code. Further information on the wellhead protection programs and results of water quality testing are provided in the 2011 Olsson report.

4. Additional Water Supply Recommendations
An evaluation of the aquifer characteristics in and around the Fairbury area indicate that the most favorable aquifer materials are located within the paleovalley deposits that cross the Little Blue River at Fairbury (Figure IV-15). The outline of the most productive aquifer materials is illustrated on the transmissivity map of the area (Figure IV-16). Based on this information, and a review of the registered well logs available through the Nebraska Department of Natural Resources, the area immediately adjacent to the East Well Field has the most favorable aquifer characteristics for additional water supply development and is closest to existing water system infrastructure. Figure IV-17 illustrates the location of the existing water distribution system, active wells registered with the State of Nebraska and the aquifer transmissivity values.

It is recommended that the next phase of investigation for water supply development in this area include the following:

- Water quality sampling of existing wells in the area. The Little Blue NRD provided nitrate sampling results from 2012 to 2016 for review, however, further information on the concentrations of nitrate and other compounds is needed to confirm that the water quality in the proposed expansion area adjacent to the East Well Field meets the requirements of the SDWA.

- A hydrogeologic investigation, including test hole drilling and aquifer testing in the proposed expansion area adjacent to the East Well Field, to confirm that the aquifer characteristics meet the production needs of the City.

V. NEED FOR PROJECT

The analysis of the existing system and the establishment of estimated demands permit a determination of present deficiencies and the development of a plan for potential improvements. An adequate supply of quality water must be backed up with adequate storage and distribution systems to provide good service to all areas of the City for the present and in the future. A review of the existing water distribution system's ability to provide domestic flows to different parts of town was not included as part of this document.

The existing facility review outlined several items that require attention. These recommendations will be discussed in more detail in order to establish the need for the project, based impacts of health, sanitary, security, and aging infrastructure to the City's water supply, treatment, storage, and distribution systems.

A. Health and Sanitation

The primary function of a PWS is to protect the health of the users.
To date, no correspondence has been received from Nebraska Department of Health & Human Services (NDHHS) regarding nitrates. However, the water treatment plant has been on the Intended Use Plan (IUP) as a potentially funded project for several years. It was submitted for consideration in November 2014. However, nitrate is 1 of only a few acute health concerns. Other water system concerns are generally not included in this category.

B. Security

No safety features are in place for monitoring or alarming water operators in the event of a break in, or tampering with the system. The Water Treatment Building, well houses, power plant, and tank hatches are locked. The existing water treatment facility and elevated water reservoir both have a perimeter fence in place. The well houses, and reservoir are not currently fenced. The well field has a locked access gate and fence along the county road. One (1) of the recommendations is that each site be secured, if not already. To date, no correspondence has been received from NDHHS or other agencies requiring installation of site fencing. The NDHHS also has a security grant program that may provide an option for the City to fund this improvement.

Provisions for fire protection are provided to the City by the existing water supply, storage, and pumping systems, and there is currently provided a sufficient volume to account for average day plus fire demand, or peak day, as calculated previously. Additional valves and fire hydrants were needed in a few areas and will be included in the recommendations.

C. Aging Infrastructure

The City has updated their system by adding new wells, and providing continued maintenance of the wells and booster pump systems. Age of the water system is noticeable, and it is recommended that corroded piping, and similar components be replaced, and repainting occur to prolong the life of the system. Minor repairs should be made to the existing structures, such as filling masonry cracks, etc.

Due to the age of the pumps, and limited production of replacement pumps, it is anticipated that maintenance of the pumps is recommended, and replacement of the existing pumps may be necessary. A potential pump curve is available for review in the Appendices. Full replacement costs for the high services pumps has been provided for reference. Ongoing maintenance and calling in manufacturer's representatives to provide service and recommendations would benefit the City to have better options moving forward.

One (1) of the 12-inch transmission mains from Crystal Springs was installed in 1988, the other is original to the facility. The City has had at least 2 main breaks west of the river and are concerned with the conditions of the main. As stated previously, with no way to accurately determine the life of buried utilities, it was recommended that a full replacement cost from Crystal Springs to the underground reservoir be provided for budgeting purposes. Some potential in-pipe survey options may be available, and will be investigated in time for the final report. It may be beneficial to install monitoring stations and valves at opposite ends of the river crossings to allow for in-place pipe inspection and to provide options for better monitoring of water transmission underneath the river.

The addition of a dehumidifier to the Treatment Building will prolong the life of the paint coating. The cartridge filters should be replaced per the manufacturer's recommendations, and based on the operator's observations.

The elevated and underground water storage reservoirs should continue to be inspected, per NDHHS requirements, every 5 years, at a minimum. The City should work to identify potential costs so that a budget, and associated water rates, can be implemented in order to pay for the proposed and recommended repairs.

D. Reasonable Growth

A review of the historical and project populations for the City, completed in a previous section of this document, has shown that a downward population trend can be anticipated in the future. However, it is recommended that the City design to maintain the existing population plus some modest growth during the planning horizon of this study. Additional capacity requests have been provided previously, and include industries already established in town, the existing RWD connections, as well as future economic opportunities for the City.

E. Water System Hydraulic Model

In conjunction with this PER, Olsson developed a hydraulic model using InfoWater software by Innovyze, Inc. The InfoWater model creates a computerized representation of the water distribution system, which allows for analysis on the system to determine its fire flow capability and to identify potential deficiencies in the system.

Fairbury's Geographical Information System (GIS) was provided for use in the PER. The 2017 GIS depicts the size and location of the water mains, valves, and hydrants in the system. InfoWater software works within ArcView GIS. Elevations at the nodes within the model were determined using USGS Quadrangle Map contours and Google Earth, and refined further when the model was calibrated. A roughness value ("C-factor") of 120 was initially used within each of the pipes and adjusted to most accurately represent field conditions during model calibration, discussed below.

As discussed herein, the City's water system consists of a single pressure zone. Field data collection was performed to calibrate the hydraulic model to real world conditions. Flow testing was performed on April 11, 2017 by Olsson Associates, with the City water department operating the hydrants, as demonstrated in the following figure.

Figure V-1: Fire Hydrant Flow Testing (17th and E Streets)

The process of the flow tests consists of the following steps:

- Identifying a representative sample of hydrants throughout the system.
- At each location, a hydrant is identified as a flow hydrant and a residual hydrant.
- A pressure gauge is installed on the residual hydrant, and its pressure is recorded.
- The flow hydrant is opened, and the pressure of the water flowing out of the hydrant is recorded using a pitot gauge. The pressure is converted to a volumetric flow rate using the following equation:

  $$Q = 29.83CD^2\sqrt{P}$$

  Where;
  Q=Flow (gpm)
  C=Opening Coefficient (0.90 used for a circular outlet at the hydrant)
  D=Opening Diameter (2.5 inches)
  P=Pitot tube pressure recorded (in psi)
- The pressure on the residual hydrant is observed and recorded.

During flow testing, Olsson requested that the high service pumps be taken offline during fire flow testing, so that all pressures were dependent upon the water tower height.

After digitizing the water system into InfoWater, the hydrant tests were used to calibrate the hydraulic model to replicate field conditions to both static and flow test conditions. To calibrate the system to static conditions, elevations at each of the nodes in the system, representing the hydrants that were pressure tested in the field are adjusted as necessary to most accurately reflect the pressures observed in the field. All locations observed during flow testing were able to be calibrated to within 3 psi of static field conditions.

Calibrating the system to flow test conditions is a slightly more involved process. Nodes are identified in the water model to represent the flow and residual hydrants from the flow tests. The flow observed in the field is input into the node representing the flow hydrant within the hydraulic model, and the residual pressure at its corresponding node is recorded. The roughness values within the nearby water mains are adjusted up and down as necessary until the values recorded in the water model most closely match what was observed in the field.

While the system calibrated to static pressures close to field conditions with little effort, it was initially difficult to calibrate the system to flow conditions, specifically on the flow tests that were performed on 4-inch water mains. Olsson contacted the City to ask if any valves may have been closed in the system, as the residual pressures were lower in the field than could be replicated in the model. The City indicated that they did not believe any valves were closed in the system. Ultimately, the model calibration was accomplished by using very low roughness values on the older, 4-inch water mains. This is typically indicative of older cast iron piping with corrosion/tuberculation present.

The ISO report was looked at as a second source to aid in calibrating the model. However, the static pressures in several locations were well above those observed in the field flow testing performed by Olsson, and it appears that 1 or both of the high service pumps may have been running during their tests. Without knowing the status of the pumps operating during the ISO report, it is difficult to use this as a resource to calibrate the model, therefore, these numbers were not used for further calibration.

The hydraulic model calibration results are provided in Table V-1, and a location map showing each of the flow tests is included in Figure V-2 of this report.

Table V-1: Hydraulic Model Calibration Results

Test	Location of Flow	Location of Residual	InfoWater Node	Field Static Pressure	Model Static Pressure	Δ (psi)	Calculated Flow (gpm)	Field Residual Pressure (psi)	Model Residual Pressure (psi)	Δ (psi)
1	31st & H	31st & E	J516	48	48	0	2,034	32	26	6
2	Enterprise	24th & L	J492	49	49	0	2,825	42	47	-5
3	22nd & J	22nd & K	J62	50	49	-1	2,663	42	46	-4
4	Circle Drive & K Street	West end of Circle Drive	J494	44	44	0	2,431	33	35	-2
5	North of 17th & E	500' North of 17th & E	J466	52	49	-3	1,762	20	22	-2
6	15th & D	16th & D	J470	52	54	2	856	42	46	-4
7	Maple & Sunburst	Maple & 14th	J352	85	86	1	2,034	50	53	-3
8	14th & Tilden	South end of Tilden	J402	92	93	1	787	52	54	-2
9	10th & Ash	10th & Maple	J482	102	104	2	336	18	15	3
10	4th & Frederick	4th & Charles	J506	100	99	-1	411	31	38	-7
11	Converse & J Street	Converse & K Street (north)	J504	98	99	1	375	18	22	-4
12	3rd & L	3rd & M	J196	78	80	2	384	36	33	3
13	11th & L	9th & L	J508	58	60	2	934	44	54	-10
14	9th & F	10th & F	J474	75	74	2	411	21	21	0
15	4th & I	4th & J	J490	85	85	0	475	45	47	-2
16	12th & C	11th & C	J480	75	76	1	336	52	58	-6
17	12th & L	13th & L	J514	64	63	-1	336	37	62	-25
18	7th & B	7th & C	J342	95	94	-1	444	49	47	2

F. Existing System Pressures

Ten States Standards indicate that a water system should provide a working pressure between 60 and 80 psi, and a minimum working pressure of 35 psi. The calibrated hydraulic model shows that the distribution system pressure range from approximately 40 to 105 psi, with pressures lower in the north part of the system and increasing towards the south end of the system. The existing distribution system pressures are displayed in Figure V-3.

G. Summary of Potential System Deficiencies

The calibrated hydraulic model was used to simulate fire flow demands throughout the City's water system and determine where there may be deficiencies present. Ten States Standard indicate that a water system should provide a working pressure between 60 and 80 psi, with a minimum pressure of 35 psi. A distribution system that provides fire protection should be capable of providing the necessary fire flow demands while retaining a minimum residual pressure of 20 psi.

Additionally, Ten States Standards indicate that water mains intended to provide fire protection should be a minimum of 6 inches in diameter. Table IV-13, which summarized the total length of water mains of various sizes in the distribution system, indicated that a small portion (around 10%) of the water system consists of 4-inch diameter or smaller water mains. Rather than recommending replacement of all water mains that are smaller than 6 inches in diameter, the water model is used to identify which portions of the system could be upsized or looped to provide the necessary fire protection in the system. Fire flow demands were determined earlier in the report, and are summarized in Table V-2.

Table V-2: Fire Flow Demand Summary

Fire Flow Type	Fire Flow Demand (gpm)
Residential	1,500
Commercial	4,500

Fire flow simulations were performed using the Fireflow scenario run manager in InfoWater. The Fireflow function applies a fire flow demand, specified by the user, throughout the water model. After the fire flows are applied, InfoWater reports the fire flow available at each node while maintaining a residual pressure of 20 psi. The fire flow analysis was performed using just the water tower in the model, without the high service pumps in place. The available fire flows are displayed in Figure V-4.

The Fire Flow Analysis, as shown in Figure V-3, shows that most the system can provide at least 1,500 gpm while maintaining a residual pressure of 20 psi, however it is deficient in several places in its ability to provide the Residential and Commercial Fire Flow needs determined earlier in this study.

Most of the anticipated deficiencies identified by the water model are located on the 4-inch water mains. As indicated previously, Ten States Standards indicate that where fire protection is provided, water mains should be a minimum of 6 inches in diameter. Rather than recommend a blanket replacement of all mains that are smaller than 6 inches, the areas that specifically are shown in the hydraulic model to be deficient in providing fire protection should be considered first, and over time, the City's water system should have a goal of upsizing all mains that are under 6 inches in diameter. The proposed improvements are discussed later in this report, along with proposed cost estimates for each.

VI. ALTERNATIVES CONSIDERED

A review of the City's existing water distribution system yielded several opportunities for improvement and future planning. In general, there are several items within a municipal water supply system that should be improved. These alternatives will be discussed in this section, including alternative water sources, funding, and existing system repair, maintenance, and improvements.

The City's current (2010-2014) Median Household Income (MHI), per the Nebraska State Revolving Fund (SRF) 2017 Intended Use Plan (IUP), was $38,641. The IUP currently shows the City to be on the funding list (Project Rank #1) for the nitrate treatment project, replacing pumps and mains in the amount of $5,920,000, as mentioned previously. Twenty percent loan forgiveness is included with this funding offer. Typically, this is reserved for a period of 5 years, and will need to be renewed or modified towards the end of 2019.

Any modifications or updates would need to be submitted to NDEQ/NDHHS for consideration. Since a loan has not yet been requested by the City, modifications in price or scope can be made for inclusion.

A. Description and Design Criteria

A completely alternate water source is not possible, as the City is already the water supply source for surrounding areas. Though there may be some provisions for supplemental water source to the south, it is not anticipated that substantial additional water supply sources will be considered, or are available to the City.

B. Recommended Distribution System Improvements

1. Fire Flow Analysis

   The majority of the deficiencies identified in the hydraulic model are in areas that are currently served by 4-inch water mains. It is not practical to recommend a blanket replacement of all 4-inch water mains in the system. A more realistic approach is to identify locations where replacing and upsizing mains will offer the most benefit to the overall system, with the goal of eventually replacing all 4-inch mains with 6-inch mains or larger where fire protection is provided. This will require a commitment from the City to systematically budget for replacement of these lines.

2. Proposed Water Distribution System Improvements

   The following improvements were identified to improve the fire flow capabilities throughout the City's Water System. The identified potential improvements are displayed in Figure VI-1, and summarized in Table VI-1.

Table VI-1: Proposed Water Distribution System Improvements

Project	Location	Description	Length of Project (LF)	Pipe Size (in.)
A	4th Street, from "F" to the block east of "M"	Upsize 4-inch mains	3,500	6
B	6th Street, from "F" to the block east of "M"	Upsize 4-inch mains	3,500	6
C	"F" Street, 8th-14th, G Street, 8th-14th	Upsize 4-inch mains	5,000	8
D	B Street, 6th-14th, C St, 5th-14th	Upsize 4-inch mains	7,000	6
E	9th Street, Ash-B	Upsize 4-inch mains	2,000	8
	9th & Ash, north to 10th, east to Maple, south to 9th	Upsize 4-inch mains	1,200	6
F	A St, 4th to 9th	Upsize 4-inch mains	2,000	6
G	3rd Street, F-M, southeast to PWF Road	Upsize 4-inch mains	4,500	6
H	3rd & J, south to Converse, east to K, then southeast to Road P332	Upsize 4-inch mains	4,000	6
I	3rd & L, south to 2nd & L	New 6-inch main interconnect	400	6
J	9th & Ash, south to 4th, east to C Street, then south to 3rd Street	Upsize loop west of school	5,000	8
K	Maple, 8th-9th; Vine, 8th to 9th, west end of 7th, west end of 5th	Upsize dead ends near school	2,000	6
L	11th Street, H-I	New Water Main	400	6
M	K Street, 14th to 7th, then east on 7th from K-M	Upsize 4-inch water mains to 8-inch along K Street, 6-inch on 7th Street	4,000	6, 8
N	J Street, Heritage Highway south to 9th, then west to I Street	Upsize 4-inch water mains	3,000	8
O	9th & K, east to L Street	Upsize 4-inch mains to 8-inch, connect existing 4-inch to 14-inch main	800	8
P	4th & Franklin, south to 3rd, east to A Street, then north to 4th	Upsize 4-inch mains	2,000	6

The fire flow capabilities were analyzed again after updating the model with the upsized and additional mains. The fire flow capabilities after implementing the proposed improvements are displayed in Figure VI-2.

The most recent ISO report was used to further analyze the anticipated effect of the improvements, which identified 9 locations throughout the water system and the corresponding fire flow needs for each. These locations, along with the ISO calculated fire flow needs and the fire flow capabilities determined in the model are presented in Table VI-2.

Table VI-2: ISO Hydrant Locations and Fire Flow Capabilities Before and After Proposed Improvements

Test	Node	Test Location	Flow Needed (gpm)	Flow Available (before)	Flow available (after)
1	J240	West of H & Arcade	1,000	1,200	1,800
10.0	J386	9th & Hubble	2,250	1,300	2,900
11	J128	20th & H	2,500	2,800	2,700
2.0	J588	2nd & H	1,750	1,100	2,100
3.0	J526	4th & C	2,000	2,900	3,500
3.1	J526	4th & C	4,500	2,900	3,500
4.0	J250	4th & E	2,250	3,700	3,700
5.0	J528	5th & E	2,500	1,200	3.700
6.0	J528	5th & E	1,750	1,200	3.700
7.0	J530	12th & G	3,500	1,000	2,600
8.0	J154	8th & F	1,000	2,400	3,300
9.0	J160	8th & K	3,000	1,300	3,000

As indicated in the preceding table, the hydraulic model shows that with the proposed improvements in place, fire flow capabilities are increased system wide. The hydraulic model shows increased fire protection capabilities at all twelve of the locations identified by ISO. Locations 3.1 and 7.0 show an increase in fire flow protection capabilities, but still slightly under what the ISO has identified as the fire flow needs.

It is recommended that approximately 15 valves (8, 4-inch; 4, 6-inch, and 3, 8-inch) and 15 fire hydrants be added to the distribution system, as demonstrated previously. However, most of the 4-inch valves will be replaced as part of the distribution system improvements. The 6 and 8-inch valves, as well as the additional fire hydrants, will be added to the cost estimations provided later in this section.

The largest question is what options are available to the City for inspecting the existing transmission main from Crystal Springs. If the lines were to installed new today, they would require installation of valves on either side of the water crossing, as well as permanent taps or other provisions to allow for the connection of a "small meter to determine leakage and obtain water samples on each side of the valve closest to the supply source", also known as monitoring stations, per Ten States Standards for Water (2012). The installation of these valves and monitoring stations would be similar to the layout shown in Figure VI-3. The installation would allow for a point inspection of the pipe at the locations of valve installation.

Substantial discussion and concern has been had regarding the existing transmission main from Crystal Springs. It is anticipated that most of the pipe is original from the 1930's. One of the river crossings was replaced in 1988, but to an unknown depth below the river. Recent river crossings installed by the RWD were done to a depth of 30-feet below the river bed, or flow line.

Opportunities to determine pipe integrity are being investigated, but will not be performed as part of the scope of this report. At least two breaks have occurred on this line within the last 10 to 15 years. The City is not able to pump the Crystal Springs facility to full capacity with the current condition of the transmission main. The cost of full replacement from the new header at the Crystal Springs treatment facility to the existing underground reservoir, a length of approximately 6,500 linear feet for each line, which includes the river crossings, monitoring stations, valves, and flushing hydrants near the underground reservoir, and included in the cost estimate for consideration. The approximate alignment location would parallel the existing transmission mains, as shown in Figure VI-4.

The option of centralized treatment was discussed in the 2011 report. This includes the treatment of water from the Crystal Springs facility and blending with the East Well Field. This requires transmission and distribution system modification for a single point of entry to the system. The system would then be limited by the pumping rate supplied by the high service pumps. The blending would need to occur after the high service pumps, and allow provisions for sampling the blended supply. Additional piping modifications between the power plant and water tower may be needed due to the increased flow. A proposed alignment of this option is provided in Figure VI-5, with an approximate length of 8,400 linear feet. The new transmission main would either be 14 or 16-inches in diameter. Features of this option include the following:

- Connection to the existing 14-inch transmission main near the intersection of 712th Road and Francis Street.
- Horizontal Directional Drilling the alignment along 3rd Street.
- Two railroad and one highway crossing, using 24-inch diameter casing. Union Pacific Railroad and Nebraska Department of Roads (NDOR) crossing and occupy permits would be required. Final alignment placement will determine what permits are needed.

3. <u>New Water Supply Well</u>
   Siting of the new well is extremely important, as it will assure protection of the well itself, as well as the City's water supply. Well siting is done in conjunction with the Nebraska Department of Health and Human Services (NDHHS), and regulated by the Nebraska Administrative Code (NAC), Title 179. The well site should be located so that it is protected from flooding, a safe distance away from existing and future contamination sources, such as septic tanks, other wells, chemical containment areas, landfills, and other similar operations. In general, the well should be located between 500 feet away from contamination sources (including the cemetery) and 1,000 feet away from other wells, sewage lagoons, land application of waste, and feedlots or feedlot runoff.

The well would need to connect to the existing transmission main north of the existing point of entry sample station, located northeast of the access road gate off of PWF Road. It is anticipated that a new well could be placed in the southeast corner of the City's existing property. This location is shown in Figure VI-6, and located on property already owned by the City. The legal description is the northeast quarter of the southeast quarter, Section 13, Township 2 North, Range 2 East, Jefferson County, Nebraska.

Flow from the new well would enter the existing 14-inch transmission main. A natural question is can the existing transmission main handle the additional flow. Using the hydraulic model, and the maximum flow rate of all wells in operation (2,500 gpm, nominal), the velocity through the transmission main would be 5.2 feet per second. Adding 500 gpm presumed from the new well, the velocity would increase to 6.2 feet per second. The firm pumping capacity would be 2,000 gpm, which is an increase from 1,500 gpm. There will be a slightly higher friction loss through the transmission main, but this can be overcome with existing VFDs. The new well would be sized with all wells in operation to provide sufficient pumping head. It appears that the existing transmission main will be sufficient to handle an additional 500 gpm of pumping capacity. This will be reviewed more fully once the capacity and location of the well has been confirmed.

The existing test well site would need to be reviewed by the local NDHHS field representative. The review will include filling out the Department's *Proposed Well Site Application* (EE127 A&B). There appears to be a location 1,000 feet away from Well #2 on land owned by the City. However, there are two residential wells that encroach upon this location. The City would need to approach the homeowners and discussion options for abandoning these wells to comply with the setback distances. This would require a water service connection to these homes. The cost for the water service to these homes will be included in the cost estimation. A test well has not yet been drilled in this location. Anticipated well design capacities, depths, and sizes will be used based on information available from the existing City wells for purposes of cost estimation. The desired flow capacity will be 500 gpm, which has yet to be confirmed.

4. Proposed Water Treatment Processes

The primary contaminant of concern is nitrate, which is classified as an inorganic chemical. Nitrate has acute health effects, similar to turbidity, microbiological contaminants, and chlorine dioxide, per 179 NAC 2-002.01A. According to the US Environmental Protection Agency (EPA) (https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations), drinking water with high concentrations of nitrate can result in "infants below the age of 6 months who drink water containing nitrate in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome" also known as methemoglobinemia. The designation of "infants" also includes those that are in utero, so it is also a concern for pregnant women. Nitrate can be introduced to drinking water via discharges from runoff from fertilizer use, leaking from septic tanks, sewage, or erosion of natural deposits.

The City of Fairbury relies on both GWUDI and ground water for its municipal water supply, with water coming from the Crystal Springs facility a majority of the time. For the purposes of treatment alternatives and comparison, only the Crystal Springs facility will be considered. The pumping capacity at both the East Well Field and Crystal Springs locations are shown in Table VI-3 for comparison.

Table VI-3: Combined Pumping Capacities

	Crystal Springs (GWUDI)		**East Well Field (Groundwater)**	
	gpm	MGD	gpm	MGD
Total Treatment Capacity	2,100	3.02	-	-
Total Pumping Capacity	1,500	2.16	2,500	3.60
Firm Pumping Capacity (Crystal Springs pumps)	750	1.08	1,500	2.16
Firm Pumping Capacity (Crystal Springs pumps)	1,050	1.512	-	-
Treatment Design Capacity	750	1.08	1,500	2.16
Total Combined Firm Capacity (Crystal Springs and East Well Field)			2,250	3.24

Design of the water treatment facilities will take into consideration the water demands and potential issues related to the SDWA and aesthetics. As summarized previously in this report, and shown in Table VI-4, projected demands for design year 2040 are as follows. The numbers provided are less than what was observed in the 2011 report. The national trend is to conserve and use less water, which is being observed in the case of the City of Fairbury. In addition, different peaking factors (3.5 in 2011 to 2.4 currently for peak/average day) were calculated, and the use of the RWD was allocated differently, resulting in a lower projected water use calculation for the current water system review. The population projection was 4,000 persons in 2032, which is slightly less than what is being projected to 2040 in the current study.

The current pumping capacity of both systems is sufficient to meet the City's current and future peak day water demands, as projected in this study. A majority of the City's water supply can be accommodated solely from the East Well Field, but not by the Crystal Springs facility.

Table VI-4: Current and Projected 2040 Water Demands

	Current (2015/2016)	2040
Average (Annual) Day Demand	1.00 MGD	1.01 MGD
Average (Summer; June – August; 2012-2016)) Day Demand	1.29 MGD	1.30 MGD
Peak Day Demand	2.40 MGD	2.42 MGD
Peak Day Demand w/ Anticipated Expansion	-	2.874 MGD
Total Annual Average (2012-2016)	363 MGY	368 MGY

However, there are many instances where the capacity of the Crystal Springs system is not sufficient to accommodate the City's total water demand, the supply is then supplemented using the East Well Field. There are instances in the water use records provided, where the East Well Field has been the only water supply to the City.

The finished water from any water treatment system must meet the requirements of the SDWA. The primary constituent of concern is the increasing nitrate level, which has been on the rise. The water treatment process selected would be designed to lower the nitrate levels below the primary MCL's.

Four (4) options have been discussed for nitrate removal or reduction:

- Blending the Crystal Springs supply, treated for nitrates, with water from the East Well Field
- Reverse Osmosis (RO) – Membrane Treatment
- Ion Exchange (IX) – Sorption Treatment
- Electrodialysis Reversal (EDR) – Membrane Treatment

Current treatment methods used to mitigate nitrates from water sources generally utilize blending or treatment. Blending includes, mixing non-affected water with affected water to dilute the concentration of the contaminant to an allowable level. Since nitrate levels in the East Well Field are relatively high (over 8 mg/L), blending with Crystal Springs water as a treatment solution is not recommended. It is not expected to solve the City's water quality needs. Blending may be an acceptable option provided nitrate removal treatment is provided at the Crystal Springs facility, then blended with water from the East Well Field. Nitrate removal or reduction can be achieved using either RO, IX, or EDR. Figure VI-7 provides a potential treatment processes or modifications schematic together with the existing system.

A distinct difference between IX and RO or EDR processes is their ability to reduce the concentration of a specific contaminant. IX and certain adsorption treatment processes can be used to reduce the concentration of a specific contaminant, such as nitrate or TDS. RO and EDR are used essentially for remaining dissolved solids in the water. The type of treatment process(es) used and their associated capital, Operation and Maintenance (O&M) costs vary substantially. In general, the higher the level of treatment, and the more contaminants removed, the higher the overall cost.

All treatment processes have water losses associated with them. Water loss is defined as incoming water that does not exit the system as treated water. Water losses generally occur as a liquid waste stream. Brief descriptions of each treatment process are given in the following paragraphs.

5. <u>Treatment Process – Blending</u>
   One (1) treatment option includes the combined use of various water sources to improve water quality issues, called blending. Blending is accomplished by combining 1 source of water with contaminant levels, such as nitrate, at levels higher than the MCL, with another source of water with lower contaminant levels. The blending process is useful as it works to minimize potential peak contaminant concentrations. Blending for the City of Fairbury would include combining the Crystal Springs supply with water from the East Well Field, or a control scheme where 2 or more of the wells in the East Well Field run concurrently to address nitrate concentrations from that source. For a blending configuration to be accomplished, the distribution system tie-in location from the East Well Field would need to be modified. The best option is to route the connection point from its current location in the southeastern part of the system to the underground water storage reservoir at the City's power plant. It is not possible to reduce nitrate concentrations between the 2 water sources by blending alone. Treatment at Crystal Springs, or a combined location, is required to make this a viable option.

   For the blending control scheme at the East Well Field, SCADA or other control upgrades would be required. The well or well(s) with the lower nitrate concentration would be the first to initiate when the call for water is received. The well or well(s) with the higher nitrate concentrations would be the last to initiate, and the first to shut-off, with the call for water is terminated. This structure prevents the opportunity for higher nitrate concentrations to be fed into the system, even briefly.

6. <u>Reverse Osmosis (RO) Treatment Process – Membrane</u>
   Membrane separation technologies are attractive nitrate treatment processes for small water systems. They can address numerous water quality problems while maintaining simplicity and ease of operation. However, RO units have a much larger retention spectrum, and can be used as stand-alone nitrate treatment under most water quality conditions.

   RO is a pressure driven dissolved solids removal process. Osmosis is a natural phenomenon in which water passes through a semi-permeable membrane from low TDS water to higher TDS water to equalize the TDS on both sides of the membrane. The driving force pushing the water through the semi-permeable membrane is called osmotic pressure.

RO, as defined above, is the process used to remove a significant amount of various elements and compounds, including nitrates, arsenic, uranium, and others. The physical water quality and clarity (suspended solids) of the RO feedwater needs to be very good.

Pre-Treatment

Pre-treatment to RO systems may include various components, depending on source water quality. Cartridge-type filtration ahead of an RO system is recommended. Anti-scalants are also used in order to prevent salts from forming a scale layer on the membrane interior. Scale buildup inside the membrane will increase operating pressures and treatment costs. The need for anti-scalant pretreatment is determined as part of the membrane selection process.

Treatment Process

RO is capable of achieving over 80% removal of nitrates under high pressure conditions. Higher removal efficiencies are possible with higher TDS concentrations in the source water. As an added benefit, RO also effectively removes several other constituents from water, including organic carbon, salts, dissolved minerals, and color.

The treatment process is relatively insensitive to pH. Water recovery is typically 60–85% or higher, depending on the desired purity of the treated water. Membrane fouling can occur in the presence of Naturally-Occurring Organic Matter (NOM) and various inorganic ions, most notably calcium, magnesium, silica, sulfate, chloride, iron, manganese, and carbonate.

Post -Treatment (Decarbonation and Chemical Addition)

The RO permeate will have a pH of less than 7.0 and contain considerable carbon dioxide, which can form carbonic acid. Decarbonation may be needed to remove most of the carbon dioxide from the blended product water. Therefore, decarbonation is included in the conceptual treatment process design to remove most of the carbon dioxide from the blended product water. A decarbonator would be designed to treat blended product water flow. The decarbonator would be a packed tower, either cylindrical or square. Water would flow down through the packing. Air would be injected in the bottom of the tower (but, above the water collection sump) and flow upwards through the tower driving off the carbon dioxide in the water. Air and carbon dioxide would exhaust out the top of the tower through a vent through the roof or wall of the building housing the treatment equipment. Chemicals will be fed to increase pH and provide disinfection, as required.

Figure VI-8 shows a simplified process flow diagram for RO. Six (6) process streams are shown on the figure, which are further described as follows:

Stream 1 – Water from the wells, or Crystal Springs, or both, flows into the WTP. It is assumed that the water is “clean enough” to be fed directly to the RO equipment without the need for pretreatment to remove, for instance, suspended solids in the water.

Stream 2 – An “RO bypass” stream is shown, since the RO process can remove 98% or more of the TDS in the well water, it would not be necessary to treat all of the well water in order to meet the treated water quality goals.

Stream 3 –That portion of the well water not bypassing the RO equipment flows through the RO process. RO can reduce the concentration of all of the constituents making up the TDS including selenium, nitrate, arsenic, and uranium. RO can also remove most types of Totally Organic Carbon (TOC), should this be necessary.

Stream 4 – The permeate (desalted water) has greatly reduced concentrations of TDS and other substances that may be rejected by the membranes.

Stream 5 – RO bypass is blended with the RO permeate. The blend ratio, or the percentage of bypass water [Stream 2] and percentage of permeate [Stream 4] making up Stream 5, can be selected to meet the treated water quality goals. This blended water flows through the decarbonators, or other post-treatment processes, and into a contact basin to be pumped to the distribution system.

Stream 6 – This is the RO concentrate-the wastewater from the RO process. It contains the contaminants rejected by the RO membranes in a small volume of water, calculated as the feedwater quantity less the permeate quantity. The RO concentrate requires some means of disposal, such as into the sanitary sewer system, storm sewer, or directly discharged to a stream or river, if approved via a National Pollutant Discharge Elimination System (NPDES) permit.

7. <u>Ion Exchange (IX) Treatment Process – Membrane</u>
IX is a physical and chemical process in which ions held electrostatically on the surface of a solid are exchanged for ions of similar charge in a solution. There are 2 basic types of IX:

- Cation exchange affects positively charged ions, or cations, such as calcium, magnesium, sodium, potassium, etc. Calcium and magnesium are key hardness causing ions.

- Anion exchange affects negatively charged ions, or anions, including selenium, nitrate, sulfate, chloride, bicarbonate, arsenate, uranate (uranium), etc.

Dissolved salts in water exist as either cations or anions. For example, sodium chloride (common table salt), when dissolved in water, becomes sodium cations and chloride anions.

IX, as the name implies, relies on exchanging 1 ion for another. IX is usually accomplished in pressure vessels. The vessels contain IX resin that is made of a synthetic material that has “exchange sites.” At startup, the exchange sites have an ion that is to be exchanged for ions in the water to be treated. For example, selenium, nitrate, sulfate, and uranium, which are present in water as anions, are usually removed by exchanging chloride for these contaminants. Nitrate selective resins, which retain nitrates stronger than other ions, are available to remove higher levels of nitrate.

The resins have a finite exchange capacity. Eventually, the resins become exhausted and must be regenerated or replaced so that more water can be treated. Exhaustion occurs when all or most of the “exchange sites” on the resin have been used up. Regeneration is accomplished by passing a chemical solution through an exhausted resin. The appropriate cation (or anion) in the regenerating solutions displaces the undesirable ions removed from the water that was treated and the more desirable ion in the regenerating solution takes the displaced ion’s place on the resin. After rinsing, the IX resin is ready to treat more water. The regeneration process produces a wastewater stream that requires disposal.

IX is an effective process, depending on the process design and operation, and essentially all of the unwanted cations and/or anions in the water being treated can be exchanged for more desirable cations and/or anions.

High levels of TDS or hardness can adversely affect the performance of an IX system. In general, the IX process is not an economically viable treatment technology if source water contains over 500 mg/L of TDS or over 50 mg/L of sulfate. Hardness is also recommended to be less than 100 mg/L as calcium carbonate, or $CaCO_3$. Hardness from the City’s water supply is generally between 220 and 250 mg/L as $CaCO_3$. For IX treatment to work, additional softening may need to be provided, and may not be financially feasible. Anionic resin has reduced effectiveness (up to 30%) for removal as subsequent cycles are regenerated.

Another disadvantage of IX is that salts or chemicals are imported into the region where the IX plant is located, unless onsite regeneration is used. Disposal of the brine waste formed from the IX process will require on-site treatment, disposal to the City's sanitary sewer, or discharge to the river. Figure VI-9 shows a simplified process flow diagram for the pressure filtration and IX system.

Stream 1 – Water flowing from the wells and/or Crystal Springs to the WTP.

Stream 2 – IX Bypass. Since the IX process can remove high concentrations of nitrate in the well water, it would not be necessary to treat all of the well water in order to meet the treated water quality goals. Accordingly, a bypass stream is shown.

Stream 3 – After the IX resin has been exhausted, it can be regenerated on-site. The regeneration process includes passing a chemical through the resin. For nitrate removal, for example, the regeneration chemical would be salt (sodium chloride). The nitrate ions that have replaced the chloride on the resin during the treatment cycle are replaced by chloride from the salt solution. After backwashing and rinsing, to remove excess salt from the resin, the vessel can be returned to service to treat more water.

Stream 4 – The spent regenerating solution and backwash/rinse water are sent to disposal.

Stream 5 – Water leaving the IX vessel. The IX process is intended to remove nitrates, most of which will have been exchanged for chloride in the vessel. Therefore, Stream 5 will be lower in nitrate and higher in chloride than Stream 1.

8. <u>Electrodialysis or Electrodialysis Reversal (ED/EDR) Treatment Process – Membrane/Sorption</u>
   The Electrodialysis (ED) process, as described by the US Bureau of Reclamation (2010) includes demineralization via anion and cation transfer through a selective membrane using a direct current electrical field. The demineralization process is accomplished using an IX resin, with components in sheet form. The components include the ion exchange membranes, anion or cation elements on the opposite side of the membranes, flow-direction spacers, and electrodes at each end. Dissolved ions, when subjected to the direct current field, are attracted to the component with an opposite charge.

Membranes with a similar charge as the dissolved ions will cause those ions to continue through the component, without passing through the membrane. This process creates permeate and concentrate streams, similar to the RO process.

EDR is a variation of ED, where anion and cation movement are reversed, which creates a scalant cleaning effect. EDR is more commonly used for desalting than ED. Therefore, ED is not discussed further in this report.

EDR operates at a pressure of about 45 psi. This pressure is needed to drive the water through the process equipment. The process equipment is usually slightly more expensive than RO equipment. Since EDR is electrically driven, power costs are a significant portion of the O&M costs. The quantity of power needed is proportional to the reduction in TDS achieved. As feed water TDS increases and, therefore, the level of desalting needed increases, power cost increases. EDR also requires more labor to operate and maintain. In addition:

- ED/EDR is slightly more tolerant of particles and foulants in the feedwater than reverse osmosis.
- Decreased pre- and post-treatment requirements, such as cartridge filtration, anti-scalant feed chemicals, or degasification, to name a few; and
- In many cases a slightly higher recovery particularly if silica in the feedwater is high. Recovery is the percentage of feedwater recovered as usable water. For example, 80% recovery means that out of 100 gallons of feedwater, 80 gallons is recovered as usable water and 20 gallons is wastewater with high concentrations of dissolved solids.

Figure VI-10 shows a simplified process flow diagram for the EDR system, which was obtained from General Electric (2010). Six (6) process streams are shown on the figure, which are further described as follows:

Stream 1 – Water flowing from the wells and/or Crystal Springs to the WTP.

Stream 2 – The Dilute Feed flows through the EDR process and is desalted. The EDR process can reduce the concentration of a majority of the constituents making up the TDS including nitrate/nitrite, barium, and selenium.

Stream 3 – A subset of the Dilute Feed, is the Electrode Flush, is approximately 1% of the dilute flow. The electrode flush cleans the process by removing some of the salts taken out of the Dilute Feed. The Electrode Flush can either be directed to waste or reused as part of the Concentrate Recycle.

Stream 4 – The Concentrate includes the constituent salts and water transfer removed by the EDR process. The Concentrate can be recycled through the process and is included at the headworks as Concentrate Makeup. Recycling the concentrate allows for higher treatment process efficiencies.

Stream 5 – Treated product water from the EDR process is directed into the transmission or distribution systems, depending on location of the treatment facilities. Depending of the needs of the system, the treated water will be disinfected. If necessary, treated water may be discharged into a contact basin to be pumped to the distribution system.

Stream 6 – The EDR concentrate is the wastewater from the treatment process that is generated upon electrical polarity reversal. The concentrate is flushed to waste. It contains the contaminants rejected by the EDR membranes in a small volume of water. The EDR concentrate requires some means of disposal, such as into the sanitary system, storm sewer, or directly discharged to a river or stream, if approved via a National Pollutant Discharge Elimination System (NPDES) permit. Discharge limits and restrictions are similar to those discussed for RO.

9. Biological/Chemical Denitrification (BD/CD) Treatment Processes
Biological treatment is considered to be an emerging technology for potable water, but used extensively in wastewater applications. As such, most of the information available is in the research phase. The information presented hereafter was provided from *Technical Report 6: Drinking Water Treatment for Nitrate*, Center for Watershed Sciences, University of California, Davis, July 2012, for general information purposes.

"The United States Environmental Protection Agency (U.S. EPA) lists only Anion Exchange (IX), Reverse Osmosis (RO), and Electrodialysis Reversal (EDR) as accepted potable water treatment methods for nitrate removal (U.S. EPA 2010). Due to the production of high-strength brine residuals, sustainable application of these 3 technologies is often limited by a lack of local residual disposal options and the challenge of increasing salt loads. The lack of affordable and feasible nitrate treatment alternatives can force impacted utilities to remove nitrate contaminated sources from their available water supply. In many instances, this action can severely compromise a water utility's ability to provide an adequate supply of safe and affordable potable water. The need for additional nitrate treatment technologies has driven the drinking water community to begin developing alternative options to effectively remove nitrate while limiting cost and brine production challenges. Promising treatment options include Weak Base Anion (WBA) exchange and improvements in Strong Base Anion (SBA) exchange such as low brine residual technologies; biological treatment using fluidized bed, fixed bed, and Membrane Biofilm Reactors (MBfR); and chemical reduction using media such as Zero Valent Iron (ZVI) and Sulfur Modified Iron (SMI)."

Table S.2 from the same study, was provided as a summary, or brief comparison of treatment options.

Table VI-5: Potable Water Treatment Options for Nitrate Management (Table S.2, from UC-Davis, 2012 and WA DOH, 2005)

	IX	RO	ED/EDR	Biological Denitrification	Chemical Nitrification
Full-Scale Systems	Yes	Yes	Yes	Yes	No
Treatment Type	Removal to waste stream	Removal to waste stream	Removal to waste stream	Biological reduction	Chemical reduction
Common Water Quality Design Considerations	Sulfate, iron, manganese, TSS, metals (i.e., arsenic), hardness, organic matter	Turbidity, iron, manganese, SDI, particle size, TSS, hardness, organic matter, metals (i.e., arsenic)	Turbidity, iron, manganese, TSS, hydrogen sulfide, hardness, metals (i.e., arsenic)	Temperature and pH, anoxic conditions	Temperature and pH
Pretreatment Needs	Pre-filter, address hardness	Pre-filter, address hardness	Pre-filter, address hardness	pH adjustment, nutrient and substrate addition, need for anoxic conditions	pH Adjustment
Post-Treatment Needs	pH adjustment	pH adjustment, remineralization	pH adjustment, remineralization	Filtration, disinfection, possible substrate adsorption	pH adjustment, iron removal, potential ammonia control
Waste/Residuals Management	Waste brine	Concentrate	Concentrate	Sludge/biosolids	Waste media, iron sludge
Start-Up Time	Minutes	Minutes	Minutes	Initial plant startup: Days to weeks; After reaching steady state: Minutes	Minutes
Water Recovery	Conventional (97%); Low brine (up to 99.9%)	Up to 85%	Up to 95%	Nearly 100%	Not demonstrated full-scale
Advantages	Nitrate selective resins, common application, multiple contaminant removal	Multiple contaminant removal, desalination (TDS removal)	Multiple contaminant removal, higher water recovery (less waste), desalination, unaffected by silica	No waste brine or concentrate, nitrate reduction rather than transfer to a waste stream, high water recovery, and potential for multiple contaminant removal	No waste brine or concentrate, nitrate reduction rather than transfer to a waste stream, and potential for multiple contaminant removal
Disadvantages	Potential for nitrate peaking, high chemical use (salt), brine waste disposal, potential for disinfection byproduct (DBP) formation	Membrane fouling and scaling, lower water recovery, operational complexity, energy demands, waste disposal	Energy demands, operational complexity, waste disposal	Substrate addition, potentially more complex high monitoring needs, possible sensitivity to environmental conditions, risk of nitrite formation (potential incomplete denitrification), post-treatment to address turbidity standards and 4-log virus removal (state dependent)	Inconsistency of nitrate reduction, risk of nitrite formation (potential incomplete denitrification), reduction to ammonia, lack of full-scale systems, pH and temperature dependence, possible need for iron removal

Continued biological and chemical denitrification options from the 2012 UC Davis study are as follows: “Biological denitrification in potable water treatment is more common in Europe with recent full-scale systems in France, Germany, Austria, Poland, Italy, and Great Britain. To date, full-scale drinking water applications in the United States are limited to a single plant in Coyle, OK (no longer online). However, 2 full-scale systems are anticipated in California in the next couple of years.

Biological denitrification relies on bacteria to transform nitrate to nitrogen gas through reduction. Substrate and nutrient addition is necessary and post-treatment can be more intensive than for the removal processes. Biological denitrification offers the ability to address multiple contaminants and the avoidance of costly waste brine disposal.

"Key factors in the consideration of biological denitrification are the chemical requirements, the need for anoxic conditions, the level of operator training, the robustness of the system, and the post-treatment requirements. State regulations are expected to vary and, until more experience with the application of biological denitrification for potable water treatment is obtained in the United States, pilot and demonstration requirements may be intensive. Typically, biological treatment is thought to have a larger footprint; however, with the latest design configurations, the system footprint may be comparable to that of RO or EDR systems."

"With reduction of nitrate to nitrogen gas, the lack of a problematic brine waste stream is a clear advantage of biological treatment over the removal processes. Biological treatment has the potential to provide a sustainable nitrate treatment option for the long-term. More will be known with the completion of the anticipated full-scale systems in California; cost estimation suggests that biological treatment can be economically competitive with IX."

"Chemical denitrification uses metals to transform nitrate to other nitrogen species. As an emerging technology, no full-scale chemical denitrification systems have been installed in the United States for nitrate treatment of potable water, and application for nitrate treatment has been strictly limited to bench- and pilot-scale studies. A significant body of research has explored the use of ZVI in denitrification. Several patented granular media options have also been developed including SMI media, granular clay media, and powdered metal media."

"Key factors in the consideration of chemical denitrification are the reliability and consistency of nitrate reduction, the lack of full-scale installations, the type of media, and the dependence on temperature and pH. Chemical denitrification has the potential to become a feasible full-scale nitrate treatment alternative, with the advantage of reducing nitrate to other nitrogen species and avoiding the need to dispose of a concentrated waste stream."

"However, currently this option is an emerging technology in need of additional pilot- and full-scale testing. Due to the potential benefits, further research and optimization of chemical denitrification systems will likely make this a competitive option in the future, especially for multiple contaminants (e.g., arsenic and chromium)."

In summary: "Within the drinking water community, the options typically considered to address nitrate contamination are IX and RO. Alternative technologies are available or emerging (EDR, BD, CD) because, under some circumstances, they offer advantages over IX and RO. New technologies will continue to be investigated and developed because no single option is ideal for all situations. There is not a nitrate treatment option currently available that can affordably address all possible scenarios. The following diagram is a rough guide for treatment technology selection based on water quality concerns and possible priorities for a given water source or system (Table S.3). This diagram includes generalizations and is not intended to be definitive. In the selection of nitrate treatment technologies, the unique needs of an individual water system must be assessed by professional engineers to optimize treatment selection and design."

Table VI-6: Comparison of Major Treatment Types[1] (Table S.3, from UC-Davis, 2012 and WA DOH, 2005)

Concerns	IX	RO	EDR	BD	CD
High Nitrate Removal	Yellow	Yellow	Yellow	Green	
High TDS Removal	Red	Green	Green	Red	Red
Arsenic Removal	Green	Green	Green	Yellow	Green
Radium/ Uranium Removal	Green	Green	Green		
Chromium Removal	Green	Green	Green	Green	Green
Perchlorate Removal	Green	Green	Green	Green	
	Green	Yellow	Red		
Unknown (blank)	Good	To	Poor		

Priorities	IX	RO	EDR	BD	CD
High hardness not a major concern	Red	Red	Yellow	Green	
Reliability	Green	Green	Green	Yellow	Red
Training/ Ease of Operation	Green	Green	Green	Yellow	
Minimize Capital Cost	Green	Yellow	Yellow	Yellow	
Minimize Ongoing O&M Cost	Green	Yellow	Yellow	Green	
Minimize Footprint	Green	Green	Green	Yellow	
Industry Experience	Green	Green	Yellow	Red	Red
Ease of Waste Management	Red	Red	Yellow	Green	Green

"1-This table offers a generalized comparison and is not intended to be definitive. There are notable exceptions to the above classifications."

10. <u>Treatment Process Residuals Disposal</u>
All treatment processes generate residuals. Residuals are defined as the waste byproducts resulting from the treatment process. There are 2 types of residuals, solids and liquids. Disposing of residuals can be a very significant portion of the cost of treating water. Minimizing disposal costs is important to minimizing the cost of water treatment. With respect to disposing of residual solids, the least expensive means is usually to reuse, recycle, land apply, or haul to a municipal landfill. To do this, residual solids must meet certain standards.

For residual liquids, the most economical means of disposal may be to discharge them to the City's sewer system where the residual liquids, and any solids they may carry, would be mixed with the City's wastewater stream. This option may not be available since the existing wastewater treatment system is near capacity, based on the amount of waste generated, or not able to handle the brine concentrate. This may require disposal to the river. If construction in or around an existing levee is necessary, additional permitting, oversight, and cost may be necessary, based on the type of levee. According to Flood Insurance Rate Map (FIRM) Panel 31095C0140D, 31095C0250D, and 31095C0145D, revised August 17, 2015, a levee does exist between the proposed treatment plant location and the river. A copy of these maps is included in Appendix "N."

In lieu of discharging water treatment process residuals to the river or sanitary sewer system, on-site ponds could be constructed. The wastewater would be discharged into the ponds where the water would evaporate. In this case, several tens of acres of ponds may be required.

Based on the City's proposed in town treatment facility site, sufficient space is not available for construction of evaporation ponds. It is likely that it would be necessary to line the ponds with a clay, membrane, or some other material so that the wastewater would not percolate back into the groundwater. The cost of the evaporation ponds is tied to the size and volume required, with larger ponds requiring more land and incurring more expense. The ponds would require maintenance and occasional removal and disposal of solids, such as precipitated salts left behind as the water evaporates. The ponds would be regulated by NDEQ, generally concentrated wastes of this type to require higher precautions and regulatory oversight.

However, it may be possible for disposal of liquid wastewater from the WTP directly to the river if allowed by the NDEQ. In this case, limits on what kind of contaminants and how much of the contaminants can be discharged into the river need to be considered and approval acquired. Preliminary discharge limits have been obtained from the NDEQ.

The Little Blue River (10000, Subbasin LB1), from Big Sandy Creek to the Nebraska-Kansas border, is classified as a drinking water source. Per 117 NAC Chapter 4, effective December 13, 2014, the current limits for drinking water source are essentially the same as an MCL or SMCL for the constituent. Nitrate, chloride, and TDS limits are 10, 250, and 500 mg/L, respectively. Final guidance and instruction will be provided by the Department.

It may also be possible to route the discharge piping to the WWTP outlet and blend water at that point except for brine salt. This would require approximately 1 mile of discharge piping. This would need to be approved by the NDEQ. Preliminary limits for combining these sources, if selected, will be requested as part of the design memorandum process to verify compliance and attainability of a new or modified NPDES permit. There may be other discharge limitations for discharging to the river. For example, TDS, nitrate, chloride, etc. limits may exist or be imposed. Any such constraints could be reflected in concentration (mg/L) or mass (lbs/day) limits.

One (1) argument in favor of discharging high TDS water to the river is that much of the dissolved solids in the well water currently ends up in the river. The dissolved solids in the municipal water supply pass through the homes and businesses of the community and are conveyed to the WWTP. The City then discharges its treated wastewater to the river. However, water that is used for irrigating lawns, for example, does not end up in the river. Therefore, although the TDS concentration in the treated wastewater is essentially that of the well water supplied to the City, plus whatever dissolved solids are added by the water users, the mass loading (lbs/day) may be less than if all of the well water were discharged into the river. The appropriate regulatory agencies will need to be contacted to ascertain if other contaminant discharges into the river are regulated and what the constraints would be.

Each treatment option has varied levels of waste generation, and associated disposal needs. A summary of waste generation needs are provided in Table VI-5 for RO, IX, and EDR treatment processes. Preliminary waste loads of 435 gpm were provided by the treatment equipment suppliers. However, it is our opinion that this waste load is artificially high. The higher rates were used in the preliminary NPDES permit request. It is envisioned that the City would have more bypass water for the RO process. The modified waste stream calculation would be approximately 650 gpm treated flow, with 80% recovery, which yields 130 gpm waste. This waste flow rate is shown in the Table VI-6 calculations. The blending option does not have a waste stream. The WWTP O&M manual was prepared by Olsson (#97-0100) in 1999.

Table VI-7: Water Treatment Facility Waste Comparison

Waste Type and Calculation	Treatment Options		
	RO	IX	EDR
Concentrate/Reject, gpm	130	NA	96
Hours of Operation per day	24	NA	24
Total Concentrate per day, gal	187,200	NA	138,240
Total Annual Amount, gal	68,328,000	NA	50,457,600
Brine Regeneration, gal	NA	13,900	NA
Number of Regeneration per day, gal	NA	1.0	NA
Daily Regeneration quantity, gal	NA	13,900	NA
Monthly Regeneration quantity, gal	NA	417,000	NA
Annual Regeneration quantity, gal	NA	5,073,500	NA
Clean In-Place volume, gal	1,000	NA	2,400
Cleanings per year	2	NA	6
Annual Amount, gal	2,000	NA	14,400
Total Waste volume, gal	68,330,000	5,073,500	50,472,000
Average Daily Amount, gal	187,205	13,900	138,279
24-Hour Average Flow Rate, gpm	130	10	96
Maximum Daily Amount, gal	188,200	13,900	140,640
24-Hour Average Flow Rate, gpm	131	10	98
Complete Retention Lagoon,1/16” seepage per day, acres	53.1	3.92	39.7
Complete Retention Lagoon size, zero seepage, acres	101.8	7.52	76.1

On Page I-7 of the O&M Manual, it lists the following information:

- Average Peak Month Design Flow Rate: 0.941 MGD
- Average Annual Peak Day Design Flow Rate: 2.00 MGD
- BOD_5, Influent: 3,400 lbs/day
- TSS, Influent: 1,337 lbs/day
- TKN, Influent: 400 lbs/day

A review of the online NDEQ Public Records (http://deq.ne.gov/NDEQProg.nsf/OnWeb/PRS) for quarterly results for Fairbury's WWTP (Facility #57717) from August 2011 to January 2017 provides a glimpse of the plant's operational results, summarized in Appendix "O." The average, minimum, and maximum values from the Historical Data is available in Table VI-7.

Table VI-8: Wastewater Treatment Facility Historical Flows (8/2011 to 1/2017)

Date	Avg. Flow Rate, MGD	Max Flow Rate, MGD
Average	0.29495	0.47654
Minimum	0.19598	0.22073
Maximum	0.50875	1.52444

Based on a recent review of the City's WWTP capacity and historical flows, the highest average value observed during the period of record, 0.356 MGD which is well under the average design flow of 0.941 MGD. The maximum flow rate observed was 1.876 MGD, which was approximately 6% below the peak design flow of the plant. Combining summary information from Table VI-5, a comparison of the proposed waste flow rates and existing plant capacities is provided in Table VI-8.

Table VI-9: Nitrate Removal Wastewater Effect on City's WWTP

Waste Type and Calculation	Treatment Options		
	RO	**IX**	**EDR**
Maximum Daily Amount, gal (From Table VI-7)	188,200	13,900	140,640
Maximum Daily Amount, MGD	0.188	0.014	0.141
Treatment Plant Average. Capacity, MGD	0.94	0.94	0.94
Percent Average Capacity	20.0%	1.48%	14.95%
Observed Average Plant Capacity, MGD	0.356	0.356	0.356
Percent Average Plant Capacity, MGD	37.88%	37.88%	37.88%
Observed Average. Plant Capacity with WTP Max. Daily Amount, MGD	0.545	0.370	0.497
Percent Average Capacity	57.9%	39.35%	52.82%

The City's WWTP is currently functioning at approximately 38% of their average hydraulic capacity, but nearing their organic loading capacity. Adding waste to the process will require a review of the City's plant prior to proceeding with a water treatment process. NDEQ will also require a review of any proposed modifications. A more detailed review of impacts to hydraulic and organic loading capacity will be necessary prior to final design. A wastewater facility plan is currently in progress for the City.

As part of their review, each of the suppliers provided information regarding the process equipment waste stream. Full waste stream information is provided in the Appendices of the respective treatment suppliers for reference. A summary of each is provided in the following table.

Table VI-10: Expected Wastewater Quality

Waste Constituent	RO	IX	EDR
Nitrate, mg/L	310	1,250	260
Brine Salinity/TDS, mg/L	2,221	41,096	8,423
Conductivity, uS/cm	Not Provided	Not Provided	9,164

Even though some of the hydraulic loads may be acceptable at the City's WWTP, the projected waste load from the processes may not be compatible due to the high salt concentrations shown in Table VIII-6. Additional review will be necessary. For the purposes of this study, it was presumed that the RO, IX, and EDR processes would discharge directly into the Little Blue River. A National Pollutant Discharge Elimination System (NPDES) permit would be required, as would approximately 500 feet of drainage pipe from the proposed treatment location to the river, with a route and discharge location selected during the next design phase. If an NPDES permit is not attainable with a particular treatment option, then that option would not be viable for the City. It should also be determined whether any impacts to existing levies would be required, and included in the project discussion.

11. Treatment and Supply Alternatives

The conceptual treatment alternatives for the City of Fairbury include a mix of different processes for nitrate removal. The following paragraphs will summarize the viable treatment alternatives including the capital and O&M costs for each alternative. Based on a review of the LBNRD data and Olsson's hydrogeologic determination, the option of improved water supply quality is not viable due to the extent of nitrate contamination in the area and projected nitrate concentrations. Therefore, improved water quality through additional supply is not considered in the final recommendations.

Based upon the design criteria established in previously, the treatment plant design capacity proposed is 2.16 MGD (1,500 gpm) for the Crystal Springs facility. Provisions will be made during design to allow for plant expansion to accommodate future industrial or economic growth. It is to the City's benefit to locate the proposed treatment process(es) after the Crystal Springs filtration facility to take advantage of and remove the necessity of pre-treatment filters that are generally recommended by treatment equipment manufacturers.

The treatment process design capacity for the purposes of this study will be 2.16 MGD (1,500 gpm). Existing pumping capacity, and associated treatment capacity, may not be sufficient to provide needed water supply to the proposed treatment process. Based on the existing pumping capacity and estimated populations, provisions were made in the alternative selection process for additional space for future equipment.

Well Water Quality—Table IV-13 summarized the water quality for the City of Fairbury's wells. The Crystal Springs column on the table shows the well water quality assumed as the basis for a conceptual treatment process design.

Treatment Requirements – The following are comments on the specific constituents for which treatment is proposed to reduce the concentrations in the water supply:

Table VI-11: Proposed Product Water Quality Goals

Current Concentrations		Proposed Limits	
Constituent	**Source Water Concentrations**	**Value**	**Basis**
Nitrate	8 – 15 mg/L	<5 mg/L <3 mg/L	Primary Standard (10 mg/L) Future Standard (5 mg/L)

The treatment processes to be employed at the proposed treatment plant will be influenced by many factors such as regulatory requirements, raw water quality, finished water quality goals, space requirements, utility requirements, process waste disposal, chemicals needed, O&M costs, and capital cost. The WTP will be required to be designed to meet the requirements of the SDWA Regulations. Treatment processes identified with potential to achieve the treatment needs for the proposed facility include nitrate removal using:

- Blending
- RO
- IX
- EDR

Appendices "P" to "R" provide treatment system components provided by different manufacturers, as well as a list of treatment assumptions made for each treatment type.

C. Map

The location(s) of the proposed improvements are shown in previous figures.

D. Environmental Impacts

Since the work will be completed within the existing City Right-of-Way (ROW) or on existing City property, it is not anticipated that environmental impacts will be present, other than temporary impacts from construction. These temporary impacts can be mitigated through construction requirements and best management practices. Flood plain maps were reviewed on the Federal Emergency Management Agency (FEMA) map portal. There are several maps available, as the City is located on the dividing line between 3 maps. These maps are available for review in the Appendices as firmettes of maps 31095C0140D, 31095C0145D, and 31095C0250D, respectively, revised August 17, 2015. Base Flood Elevation (BFE) determinations were requested for the City and surrounding areas, located in Sections 13-15, and 21-24 of Township 2 North, Range 2 East. At this time, a majority of the City corporate limits are outside of the flood plain. All of the City's wells and water system components are also located outside of the flood plain areas.

E. Land Requirements

Centralized treatment will treat the raw water from the Crystal Springs facility. Another treatment option includes treatment at the Crystal Springs facility and blending with the East Well Field. This option would require transmission and distribution system modifications to have a single Point-of-Entry (POE) to the system.

The City does not currently own the proposed location for the treatment facility. A minimum of 1.0 acre of land would be required for construction of each treatment facility. Additional land may be necessary based on the treatment disposal and options selected. Water main replacement is anticipated to be done in the existing City ROW.

F. Potential Construction Problems

A majority of the recommended improvements will occur within either existing structures, or in areas previously affected by construction activities. Other construction problems will be manifest in locating valves that are below concrete, or not visible at the existing ground surface. The exploratory excavation required to locate and replace these valves may result in additional cost due to time, concrete or asphalt replacement, and other similar items. Once repairs and maintenance begins, other repairs and replacement may be necessary as existing components are unearthed, or additional inspections are possible. This may result in increased cost and scope creep. Replacement of distribution system components will result in additional costs due to roadway repair. The City has been working to add asphalt pavement to the streets. A majority of these repairs will involve impacts to the roadway.

G. Sustainability Considerations

1. Water Efficiency

   The per capita water use identified previously in this report was just over 2 times higher than the national average of 100 gpcd. This is primarily due to water use during the summer for irrigation and livestock watering. Replacement of older water mains, or those with a high disruption of service percentage, replacement of inoperable water valves, and other similar repairs to the water distribution system will also improve water efficiencies.

2. Energy Efficiency

   Installation of new distribution system piping will increase flows to various parts of town, with no additional pumping or energy use.

3. Green Infrastructure

   The proposed improvements are not anticipated to have green infrastructure components. This section does not apply to the preliminary engineering report.

H. Budget Cost Estimates

Budget costs have been prepared for each of the improvements recommended in the preceding sections. The opinions of cost assume that the projects are designed by a Professional Engineer, and that the work is performed by a contractor with complete plans and specifications. Costs of potential easements and land purchase costs are not included in the estimates.

The rate of inflation in construction costs is difficult to forecast. Inflation has been minimal in recent years, but may accelerate before all of the proposed improvements are completed. Opinions of cost for improvements, which are not completed in the near future will require updating at the time it is decided to proceed.

The City should consider ways to fund these projects by reviewing the water rate structure, hook-up fees, and evaluating the possibility of implementing impact fees. In addition, there are low interest loans available through the SRF, USDA, or the City could consider Municipal Bonds as a way to fund these projects. The City has not submitted project information for inclusion in the current IUP. Additional project requirements, including environmental review, Davis-Bacon wage determination, and other factors will be included in the project.

For proposed water distribution system improvement projects, a budget cost per inch diameter of water main was used to estimate the potential cost for each project, which is anticipated to include hydrants, valves, and other miscellaneous items included in construction of the water main. budget costs were determined by using a combination of recently bid projects, Means Estimating Guide, and information provided by vendors and suppliers. Each project includes both a contingency of 20% and an engineering fee of 15% of the total budget cost for the project.

The budget costs for the distribution system improvements are separated into 2 categories, with a higher cost associated with construction in established residential areas, and a lower cost associated with undeveloped areas. Budget unit costs for main replacement are displayed in Tables VI-11 and VI-12.

Table VI-12: Budget Estimate Unit Costs - Replacement in Established Areas

Item	Unit	Cost/Unit
6" Water Main	LF	$70
8" Water Main	LF	$94
10" Water Main	LF	$125

Table VI-13: Budget Estimate Unit Costs - Unestablished Areas

Item	Unit	Cost/Unit
6" Water Main	LF	$46
8" Water Main	LF	$61
10" Water Main	LF	$76

The opinions of probable construction cost for the proposed improvements are summarized in the following tables, rounded to the nearest thousand dollars. The improvement designations match previous recommendation tables. The installation of new 6 and 8-inch water valves is designated as Improvement Q. Improvement R is the installation of new fire hydrants. Improvement S is the installation of monitoring stations and valves on the existing transmission main on either side of the river crossings. Improvement T is the installation of new transmission piping from Crystal Springs, but does not include Improvement S, which will need to be added if selected. Please note that the City should budget a minimum of $100,000 for inspection of the existing transmission main. With engineering, contingencies, and 2-inch taps for access, it is recommended that the City budget $150,000 for this investigation, which is approximately 9-percent of the pipe replacement cost.

Table VI-14: Water Distribution System Improvements Opinion of Probable Cost

#	Est. Qty. (LF)	Pipe Size	Cost/ Unit	Unit Price Total	Total w/ 20% Contingency and Engineering, etc
A	3,500	6	$70	$245,000	$353,000
B	3,500	6	$70	$245,000	$353,000
C	5,000	8	$94	$470,000	$677,000
D	7,000	6	$70	$490,000	$706,000
E	2,000	8	$94	$188,000	$271,000
	1,200	6	$70	$84,000	$121,000
					$392,000
F	2,000	6	$70	$140,000	$202,000
G	4,500	6	$70	$315,000	$454,000
H	4,000	6	$70	$280,000	$404,000
I	400	6	$70	$28,000	$41,000
J	5,000	8	$94	$470,000	$677,000
K	2,000	6	$70	$140,000	$202,000
L	400	6	$70	$28,000	$41,000
M	1,000	6	$70	$70,000	$101,000
	3,000	8	$94	$282,000	$407,000
					$508,000
N	3,000	8	$94	$282,000	$407,000
O	800	8	$94	$75,200	$109,000
P	2,000	6	$70	$140,000	$202,000
Q	-	6 & 8	-	$16,500	$25,000
R	-	-	-	$130,000	$173,000
S	-	12	-	$30,000	$44,000
T	13,000	12	-	$1,181,000	$1,701,000
			Total	**(Rounded)**	**$7,671,000**

It should be noted that for distribution system improvements, when smaller projects are combined, the overall cost of the project is generally reduced. Earlier, it was indicated that there is a great deal of 4-inch water main in place where fire protection is provided, while 6-inch mains are recommended to be utilized in the Ten States Standards. The City should use the projects identified in this study to prioritize the projects necessary to improve the overall system, but have a long-term goal of eventually replacing all of the 4-inch mains with 6-inch or larger mains.

The cost option for blending the two supplies near the underground reservoir are provided in the following table.

Table VI-15: Water Distribution System Improvements for Blending Supply Opinion of Probable Cost

Description	Estimated Cost
Mobilization/Demobilization, Clearing/Grubbing	$21,000
14" Transmission Main, fittings, valves, directional drilling, bored crossings, wet cut-in, remove/replace existing water system, etc.	$1,261,000
Concrete, Miscellaneous Site Work, Seeding, SWPPP, etc.	$41,000
Flow Meter and Vault	$50,000
Subtotal	**$1,373,000**
Contingencies (20%)	**$275,000**
Engineering, Admin, and Construction Services	**$330,000**
Opinion of Probable Construction Cost	**$1,978,000**

Another company visited and inspected the elevated water storage reservoir. They recommended tower painting and safety repairs in the range of $300,000 to $400,000, though specific details are yet to be provided for consideration. The addition of a passive tank mixing system, if desired, would increase this amount to $355,000 to $465,000

Table VI-16: New Water Supply Well Opinion of Probable Cost

Description	Estimated Cost
Mobilization/Demobilization	$28,000
Test Well	$25,000
Well House	$85,000
Well Construction	$60,000
Well Pump/Motor	$40,000
Electrical (incl. VFD), HVAC, and Emergency Generator	$65,000
SCADA	$17,500
Chemical Feed Systems	$25,000
Transmission Piping	$104,000
Service Piping	$25,000
Service Connections (Tapping Saddle, Corp & Curb Stops, etc.)	$2,500
Miscellaneous Sitework, Seeding, Fence, etc.	$26,000
Subtotal	**$503,000**
Contingencies (20%)	**$101,000**
Engineering, Admin, and Construction Services	**$121,000**
Opinion of Probable Construction Cost	**$725,000**

Operation and maintenance costs for the new water supply well are anticipated to be similar to what the City experiences with its current wells. The new well will initially be used as a redundant supply. As the new well operates in addition to the existing wells, there will be an associated increase of operation and maintenance costs. It is recommended that the City work to maintain their existing wells with their well service provider to improve performance of the wells.

The estimated capital and annual O&M costs for an RO, IX, and EDR water treatment facility with a finished treatment capacity of 1,500 gpm are presented in the subsequent tables.

Table VI-17: RO Treatment Facility Estimated Capital and Annual O&M Costs

Description	Estimated Cost
Mobilization, Demobilization, General, etc.	$142,000
Pilot Testing	$50,000
General Items for WTP (Structure, Sitework, Paving, Yard Piping, Etc.)	$1,450,500
Treatment Equipment	$1,430,000
Waste Drain Piping	$32,500
Chemical Feed & Laboratory Equipment	$100,000
Subtotal	$3,205,000
Contingency (20%)	$641,000
Legal, Fiscal, Admin, Engineering, Survey, & Construction Services (20%)	$769,000
Project Total	**$4,615,000**
Annual Cost (20 yr, 4% interest) – Factor: 0.0802	**$370,123**

Production Costs, Electricity, and Chemicals	$120,000
Labor	$90,000
Maintenance	$20,000
Membrane Replacement, Amortized	$70,000
Professional Services	$30,000
Subtotal	**$330,000**
Contingency (10%)	**$33,000**
Total	**$363,000**

Table VI-18: IX Treatment Facility Estimated Capital and Annual O&M Costs

Description	Estimated Cost
Mobilization, Demobilization, General, etc.	$131,950
Pilot Testing	$50,000
General Items for WTP (Structure, Sitework, Paving, Yard Piping, Etc.)	$1,583,550
Filtration Equipment	$1,149,500
Waste Drain Piping	$32,500
Chemical Feed & Laboratory Equipment	$67,500
Equalization Tank	$75,000
Subtotal	$3,090,000
Contingency (20%)	$618,000
Legal, Fiscal, Admin, Engineering, Survey, & Construction Services (20%)	$742,000
Project Total	**$4,450,000**
Annual Cost (20 yr, 4% interest) – Factor: 0.0802	**$356,890**

Labor	$54,000
Electricity	$16,165
Annual Salt Use	$107,000
Maintenance	$20,000
Resin Replacement, Amortized	$16,835
Professional Services	$30,000
Subtotal	**$244,000**
Contingency (10%)	**$24,500**
Total	**$268,500**

Table VI-19: EDR Treatment Facility Estimated Capital and O&M Costs

Description	Estimated Cost
Mobilization, Demobilization, General, etc.	$259,172
Pilot Testing	$60,000
General Items for WTP (Structure, Sitework, Paving, Yard Piping, Etc.)	$3,004,828
Filtration Equipment	$2,475,000
Backwash Drain Piping	$32,500
Chemical Feed & Laboratory Equipment	$67,500
Modify or Replace Existing Filtration Plant Pumps	$85,000
Subtotal	$5,984,000
Contingency (20%)	$1,197,000
Legal, Fiscal, Admin, Engineering, Survey, & Construction Services (20%)	$1,436,000
Project Total	**$8,617,000**
Annual Cost (20 yr, 4% interest) – Factor: 0.0802	**$691,083**

Labor	$90,000
Electricity	$59,000
Chemicals	$21,000
Maintenance	$43,000
Electrode Replacement, Amortized	$5,000
Professional Services	$30,000
Subtotal	**$248,000**
Contingency (10%)	**$25,000**
Total	**$273,000**

Additional design information regarding these options is contained in the Appendices, which includes a preliminary layout of the treatment facility building, as well as a list of treatment assumptions.

As each project nears preparation for design and construction, the costs will need to be revisited to verify the scope, budget, and assumptions are still valid. Operation and maintenance information was not calculated as the values will be similar to existing potable water system components.

Table VI-20: Opinion of Probable Cost Summary

Improvement	Description	Estimated Costs
1	Distribution System Improvements (including Crystal Springs Transmission Main replacement of approx. $1.7 million)	$7,671,000
2	Blending Transmission Main	$1,978,000
3	New Well	$725,000
4	RO Water Treatment	$4,615,000
5	IX Water Treatment	$4,450,000
6	EDR Water Treatment	$8,617,000
-	Existing Transmission Main Investigation	$150,000
-	Existing Elevated Water Storage Reservoir Recommended Repairs	$465,000

The entire cost of the proposed improvements are not anticipated to be completed in a single project, unless so desired by the City. Only one of the treatment options would be selected, if required by the City's water quality.

VII. ALTERNATIVE SELECTION

With all of the information prepared as part of this document, it is possible to weigh the pros and cons of each proposed improvement. This comparison is meant to help the community to know which improvements should be completed expeditiously, and which improvements may be eliminated from consideration.

A. Prioritization of Improvements-Distribution System Projects

The costs that were estimated for the distribution system improvements to improve fire protection capabilities provide 1 method of comparison of the proposed projects. However, when prioritizing and budgeting for the improvements, each project should be analyzed for its anticipated benefit to the overall water system in addition to its cost. To compare the proposed projects, a Benefit Cost Ratio (BCR) is calculated for each, which analyzes each project for its overall benefit by scoring on several factors, and dividing it by a factor related to the anticipated cost of the project. A higher BCR indicates that the project is anticipated to provide a higher benefit to the overall system than a lower BCR. After scoring each of the projects, they are sorted from highest to lowest BCR to aid in prioritizing the proposed projects. The factors used to score the proposed projects are as follows:

- Improves operation of the overall system: A higher score in this factor indicates that the proposed project is anticipated to improve operations of the overall system, a lower score indicates that it helps a small, specific part of the system.
- Ease of Implementation: A higher score indicates that the project is anticipated to be designed and constructed with little coordination with existing utilities, minimal disruption to traffic, and a quick turnaround. A lower score would indicate a more difficult project to design and/or construct the project.
- Increases ability to serve new areas: A high score indicates that the project will aid in expansion of the City by increasing service to an area not currently served by the water service. A low score indicates that the project is anticipated to serve an existing, established location in the system.
- Addresses an immediate need: A map showing the proposed distribution system improvements was provided to the City of Fairbury for review. The City reviewed the map and listed the number of main breaks that the City has had to address in recent years. The number of breaks ranged from zero to five main breaks. The number of reported main breaks at each location was used to further weight the proposed improvements as indicated in Table VII-1, below:

Table VII-1: Maintenance Issues Scoring Chart

Number of Reported Main Breaks	Score
0	1
1-2	2
3	3
4	4
5	5

In addition to scoring each of the projects on its anticipated benefit to the system, each project is given a score based upon its anticipated project cost. Table VII-2 summarizes the scoring system used to evaluate each project based upon its anticipated project cost. After scoring each project, both by its anticipated benefit and anticipated project cost, a Benefit to Cost Ratio (BCR) is calculated for each by dividing the benefit score by the cost score. A higher BCR indicates that a project provides a higher benefit to cost value.

Table VII-2: Budget Cost Factors

Cost Range	Cost Factor
<$50,000	1
$50,000-$100,000	2
$100,000-$200,000	3
$200,000-$500,000	4
$500,000 or greater	5

The score of each of the sixteen proposed projects is included in Table VII-3.

Table VII-3: Benefit Cost Matrix

Project	Improves operation of the overall system	Ease of Implementation	Increases ability to serve new areas	Addresses an immediate need	Total Benefit Factor	Cost Factor	Benefit to Cost Ratio
A	4	1	1	2	8	3	2.7
B	4	1	1	1	7	3	2.3
C	5	1	1	2	9	5	1.8
D	5	1	1	1	8	5	1.6
E	3	3	3	2	11	3	3.7
F	3	3	1	2	9	2	4.5
G	3	4	4	2	13	3	4.3
H	2	4	5	5	16	3	5.3
I	2	4	1	1	8	1	8.0
J	2	3	1	3	9	5	1.8
K	1	4	1	2	8	2	4.0
L	2	3	1	1	7	1	7.0
M	4	2	1	1	8	4	2.0
N	3	3	1	1	8	3	2.7
O	3	3	1	1	8	2	4.0
P	3	3	1	1	8	2	4.0

Using the total scores calculated in Table VII-3, the projects are prioritized as follows: 1) Project I, 2) Project L, 3) Project H, 4) Project F, 5) Project G, 6) Project K, 7) Project O, 8) Project P, 9) Project E, 10) Project A, 11) Project N, 12) Project B, 13) Project M, 14) Project C, 15) Project J, 16) Project D.

B. Life Cycle Cost Analysis

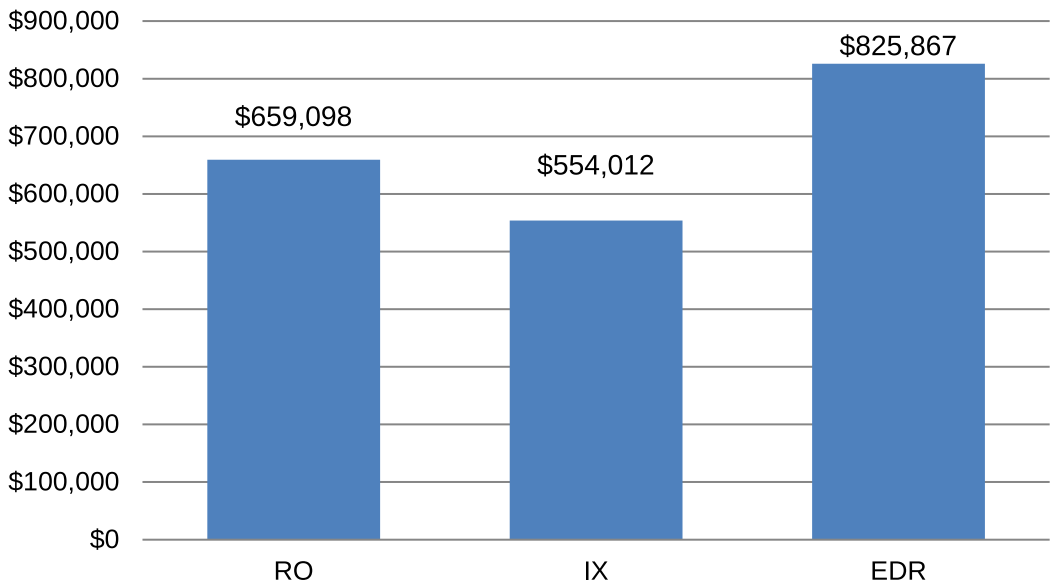
A present worth cost analysis was prepared for each of the likely system improvements. The cost analysis will use a time-frame of 20 years and an interest percentage rate of 4%. Longer terms are available, if desired. The current SRF interest rate is 3.0%, or 2.0% with a 1.0% administrative fee. The interest rate of 4% provides a measure of contingency. The cost analysis includes construction, land acquisition, administration, and financing calculations. The current annual Operation and Maintenance (O&M) costs were included as the stated costs are not anticipated to change based on the system improvements made, for those improvements that match the City's current system. O&M information has been provided for new treatment options. It should be noted that the $550,000 for existing transmission main investigation and elevated water tower repairs were not included in these costs as they are items to be budgeted by the City.

Table VII-4: Economic Alternative Evaluation

	Dist. System	Blend	New Well	RO	IX	EDR
Capital	$5,321,000	$1,373,000	$503,000	$3,205,000	$3,090,000	$5,984,000
Contingencies - 20%	$1,070,000	$275,000	$101,000	$641,000	$618,000	$1,197,000
Eng, Legal, Admin, Etc. - 20%	$1,280,000	$330,000	$121,000	$769,000	$742,000	$1,436,000
Present Worth	$7,671,000	$1,978,000	$725,000	$4,615,000	$4,450,000	$8,617,000
Term	20	20	20	20	20	20
Interest Rate	4%	0.04	4%	0.04	0.04	4%
Payment Factor	0.0802	0.0802	0.0802	0.0802	0.0802	0.0802
Annual Payment	$615,214	$158,636	$58,145	$370,123	$356,890	$691,083
Calc. Annual O&M	NA	NA	NA	$363,000	$268,500	$273,000
Net Annual Cost	NA	NA	NA	$733,123	$625,390	$964,083
Net Annual Cost w/ 20% Loan Forgiveness	$492,171	$126,908	$46,516	$296,098	$285,512	$552,867
Number of Connections (incl. NCL)	1,932	1,932	1,932	1,932	1,932	1,932
Calculated Monthly User Fee Increase	$29.19	$7.53	$2.76	$34.78	$29.67	$45.74
Calculated Monthly User Fee Increase w/ 20% Loan Forgiveness & 10% Reserve (SRF)	$23.35	$6.02	$2.21	$31.27	$26.29	$39.18

Figure VII-1 shows a comparison of the total annual costs presented in the previous table.

Figure VII-1 - Estimated Total Annual Cost - Treatment



Based on the results of this table, the lowest total annual treatment cost is IX. The main question for this option is in regards to the availability of waste treatment. A wastewater facility plan is currently being completed at this time to determine the potential impacts and ability of the wastewater treatment facility's capacity to accept waste of this type. The following table provides a summary of the total potential improvement costs, including IX treatment for nitrates at the Crystal Springs facility.

This option will need to be evaluated at the time that design of a treatment facility is to begin. If IX is determined to not be feasible, then a review of the alternatives will need to be made at that time.

Table VII-5: Economic Alternative Evaluation at Crystal Springs with Transmission and Blending Modifications, Well, and Distribution System Improvements

	Dist. System	Blend	New Well	IX	Total
Capital	$5,321,000	$1,373,000	$503,000	$3,090,000	$10,287,000
Contingencies - 20%	$1,070,000	$275,000	$101,000	$618,000	$2,064,000
Eng, Legal, Admin, Etc. - 20%	$1,280,000	$330,000	$121,000	$742,000	$2,473,000
Present Worth	$7,671,000	$1,978,000	$725,000	$4,450,000	$14,824,000
Term	20	20	20	20	20
Interest Rate	4%	4%	4%	4%	4%
Payment Factor	0.0802	0.0802	0.0802	0.0802	0.0802
Annual Payment	$615,214	$158,636	$58,145	$356,890	$1,188,885
Calc. Annual O&M	NA	NA	NA	$268,500	$268,500
Net Annual Cost	NA	NA	NA	$625,390	$1,457,385
Net Annual Cost w/ 20% Loan Forgiveness	$492,171	$126,908	$46,516	$285,512	$1,219,608
Number of Connections (incl. NCL)	1,932	1,932	1,932	1,932	1,932
Calculated Monthly User Fee Increase	$29.19	$7.53	$2.76	$29.67	$69.15
Calculated Monthly User Fee Increase w/ 20% Loan Forgiveness & 10% Reserve (SRF)	$23.35	$6.02	$2.21	$26.29	$57.87

The proposed increases to user rates are preliminary in nature, and will need to be confirmed closer to the time of actual implementation.

C. Non-Monetary Factors

Examples of non-monetary factors affected by the proposed system improvements include operating requirements and community objections. Operating requirements for the proposed improvements are of similar complexity as the existing system, since these improvements are replacements of the existing components. Adding water treatment to the existing system would require additional learning, system operation, and increased O&M costs, if selected. With the exception of adding water treatment, the annual O&M costs are anticipated to be similar to those of the current system. In regards to community objections, the anticipated concerns will be limited to the impact of project cost and installation of the proposed improvements. The project costs presented herein may require the City to perform the recommended improvements over a longer period of time. Other non-monetary factors are not anticipated at this time.

D. Funding Options

Several funding options are available to the City, including Revenue Bonds, General Obligation Bonds, Water Wastewater Advisory Committee (WWAC) which includes Community Development Block Grants (CDBG), Drinking Water State Revolving Fund (DWSRF), and USDA RD programs, and Public-Private Partnerships.

1. Revenue Bonds

   These bonds are tax-exempt bonds in which the debt service is paid by a dedicated revenue source, such revenue from the sale of water to consumers, property or sales taxes.

2. General Obligation Bonds

   General obligation bonds are backed by the full faith and credit of the taxing authority. Utility revenues can be used to pay the annual debt service, and/or a tax can be levied on properties within the City. These are considered to be more secure than revenue bonds. As with revenue bonds, voter approval is often required prior to issuance. General obligation bonds typically have an interest rate lower than revenue bonds.

3. WWAC

   In order to assist communities seeking funding for water projects, Nebraska established the WWAC in 1997. WWAC is an advisory panel for municipalities, counties, and RWDs that are seek public financing from the following programs: CDBG, DWSRF, or USDA RD.

   Communities seeking funds must go through the WWAC, which consists of representatives from NDEQ, NDHHS, NeDED, and USDA RD. The process for submitting to the WWAC includes a pre-application and a completed facility plan or preliminary engineering report. The pre-application and other associated guidance can be found at: http://deq.ne.gov/.

   The WWAC reviews submittals monthly to determine actions taken. If the project is selected for funding, and the community meets the eligibility requirements, the WWAC will recommend 1 or a combination of funding sources. It should be noted that competition for funding is highly competitive, and the City may not qualify for funding from all agencies.

   a. CDBG Funding

      CDBG is a highly competitive program administered by the NeDED. In order to be eligible for a CDBG grant, a community must have a maximum population less than 50,000 and a minimum of 51% of low to moderate income families. Applications are accepted throughout any given year. CDBG provides matching grants for water or wastewater project to a maximum of $350,000. The City’s match ranges from 25 to 75%, as determined by the program.

b. SRF Loan Program
This loan program is administrated by the NDEQ and NDHHS through their DWSRF. Presently, the SRF loan would have a 20-year repayment term at an interest rate estimated at 2.0%. In addition, a 1.0% administration fee is charged on the unpaid loan balance. Therefore, the interest rate used for amortization of the loan would be 3.0%.

The City's eligibility to qualify for a State or Federal funds SRF loan is dependent on the SRF IUP. This process is repeated each year and allows for communities to submit their project needs to the State. The State then ranks the projects based on several criteria.

Funding for these types of projects are ongoing based on those projects considered to be high priority. The City of Fairbury is currently on the 2017 IUP funding list, at the very top of the list, for the nitrate treatment project previously described. If it appears that the City will be moving forward with the treatment and other system improvement option(s), it is recommended that the City include the selected project on the next available IUP for funding consideration. This is done by submitting an updated application to the WWAC committee.

c. USDA RD Program
The Water and Waste Disposal Program of the USDA's Rural Development Division (RDD) provides funding through direct loans and grants and guaranteed loans to develop and/or upgrade rural water distribution and wastewater facilities.

- *Direct Loans and Grants*
  Public entities such as municipalities, counties, special purpose districts, Indian Tribes and corporations operated on a not-for-profit basis (communities) may apply for loans or grants to develop drinking water and waste disposal systems including solid waste disposal and storm drainage. In order to apply, communities must have a population of 10,000 or less, be unable to obtain sufficient credit from commercial sources at reasonable rates and terms and have a MHI below the non-metropolitan MHI for the State of Nebraska.

  Loans may be made at 1 of 3 interest rates, the poverty rate, intermediate rate and market rate. The rate of the loan depends on the need to meet applicable health or sanitary standards and the MHI of the community. Once the loan rate is established, it remains fixed for the life of the loan maximum term, of which is up to 40 years. Normal term for treatment projects is 20 years. Funding preference is given to low income communities, communities with fewer than 5,500 residents, restoring deteriorating water supplies, improving, enlarging or modifying a water facility or an inadequate waste facility or merging small water facilities.

The RDD considers reasonable user rates to be $35-40/mo per household for 5,000 gallons used. Loan amounts are based on the reasonable rate amount multiplied by the number of user households. If repayment of loans increase monthly residential rates beyond this reasonable amount RDD grant monies will be sought to maintain rates at such levels. If monthly rates are below this reasonable amount they will need to be increased to such an amount in order for a loan to be secured.

Grants are made in combination with direct loans or with funding from other sources. Grants may be up to 75% of eligible project costs, but are limited to the amount necessary to enable the residents to be charged reasonable user rates. The MHI of the service area must be below that of the non-metropolitan MHI for the state as well as generally below the national poverty rate or 80% of the state figure. Grants can only be made for projects which address health or safety issues.

- *Guaranteed Loans*
  This method is most often used when communities with populations of 10,000 or less identify a private lender interested in financing a project but that lender will only do so if risk is reduced. Loan guarantees are 90% of the total loan amount. Interest rates are negotiated between the lender and the borrower and may be either fixed or variable, but must be in line with rates customarily charged to borrowers in similar circumstances.

4. <u>Public-Private Partnerships</u>
   In addition to traditional funding methods, there are several forms of public-private partnerships that can be used to fund water projects. The first is a lease-purchase agreement. This is a contract in which a private entity funds the project, and the City makes scheduled lease payments until the lease is paid in full. Another option is complete privatization of the water system. The private entity funds the design, build, and operation of the facility, and the City pays for the private entity to provide water to the community.

The most appropriate funding mechanisms for the construction of Fairbury's proposed system improvements appear to be either conventional bond financing or financing through the state revolving loan fund. Both bond issues and loan payments are supported through the rates charged to the utility customer. SRF interest rates are estimated to be 3.0% while general obligation bond interest rates are approximately 2.85% (10-year), 3.50% (15-year) 3.75% (20 years). Most are not issuing non-rated bonds beyond 10 years. The interest rate provided in a blended rate over a 20-year period.

It is recommended that the City's Financial Advisor be consulted for recommendations as to the best financing options, if desired. The rates available to the City may be dependent on the amount of financing desired.

In order to submit for state and federal funding through the WWAC, the City must have an approved Preliminary Engineering Report and must successfully navigate the application procedures, if this is the desired funding source.

VIII. PROPOSED PROJECT

The original purpose for the preparation of this document was to assist the City in their water system capital improvement planning. This has not been done in the history of the system. Several improvements were recommended and discussed with the City to put together a plan over the next several years where these improvements will be implemented. The recommended implementation is dependent upon the potential impact to the health, safety, and operation of the water treatment and distribution system.

A. Preliminary Project Design

At the present time, the water quality sampled during this evaluation was determined to be below the current primary and secondary MCLs as set by EPA, with exceptions presented herein.

Based on the information presented herein, it is recommended that the City proceed with the new water supply well, adjustment of rates with the higher water users (primarily RWD and Westin Foods), additional condition assessment of the high service pumps (Power Plant) and transmission main from Crystal Springs, budgeting of other system repairs and updates, and additional discussion or planning regarding distribution and transmission piping updates. Water treatment will continue to remain in its current state, unless nitrate concentrations continue to increase.

General locations of recommended improvements were provided in Figures referenced previously in this document. Other preliminary design information has been included in several different sections of this evaluation. The overall function and design of the supply, treatment, storage, and distribution system are not being changed. Therefore, additional design information is not included in this section.

B. Project Schedule

With the number of recommended system improvements, the task of choosing which project to begin and when each project should be completed can seem daunting. The water system improvements were prioritized based on the potential impact to the health, safety, and operation of the water treatment and distribution system. The results, recommended order, and anticipated timeframe for the improvements are provided in Table VIII-1.

Table VIII-1: Recommended Improvements

Order	Description	Timeframe
1	Existing Transmission Main Investigation and/or Crystal Springs Transmission Main Replacement	1-2 years
2	Chemical Feed Addition/Modification	1-2 years
3	Existing Elevated Water Storage Reservoir Recommended Repairs	1-2 years
4	New Well	1-5 years
5	Distribution System Improvements	1-25 years
6	Water Treatment	As needed
7	Blending Transmission Main	As needed

At this time, it is anticipated that the City will complete the recommended improvements over an extended timeframe. The actual project schedules will be refined as the City confirms the proposed timeframes. Should the City elect to complete all recommended improvements as a larger project, or groups of projects, a more refined schedule will be provided at that time. For the purposes of this study and project funding consideration, the City will submit Improvements 1-4 and 6 for consideration by funding agencies.

The project schedule and summary provided are meant to assist the City in identifying the immediate water system needs. Continued maintenance and operation are required to keep the system operable and maintained so that replacement is spread out. The City has been fortunate in that the system has performed in such a maintenance-free manner. However, increased attention should be provided in the future to budget for and implement scheduled replacements.

C. Permit Requirements

The water system is regulated by the NDHHS. The regulations that apply to water supply, treatment, and distribution systems are contained in the Nebraska Administrative Code Title 179. In order to modify or replace major equipment or modify the treatment process, a construction permit from NDHHS is required. A construction permit requires submission of plans and specifications from a registered professional engineer. A review fee of $100 plus 0.5% of the project cost, up to a maximum of $7,500, is also required to be provided by the City at the time of construction permit request. It is anticipated that all recommended project components will require an NDHHS construction permit.

Based on the improvements recommended herein, it is not anticipated that permits from other State, Federal, or Local agencies will be required. However, should the City decide to participate in funding through the WWAC, additional coordination and environmental review of the proposed project(s) by State, Federal, and Local agencies may be required.

D. Sustainability Considerations

1. Water Efficiency

   The per capita water use identified previously in this report was just over 2 times higher than the national average of 100 gpcd. This is primarily due to water use during the summer for irrigation and livestock watering. Replacement of older water mains, or those with a high disruption of service percentage, replacement of inoperable water valves, and other similar repairs to the water distribution system will also improve water efficiencies.

2. Energy Efficiency

   Installation of new transmission and distribution system piping will increase flows to various parts of town, with no additional pumping or energy use. The addition of a new well will increase energy use, but with a VFD and other controls will be more efficient. Water treatment options, if selected, will be designed with energy efficiency in mind.

3. Green Infrastructure

   The proposed improvements are not anticipated to have green infrastructure components. This section does not apply to the preliminary engineering report.

4. Other Sustainability Considerations

   The proposed improvements are sustainable in the effect that the existing O&M required will not be substantially modified, thus maintaining the simplicity of the system. A majority of the recommended improvements are replacements of existing components. These updates will include technology as well as physical updates to the existing system. It is anticipated that information available to the City through updated flow meters and other sampling instruments will increase the system operational efficiency and record-keeping abilities.

E. Total Project Cost Estimate

A project cost summary was compiled from information provided in other sections of this document, as shown in the following table.

Table VIII-2: Total Project Opinion of Probable Cost and Timeframe

Description	Estimated Cost	Anticipated Timeframe
Existing Transmission Main Investigation and/or Crystal Springs Transmission Main Replacement	$1,850,000	1-2 years
Chemical Feed Addition/Modification	$65,000	1-2 years
Existing Elevated Water Storage Reservoir Recommended Repairs	$465,000	1-2 years
New Well	$725,000	1-5 years
Water Treatment (RO or IX) – without transmission and blending modifications	$4,615,000	As needed
Total Estimated Cost	**$7,255,000**	**-**
Annual Payment (A/P,4%,20 yrs) – 0.0802 Factor	**$581,850**	**-**
Total Estimated Cost w/ 20% Loan Forgiveness	**$5,804,000**	**-**
Annual Payment (A/P,4%,20 yrs) – 0.0802 Factor	**$465,480**	**-**
Calculated Annual O&M Costs	**$268,500**	**-**
Total Calculated Annual Project Costs	**$850,350**	**-**
Total Calculated Annual Project Costs w/ 20% Loan Forgiveness	**$733,980**	**-**

Based on the information contained in the previous tables, the annual amount that the City would need to financially sustain the recommended improvements and current operation and maintenance costs is approximately $850,000, which does not include the current water rate, or funding assistance. This presumes that all of the improvements are financed. It is recommended that the City work to increase the user rates to account for these expenditures for the water system.

F. Annual Operating Budget

Income, annual O&M costs, debt repayments, and reserves are all part of the City's annual operating budget. The budgets for the last few years were reviewed previously as a part of this report, and summarized herein. It is anticipated that the annual operating and maintenance budget will not change based on the recommended improvements and the lack of existing debt. Therefore, the annual maintenance budget, as documented previously, will remain the same. The biggest change to the City water system budget will be the annual cost of improvements or debt payments. It is also recommended that the City work to build a reserve to account for unanticipated system repairs and emergencies. In discussions with the City, a reserve amount was not requested for this calculation. A dollar amount placeholder is provided as part of this evaluation; however, the City should look at other projects and financial needs to determine if adjustment is necessary. A summary of these costs is provided in Table VIII-3.

Table VIII-3: Annual Operating Budget Summary

Description	Annual Cost
Current Annual O&M (average)	$750,000
Proposed Annual Improvement Cost/Debt Service	$850,350
Proposed Annual Improvement Cost/Debt Service w/ 20% Loan Forgiveness	$733,980
Annual Reserve	Not Included
Total Annual Operating Budget	$1,600,350
Total Annual Operating Budget w/ 20% Loan Forgiveness	$1,483,980
Monthly User Fee (1,932 Connections), rounded	$69
Average Monthly User Fee (1,932 Connections) plus 10% Reserve Capacity, rounded	$76
Monthly User Fee (1,932 Connections), rounded w/ 20% Loan Forgiveness	$64
Average Monthly User Fee (1,932 Connections) plus 10% Reserve Capacity, rounded w/ 20% Loan Forgiveness	$70

It is recommended that this information be confirmed and verified by the City prior to adjusting user rates through a full rate study, which is beyond the scope of this evaluation. This evaluation is currently being provided to the City and will be completed by the end of 2017 or early 2018.

It is also recommended that the City work to identify other water system components that require maintenance or replacement. This summary should be included in an asset management program. The EPA has developed a program for small systems to go through this exercise and work through the documentation and replacement process. This system is called the Check Up Program for Small Systems, or CUPSS, and can be accessed at: http://water.epa.gov/infrastructure/drinkingwater/pws/cupss/. As stated on the website, the purpose of the program is to help small systems to develop: a record of City assets; A schedule of required tasks; An understanding of your financial situation; and, A tailored asset management plan. The website provides information, instruction, and the ability to either download or order the kit.

IX. CONCLUSIONS AND RECOMMENDATIONS

At the present time, the City has committed to completing the recommended improvements to the existing water supply, treatment, storage, and distribution systems. The City will need to determine whether they will follow the recommended replacement schedule, or amend the schedule based on available funding.

It is recommended that those projects requiring engineer approved plans and specifications also go through a preliminary design process to better define and quantify the limits of each individual project and update the costs. Some projects are recommended to be completed concurrently, and the preliminary design process will allow for expedited project development and system interruption.

Due to the varied design nature of each proposed infrastructure improvement, a preliminary and generic timetable for the initiation of these projects is shown below:

Event	Date
City Approval of Preliminary Engineering Report	August 2017
Submit WWAC Funding Application	To Be Determined
Acquire Funding for Project(s)	To Be Determined
Preliminary Design of Selected Project(s)	To Be Determined
Pilot Study – Water Treatment	To Be Determined
Begin Final Design of Selected Alternative	To Be Determined
Submit Plans and Specifications to NDHHS	To Be Determined
Bidding (if Necessary)	To Be Determined
Construction Start	To Be Determined
Construction and Start-Up Services	To Be Determined

X. REFERENCES

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- American Water Works Association, 1999, *Reverse Osmosis and Nanofiltration, Manual of Water Supply Practices, AWWA M46,* First Edition, American Water Works Association, Denver, Colorado.

- Insurance Service Office, 2008, *Guide for Determination of Needed Fire Flow*, Jersey City, New Jersey, http://www.isomitigation.com/downloads/ppc3001.pdf.

- Kenny, J.F., Barber, N.L., Hutson, S.S., Linsey, K.S., Lovelace, J.K., and Maupin, M.A., 2009, *Estimated use of water in the United States in 2005*: U.S. Geological Survey Circular 1344.

- Prato, Ted and Richard Parent, 2010, *Nitrate and Nitrite Removal from Municipal Drinking Water Supplies with Electrodialysis Reversal*, General Electric Power and Water Technical Paper TP1072EN, http://www.gewater.com/pdf/Technical%20Papers_Cust/Americas/English/TP1072EN.pdf, Reprinted from Proceedings of 1993 American Water Works Association (Denver, CO) Membrane Conference, held in Baltimore, MD.

- United States Department of the Interior, 2010, Bureau of Reclamation, *Electrodialysis and Electrodialysis Reversal*, http://www.usbr.gov/pmts/water/publications/primer.html Revision date, September 20, 2010.

- Walski, Thomas, Donald Chase, Dragan Savic, 2001, *Haestad Methods Water Distribution Modeling*, First Edition, Haestad Press, Waterbury, Connecticut.

APPENDIX "A"

Water System Photos


FAIRBURY


FAIRBURY


FAIRBURY


STENNER

APPENDIX "B"

Water Well Registration Information:

For Crystal Springs Facility:
A-10553 A through H

For East Well Field:
G-032647, G-068253, G-096478

Revised December, 1978 DWR Form 602

DO NOT WRITE IN THIS SPACE

PRIORITY DATE: 7/1887

Registration No. A-10553A County Jefferson Date Filed 9/1/81

STATE OF NEBRASKA
DEPARTMENT OF WATER RESOURCES
WELL REGISTRATION

1. General information:
   A. Connected well
      Is this well connected to another well? [ ] Yes [X] No
      If yes, give registration number of previously registered well ______
      (If new installation consists of a series of wells with one outlet, complete registration forms and driller's certificates for each and submit $7.50)
   B. Replacement well
      Is this well to replace a permanently abandoned well? [ ] Yes [X] No
      If yes, give registration number of abandoned well ______
   C. Permit No. -- (xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx)

Type of well to be registered: (Check One)
[ ] IRRIGATION
[X] MUNICIPAL
[ ] INDUSTRIAL
[ ] Other ______

2. Name & address of well owner: CITY OF FAIRBURY
   612 D Street
   Fairbury, Nebraska

   Zip Code 683522399 Phone (402) 729-3030

3. Name & address of well driller: DALE VEATCH (DECEASED)
   117 W 3rd Street
   Fairbury, Nebraska

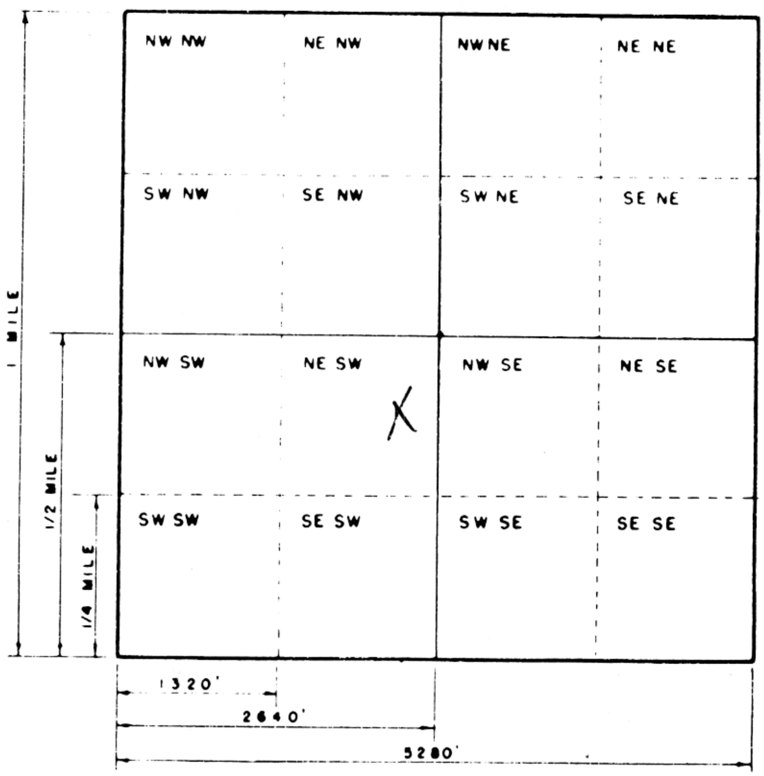
   Zip Code 68352 Phone: ( ) None

4. Location & purpose of the well: Well Designation: North H Street CA
   A. MUNICIPAL WATER SUPPLY xxxxxxxxxxxxxxxxxxxxxxx (Identify)
   B. NE ¼ of the SW ¼ of Section 11, Township T2N, Range R2 [X] E [ ] W, (check one)
      JEFFERSON County.
   C. The well is Over 1 mi feet from the nearest municipal, irrigation, or industrial well. The nearest well is owned by [X] you [ ] someone other than you. (check one)
   D. The well is intended to irrigate None acres of land, and it is intended to irrigate all or parts of the following land: ______
   OR
   E. The well shall be used for purposes of: MUNICIPAL WATER SUPPLY.

5. Well and pump specifications:
   A. Pumping rate under normal conditions: 200 gallons per minute.
   B. Total well depth: 176 feet.
   C. Inside diameter of the casing: 18 inches.
   D. Static (non-pumping) water level in the well: 117 feet below ground surface.
   E. Depth of water under normal pumping conditions: 150 feet below ground surface.
   F. Pump column: Diameter 5 inches. Length 155 feet.
   G. The well was completed on or about May, 1957.

MORE ON BACK MORE ON BACK

(With an "X" mark the location of the well)



This drawing represents one square mile (a section).
Each small subdivision is a 40-acre tract.

I certify that I am familiar with the information contained on this registration, and that to the best of my knowledge and belief such information is true, concise and accurate.

Glen R Boechler — Aug 31 1981
Well Owner's Signature — Date
Supt of Utilities

Both a Well Registration and Driller's Certificate must be completed in triplicate and in full. An incomplete or defective form will be returned. A non-refundable $7.50 fee (payable to the Director of Water Resources) must accompany your submittal. No fee is required to register: (1) a permitted well within a Ground Water Control Area; (2) a well constructed to replace a previously registered well; or (3) a well connected in a series with another well previously registered. Forward to:

State of Nebraska
Department of Water Resources
301 Centennial Mall-South
P.O. Box 94676
Lincoln, Nebraska 68509

Revised April, 1976

PRIORITY DATE: 7/1887.

Registration No. A-10553A County Jefferson Date Filed 9/1/81

STATE OF NEBRASKA
CERTIFICATE OF WELL DRILLER

Permit No. .... (required only in a control area)

Name & Address of well driller: DALE VEATCH (DECEASED)
117 W 3rd Street
Fairbury, Nebraska

Well Location:

.... Natural Resources District

NE Quarter of the SW Quarter of Section 11, Township T2N, Range R2E,

JEFFERSON County, and owned by CITY OF FAIRBURY, NEBRASKA

Drilling & construction specifications:

1. Date construction was begun: AUGUST, 19 56.
2. Date construction was completed: ...., 19 57.
3. Diameter of the drilled hole: 18 inches.
4. Was the hole electronically logged? ☐ Yes ☒ No.
5. How is drilled hole sealed (not sealed)? ....
6. Well casing & screen: Steel casing to 154½ feet, screen to bottom
(Give type of casing, lengths and vertical position of plain and slotted segments, slot or perforation size.)
7. Is the well artifically gravel stabilized? ☐ Yes ☒ No

Pumping test information:

1. Pumping rate: .... gallons per minute.
2. Depth to water before pumping: .... feet.
3. Depth to water .... feet after pumping .... minutes.

	Drawdown	
At 150 GPM -	147'7" -	15 Min
200 " -	157'8"	15 Min
235 " -	169'	

DRILLING LOG ON BACK

DRILLING LOG ON BACK

DRILLING LOG

DEPTH IN FEET FROM	TO	MATERIAL DRILLED
1' to	25'	Clay
25'	95'	Sand & Gravel
95'	126'	Clay - Some shale (not to hard)
126'	140'	Yellow sandstone
140'	150'	Water baring sandstone dirty, with layers of soapstone
150'	164'	Good yellow water baring sandstone
164'	168'	Good light sandstone
168'	172'	Sandstone

DALE VEATCH
(DECEASED)
Well Driller's Signature

August 25, 1956
Date

Revised December, 1978 DWR Form 602

DO NOT WRITE IN THIS SPACE

PRIORITY DATE: 7/1887

Registration No. A-10553B County Jefferson Date Filed 9/1/81

STATE OF NEBRASKA
DEPARTMENT OF WATER RESOURCES
WELL REGISTRATION

Type of well to be registered: (Check One)

- [ ] IRRIGATION
- [XX] MUNICIPAL
- [ ] INDUSTRIAL
- [ ] Other ________

1. General information:
   A. Connected well
      Is this well connected to another well? [ ] Yes [XX] No
      If yes, give registration number of previously registered well ________
      (If new installation consists of a series of wells with one outlet, complete registration forms and driller's certificates for each and submit $7.50)
   B. Replacement well
      Is this well to replace a permanently abandoned well? [ ] Yes [XX] No
      If yes, give registration number of abandoned well ________
   C. Permit No. A-10553 (reXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX)

2. Name & address of well owner: CITY OF FAIRBURY, 612 D street FAIRBURY, NEBRASKA.

   Zip Code 683522399 Phone (402) 729 3030

3. Name & address of well driller: DALE VEATCH (DECEASED) 117 W 3rd st. FAIRBURY, NEBR.

   Zip Code 68352 Phone: (____) none

4. Location & purpose of the well: well designation AF # 6
   A. MUNICIPAL WATER SUPPLY Natural XXXXXXXXXXXXXXX (Identify)
   B. SE ¼ of the SW ¼ of Section 16, Township 2N, Range 2 [X] E [ ] W, (check one)
      JEFFERSON County.
   C. The well is 50 feet from the nearest municipal, irrigation, or industrial well. The nearest well is owned by [XX] you [ ] someone other than you. (check one)
   D. The well is intended to irrigate none acres of land, and it is intended to irrigate all or parts of the following land: ________
      OR
   E. The well shall be used for purposes of: MUNICIPAL WATER SUPPLY.

5. Well and pump specifications:
   A. Pumping rate under normal conditions: ________ gallons per minute.
   B. Total well depth: ________ feet.
   C. Inside diameter of the casing: ________ inches.
   D. Static (non-pumping) water level in the well: ________ feet below ground surface.
   E. Depth of water under normal pumping conditions: ________ feet below ground surface.
   F. Pump column: Diameter ________ inches. Length ________ feet.
   G. The well was completed on or about ________, 19____.

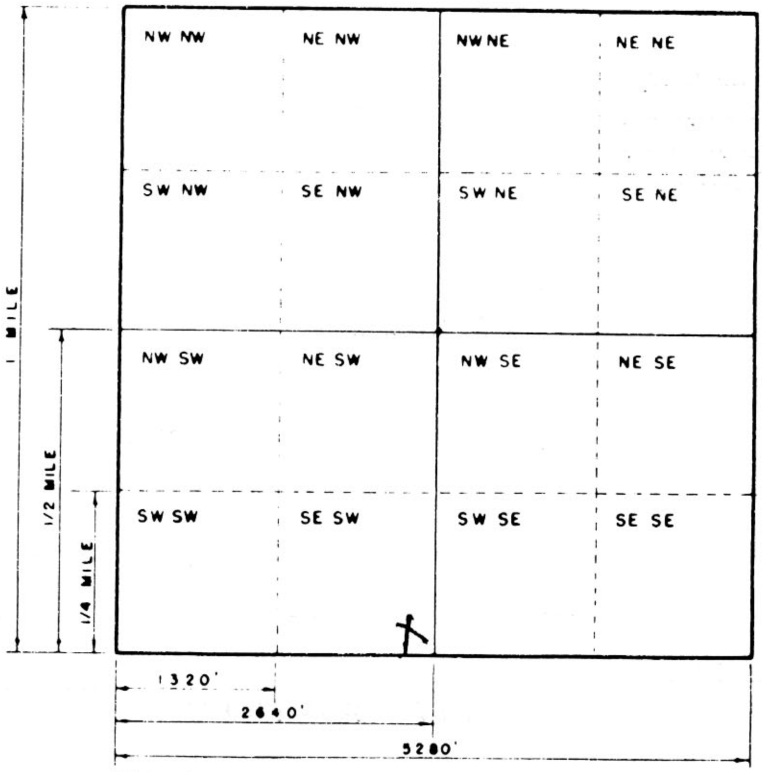
NOTE

This well designation AF # 6 is a siphon well to AE # 5 Pumping info. is combined as given on Well AE # 5........

MORE ON BACK

MORE ON BACK

(With an "X" mark the location of the well)



This drawing represents one square mile (a section).
Each small subdivision is a 40-acre tract.

I certify that I am familiar with the information contained on this registration, and that to the best of my knowledge and belief such information is true, concise and accurate.

Glen R Beachler — Aug 31 1981
Well Owner's Signature — Date
Supt of Utilities

Both a Well Registration and Driller's Certificate must be completed in triplicate and in full. An incomplete or defective form will be returned. A non-refundable $7.50 fee (payable to the Director of Water Resources) must accompany your submittal. No fee is required to register: (1) a permitted well within a Ground Water Control Area; (2) a well constructed to replace a previously registered well; or (3) a well connected in a series with another well previously registered. Forward to:

State of Nebraska
Department of Water Resources
301 Centennial Mall-South
P.O. Box 94676
Lincoln, Nebraska 68509

DO NOT WRITE IN THIS SPACE

PRIORITY DATE: 7/1887.1

Registration No. A-10553C County Jefferson Date Filed 9/1/81

STATE OF NEBRASKA
DEPARTMENT OF WATER RESOURCES
WELL REGISTRATION

1. General information:
   A. Connected well
      Is this well connected to another well? [ ] Yes [X] No
      If yes, give registration number of previously registered well ____
      (If new installation consists of a series of wells with one outlet, complete registration forms and driller's certificates for each and submit $7.50)
   B. Replacement well
      Is this well to replace a permanently abandoned well? [ ] Yes [X] No
      If yes, give registration number of abandoned well ____
   C. Permit No. A-10553 (XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX)

Type of well to be registered: (Check One)

[ ] IRRIGATION

[X] MUNICIPAL

[ ] INDUSTRIAL

[ ] Other ____

2. Name & address of well owner: CITY OF FAIRBURY
   612 D Street
   Fairbury, Nebraska

   Zip Code 683522399 Phone (402) 729-3030

3. Name & address of well driller: DALE VEATCH (DECEASED)
   117 W 3rd Street
   Fairbury, Nebraska

   Zip Code 68352 Phone: ( ) None

4. Location & purpose of the well: Well Designation AA #1
   A. MUNICIPAL WATER SUPPLY XXXXXXXXXXXXXXXXXXXXX(Identify)
   B. NE ¼ of the NW ¼ of Section 21, Township 2N, Range 2 [X] E [ ] W, (check one)
      JEFFERSON County.
   C. The well is 70 feet from the nearest municipal, irrigation, or industrial well. The nearest well is owned by [X] you [ ] someone other than you. (check one)
   D. The well is intended to irrigate None acres of land, and it is intended to irrigate all or parts of the following land: ____
      OR
   E. The well shall be used for purposes of: MUNICIPAL WATER SUPPLY.

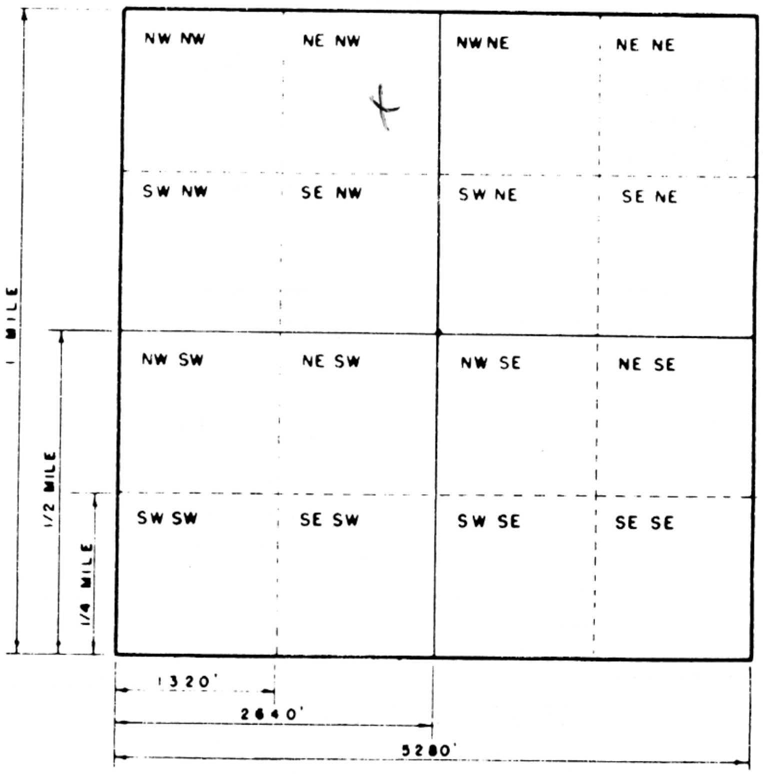
5. Well and pump specifications:
   A. Pumping rate under normal conditions: ____ gallons per minute.
   B. Total well depth: ____ feet.
   C. Inside diameter of the casing: ____ inches.
   D. Static (non-pumping) water level in the well: ____ feet below ground surface.
   E. Depth of water under normal pumping conditions: ____ feet below ground surface.
   F. Pump column: Diameter ____ inches. Length ____ feet.
   G. The well was completed on or about ____, 19__.

NOTE

This well designation AA #1 is a siphon well to AB #2 Pumping info. is combined as given on AB #2..........

MORE ON BACK MORE ON BACK

(With an "X" mark the location of the well)



This drawing represents one square mile (a section).
Each small subdivision is a 40-acre tract.

I certify that I am familiar with the information contained on this registration, and that to the best of my knowledge and belief such information is true, concise and accurate.

Glen R Beachler Aug 31 1981

Well Owner's Signature Date

Supt of Utilities

Both a Well Registration and Driller's Certificate must be completed in triplicate and in full. An incomplete or defective form will be returned. A non-refundable $7.50 fee (payable to the Director of Water Resources) must accompany your submittal. No fee is required to register: (1) a permitted well within a Ground Water Control Area; (2) a well constructed to replace a previously registered well; or (3) a well connected in a series with another well previously registered. Forward to:

State of Nebraska
Department of Water Resources
301 Centennial Mall-South
P.O. Box 94676
Lincoln, Nebraska 68509

Revised December, 1978 DWR Form 602

DO NOT WRITE IN THIS SPACE

PRIORITY DATE: 7/1887. 1

Registration No. A-10553D County Jefferson Date Filed 9/1/81

STATE OF NEBRASKA
DEPARTMENT OF WATER RESOURCES
WELL REGISTRATION

1. General information:
   A. Connected well
      Is this well connected to another well? [ ] Yes [X] No
      If yes, give registration number of previously registered well ______
      (If new installation consists of a series of wells with one outlet, complete registration forms and driller's certificates for each and submit $7.50)
   B. Replacement well
      Is this well to replace a permanently abandoned well? [ ] Yes [X] No
      If yes, give registration number of abandoned well ______
   C. Permit No. A-10553 (xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx)

Type of well to be registered: (Check One)
[ ] IRRIGATION
[X] MUNICIPAL
[ ] INDUSTRIAL
[ ] Other ______

2. Name & address of well owner: CITY OF FAIRBURY
612 D Street
Fairbury, Nebraska

Zip Code 683522399 Phone (402) 729-3030

3. Name & address of well driller: DALE VEATCH (DECEASED)
117 W 3rd Street
Fairbury, Nebraska

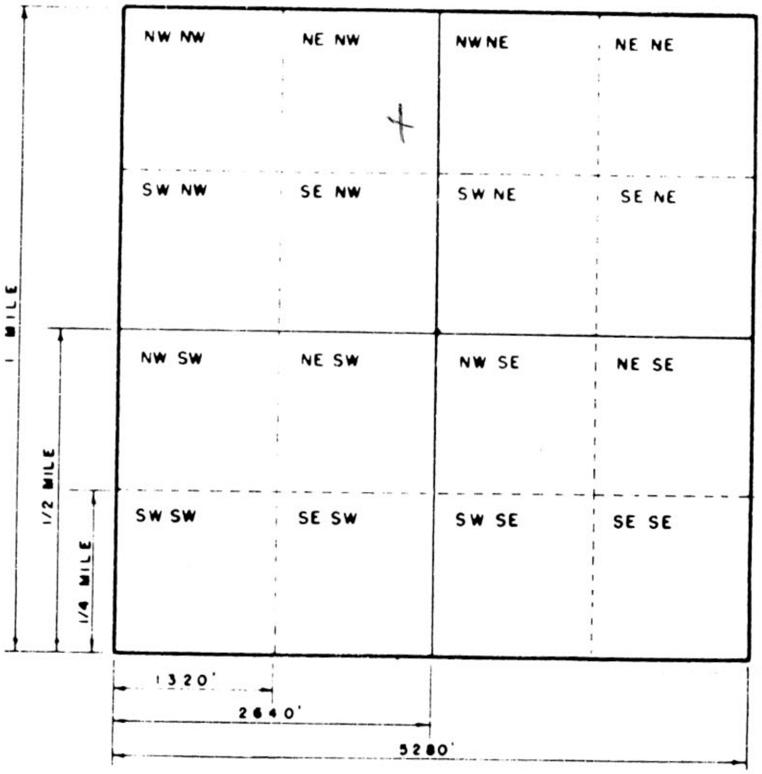
Zip Code 68352 Phone: (____) None

4. Location & purpose of the well: Well Designation AB #2
   A. MUNICIPAL WATER SUPPLY xxxxxxxxxxxxxxxxxxxx (Identify)
   B. NE ¼ of the NW ¼ of Section 21, Township 2N, Range 2 [X] E [ ] W, (check one)
      JEFFERSON County.
   C. The well is 70 feet from the nearest municipal, irrigation, or industrial well. The nearest well is owned by [X] you [ ] someone other than you. (check one)
   D. The well is intended to irrigate None acres of land, and it is intended to irrigate all or parts of the following land: ______
   OR
   E. The well shall be used for purposes of: MUNICIPAL WATER SUPPLY.

5. Well and pump specifications:
   A. Pumping rate under normal conditions: 400 gallons per minute.
   B. Total well depth: 36 feet.
   C. Inside diameter of the casing: 18 inches.
   D. Static (non-pumping) water level in the well: 7 feet below ground surface.
   E. Depth of water under normal pumping conditions: 13 feet below ground surface.
   F. Pump column: Diameter 5 inches. Length 30 feet.
   G. The well was completed on or about UNKNOWN...., 19____.

MORE ON BACK MORE ON BACK

(With an "X" mark the location of the well)



This drawing represents one square mile (a section).
Each small subdivision is a 40-acre tract.

I certify that I am familiar with the information contained on this registration, and that to the best of my knowledge and belief such information is true, concise and accurate.

Glenn R Beachler — Aug 31 1981

Well Owner's Signature — Date

Supt of Utilities

Both a Well Registration and Driller's Certificate must be completed in triplicate and in full. An incomplete or defective form will be returned. A non-refundable $7.50 fee (payable to the Director of Water Resources) must accompany your submittal. No fee is required to register: (1) a permitted well within a Ground Water Control Area; (2) a well constructed to replace a previously registered well; or (3) a well connected in a series with another well previously registered. Forward to:

State of Nebraska
Department of Water Resources
301 Centennial Mall-South
P.O. Box 94676
Lincoln, Nebraska 68509

Revised December, 1978 DWR Form 602

DO NOT WRITE IN THIS SPACE

PRIORITY DATE: 7/1887.1

Registration No. A-10553E County Jefferson Date Filed 9/1/81

STATE OF NEBRASKA
DEPARTMENT OF WATER RESOURCES
WELL REGISTRATION

Type of well to be registered: (Check One)

- [ ] IRRIGATION
- [X] MUNICIPAL
- [ ] INDUSTRIAL
- [ ] Other______

1. General information:
   A. Connected well
   Is this well connected to another well? [ ] Yes [X] No
   If yes, give registration number of previously registered well______
   (If new installation consists of a series of wells with one outlet, complete registration forms and driller's certificates for each and submit $7.50)
   B. Replacement well
   Is this well to replace a permanently abandoned well? [ ] Yes [X] No
   If yes, give registration number of abandoned well______
   C. Permit No. A-10553 ~~(Required only in a Ground Water Control Area)~~

2. Name & address of well owner: CITY OF FAIRBURY
   612 D Street
   Fairbury, Nebraska

   Zip Code 683522399 Phone (402) 729-3030

3. Name & address of well driller: DALE VEATCH (DECEASED)
   117 W 3rd Street
   Fairbury, Nebraska

   Zip Code 68352 Phone: (____) None

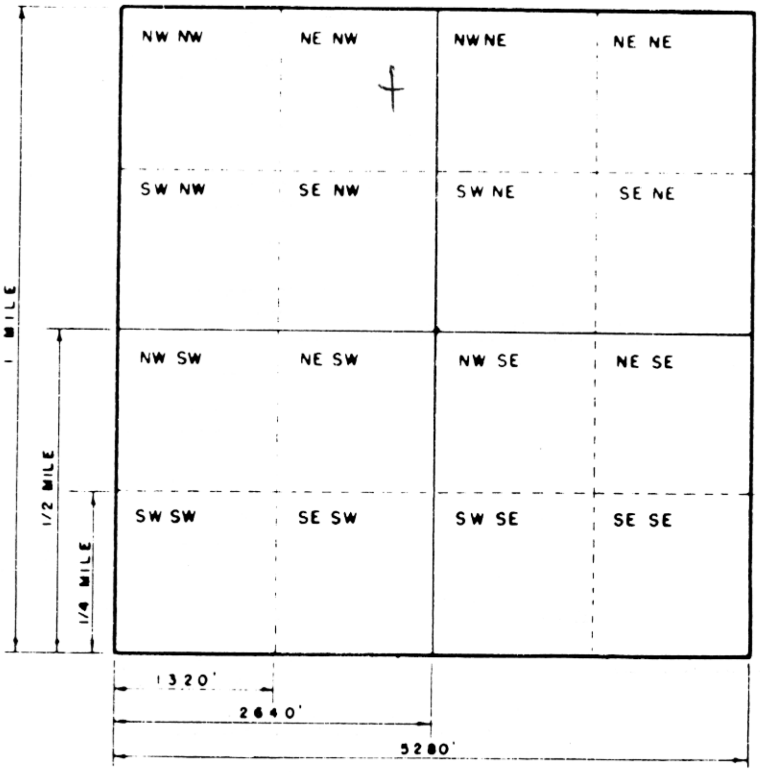
4. Location & purpose of the well: Well Designation AC #3
   A. MUNICIPAL WATER SUPPLY ~~Natural Resources District~~ (Identify)
   B. NE ¼ of the NW ¼ of Section 21, Township T2N, Range 2 [X] E [ ] W, (check one)
   JEFFERSON County.
   C. The well is 200 feet from the nearest municipal, irrigation, or industrial well. The nearest well is owned by [X] you [ ] someone other than you. (check one)
   D. The well is intended to irrigate None acres of land, and it is intended to irrigate all or parts of the following land:______
   OR
   E. The well shall be used for purposes of: MUNICIPAL WATER SUPPLY.

5. Well and pump specifications:
   A. Pumping rate under normal conditions: 400 gallons per minute.
   B. Total well depth: 36 feet.
   C. Inside diameter of the casing: 18 inches.
   D. Static (non-pumping) water level in the well: 10 feet below ground surface.
   E. Depth of water under normal pumping conditions: 18 feet below ground surface.
   F. Pump column: Diameter 5 inches. Length 30 feet.
   G. The well was completed on or about UNKNOWN..., 19____.

MORE ON BACK

MORE ON BACK

(With an "X" mark the location of the well)



This drawing represents one square mile (a section).
Each small subdivision is a 40-acre tract.

I certify that I am familiar with the information contained on this registration, and that to the best of my knowledge and belief such information is true, concise and accurate.

Glen R Beachler — Aug 31 1981

Well Owner's Signature — Date

Supt of Utilities

Both a Well Registration and Driller's Certificate must be completed in triplicate and in full. An incomplete or defective form will be returned. A non-refundable $7.50 fee (payable to the Director of Water Resources) must accompany your submittal. No fee is required to register: (1) a permitted well within a Ground Water Control Area; (2) a well constructed to replace a previously registered well; or (3) a well connected in a series with another well previously registered. Forward to:

State of Nebraska
Department of Water Resources
301 Centennial Mall-South
P.O. Box 94676
Lincoln, Nebraska 68509

Revised December, 1978 DWR Form 602

DO NOT WRITE IN THIS SPACE PRIORITY DATE: 7/1887.

Registration No. A-10553F County Jefferson Date Filed 9/1/81

1

STATE OF NEBRASKA
DEPARTMENT OF WATER RESOURCES
WELL REGISTRATION

1. General information:
   A. Connected well
   Is this well connected to another well? [ ] Yes [X] No
   If yes, give registration number of previously registered well ______
   (If new installation consists of a series of wells with one outlet, complete registration forms and driller's certificates for each and submit $7.50)
   B. Replacement well
   Is this well to replace a permanently abandoned well? [ ] Yes [X] No
   If yes, give registration number of abandoned well ______
   C. Permit No. A-10553 ~~(required only in a Ground Water Control Area)~~

Type of well to be registered: (Check One)

[ ] IRRIGATION

[X] MUNICIPAL

[ ] INDUSTRIAL

[ ] Other ______

2. Name & address of well owner: CITY OF FAIRBURY
612 D Street
Fairbury, Nebraska

Zip Code 683522399 Phone (402) 729-3030

3. Name & address of well driller: DALE VEATCH (DECEASED)
117 W 3rd Street
Fairbury, Nebraska

Zip Code 68352 Phone: ( ) None

4. Location & purpose of the well: Well Designation AD #4

A. MUNICIPAL WATER SUPPLY ~~Natural Resources District~~ (Identify)

B. NE ¼ of the NW ¼ of Section 21, Township T2N, Range 2 [X] E [ ] W, (check one)
JEFFERSON County.

C. The well is 50 feet from the nearest municipal, irrigation, or industrial well. The nearest well is owned by [X] you [ ] someone other than you. (check one)

D. The well is intended to irrigate None acres of land, and it is intended to irrigate all or parts of the following land: ______
OR

E. The well shall be used for purposes of: MUNICIPAL WATER SUPPLY.

5. Well and pump specifications:

A. Pumping rate under normal conditions: ______ gallons per minute.

B. Total well depth: ______ feet.

C. Inside diameter of the casing: ______ inches.

D. Static (non-pumping) water level in the well: ______ feet below ground surface.

E. Depth of water under normal pumping conditions: ______ feet below ground surface.

F. Pump column: Diameter ______ inches. Length ______ feet.

G. The well was completed on or about ______, 19__.

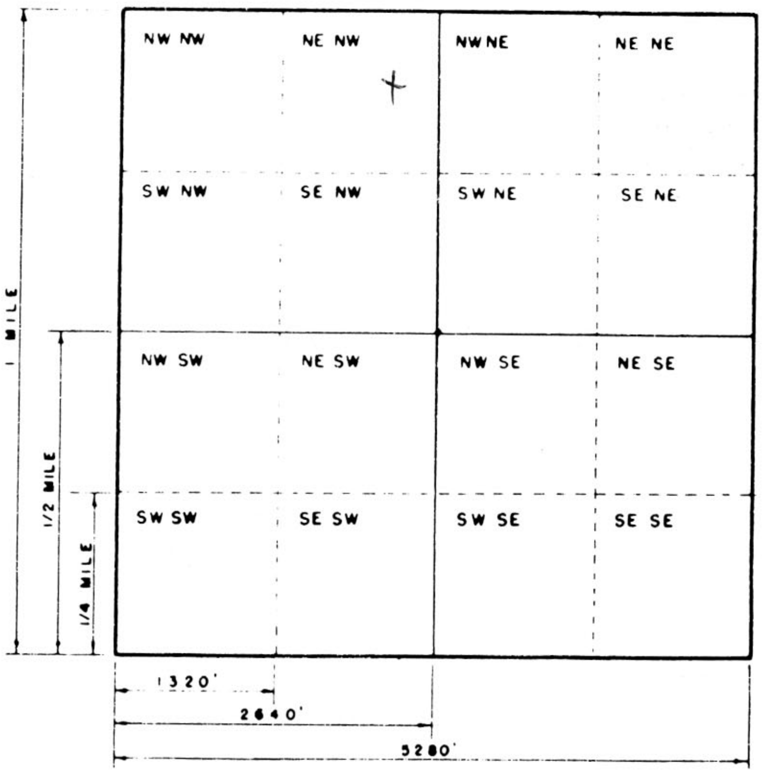
NOTE

This well designation AD #4 is a siphon well to AC #3 Pumping info. is combined as given on AC #3..........

MORE ON BACK

MORE ON BACK

(With an "X" mark the location of the well)



This drawing represents one square mile (a section).
Each small subdivision is a 40-acre tract.

I certify that I am familiar with the information contained on this registration, and that to the best of my knowledge and belief such information is true, concise and accurate.

Glen R Beachler — Aug 31 1981
Well Owner's Signature — Date
Supt of Utilities

Both a Well Registration and Driller's Certificate must be completed in triplicate and in full. An incomplete or defective form will be returned. A non-refundable $7.50 fee (payable to the Director of Water Resources) must accompany your submittal. No fee is required to register: (1) a permitted well within a Ground Water Control Area; (2) a well constructed to replace a previously registered well; or (3) a well connected in a series with another well previously registered. Forward to:

State of Nebraska
Department of Water Resources
301 Centennial Mall-South
P.O. Box 94676
Lincoln, Nebraska 68509

DO NOT WRITE IN THIS SPACE

PRIORITY DATE: 87/1887.1

Registration No. A-10553G County Jefferson Date Filed 9/1/81

STATE OF NEBRASKA
DEPARTMENT OF WATER RESOURCES
WELL REGISTRATION

Type of well to be registered: (Check One)

- [ ] IRRIGATION
- [XX] MUNICIPAL
- [ ] INDUSTRIAL
- [ ] Other ______

1. General information:
   A. Connected well
   Is this well connected to another well? [ ] Yes [XX] No
   If yes, give registration number of previously registered well ______
   (If new installation consists of a series of wells with one outlet, complete registration forms and driller's certificates for each and submit $7.50)
   B. Replacement well
   Is this well to replace a permanently abandoned well? [ ] Yes [XXX] No
   If yes, give registration number of abandoned well ______
   C. Permit No. A-10553 (required only in a Ground Water Control Area)

2. Name & address of well owner: CITY OF FAIRBURY, NEBR.
   612 D street
   FAIRBURY, NEBRASKA.

   Zip Code 683522399 Phone (402) 729 3030

3. Name & address of well driller: DALE VEATCH (DECEASED)
   117 W 3rd st.
   FAIRBURY, NEBRASKA.

   Zip Code -0-) Phone: (____) -0-

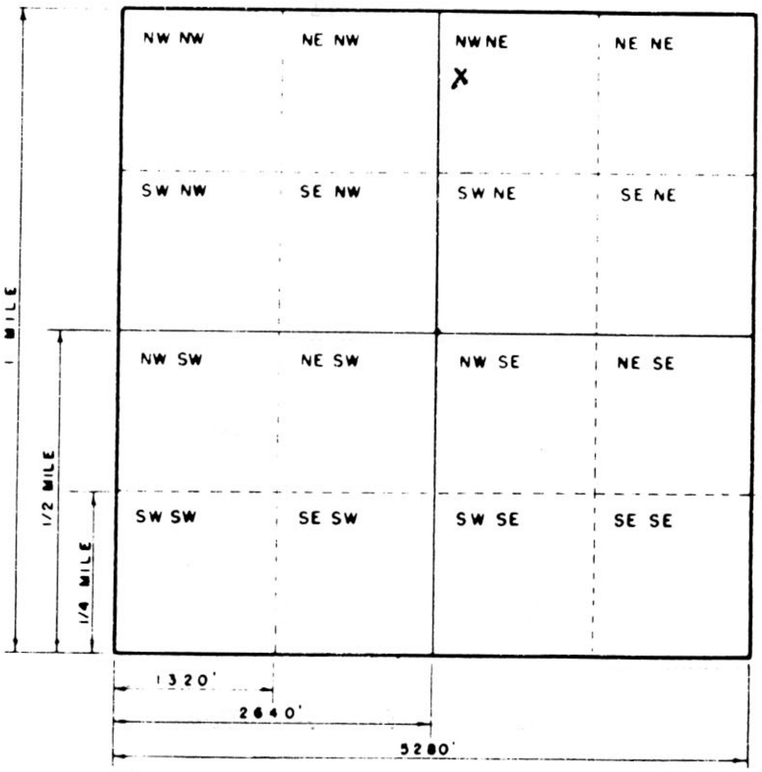
4. Location & purpose of the well: well desigantion AE #5
   A. MUNICIPAL WATER SUPPLY ______ Natural Resources District (Identify)
   B. NE ¼ of the NW ¼ of Section 21, Township T2N, Range 2 [X] E [ ] W, (check one)
   JEFFERSON County.
   C. The well is 50 feet from the nearest municipal, irrigation, or industrial well. The nearest well is owned by [X] you [ ] someone other than you. (check one)
   D. The well is intended to irrigate none acres of land, and it is intended to irrigate all or parts of the following land: ______
   OR
   E. The well shall be used for purposes of: MUNICIPAL WATER SUPPLY.

5. Well and pump specifications:
   A. Pumping rate under normal conditions: 600 gallons per minute.
   B. Total well depth: 36 feet.
   C. Inside diameter of the casing: 18 inches.
   D. Static (non-pumping) water level in the well: 12 feet below ground surface.
   E. Depth of water under normal pumping conditions 20 feet below ground surface.
   F. Pump column: Diameter 5 inches. Length 30 feet.
   G. The well was completed on or about UNKNOWN......, 19____.

MORE ON BACK

MORE ON BACK

(With an "X" mark the location of the well)



This drawing represents one square mile (a section).
Each small subdivision is a 40-acre tract.

I certify that I am familiar with the information contained on this registration, and that to the best of my knowledge and belief such information is true, concise and accurate.

Glen R Beachler — Aug 31 1981
Well Owner's Signature — Date
Supt of Utilities

Both a Well Registration and Driller's Certificate must be completed in triplicate and in full. An incomplete or defective form will be returned. A non-refundable $7.50 fee (payable to the Director of Water Resources) must accompany your submittal. No fee is required to register: (1) a permitted well within a Ground Water Control Area; (2) a well constructed to replace a previously registered well; or (3) a well connected in a series with another well previously registered. Forward to:

State of Nebraska
Department of Water Resources
301 Centennial Mall-South
P.O. Box 94676
Lincoln, Nebraska 68509

Revised December, 1978 — DWR Form 602

DO NOT WRITE IN THIS SPACE — PRIORITY DATE: 7/1887. — 1

Registration No. A-10553H County Jefferson Date Filed 9/1/81

STATE OF NEBRASKA
DEPARTMENT OF WATER RESOURCES
WELL REGISTRATION

1. General information:
   A. Connected ~~well~~ gallaries
   Is this well connected to another well? [ ] Yes [X] No
   If yes, give registration number of previously registered well ______
   (If new installation consists of a series of wells with one outlet, complete registration forms and driller's certificates for each and submit $7.50)
   B. Replacement well
   Is this well to replace a permanently abandoned well? [ ] Yes [X] No
   If yes, give registration number of abandoned well ______
   C. Permit No. A-10553 (required only in a Ground Water Control Area)

Type of well to be registered: (Check One)
[ ] IRRIGATION
[X] MUNICIPAL
[ ] INDUSTRIAL
[ ] Other ______

2. Name & address of well owner: CITY OF FAIRBURY
612 D Street
Fairbury, Nebraska

Zip Code 683522399 Phone (402) 729-3030

3. Name & address of well driller: CITY EMPLOYEES (ALL DECEASED)

Zip Code ______ Phone: (____) ______

4. Location & purpose of the ~~well~~ gallaries
   A. MUNICIPAL WATER SUPPLY ~~Natural Resources District~~ (Identify)
   B. NW ¼ of the NE ¼ of Section 21, Township T2N, Range 2 [X] E [ ] W, (check one)
   JEFFERSON County.
   C. The well is 200 feet from the nearest municipal, irrigation, or industrial well. The nearest well is owned by [X] you [ ] someone other than you. (check one)
   D. The well is intended to irrigate None acres of land, and it is intended to irrigate all or parts of the following land: ______
   OR
   E. The well shall be used for purposes of: MUNICIPAL WATER SUPPLY.

5. Well and pump specifications:
   A. Pumping rate under normal conditions: 800,000 gallons per ~~minute~~ day
   B. Total well depth: 13 feet.
   C. Inside diameter of the casing: ______ inches.
   D. Static (non-pumping) water level in the well: ______ feet below ground surface.
   E. Depth of water under normal pumping conditions: ______ feet below ground surface.
   F. Pump column: Diameter ______ inches. Length ______ feet.
   G. The well was completed on or about ______, 19____.

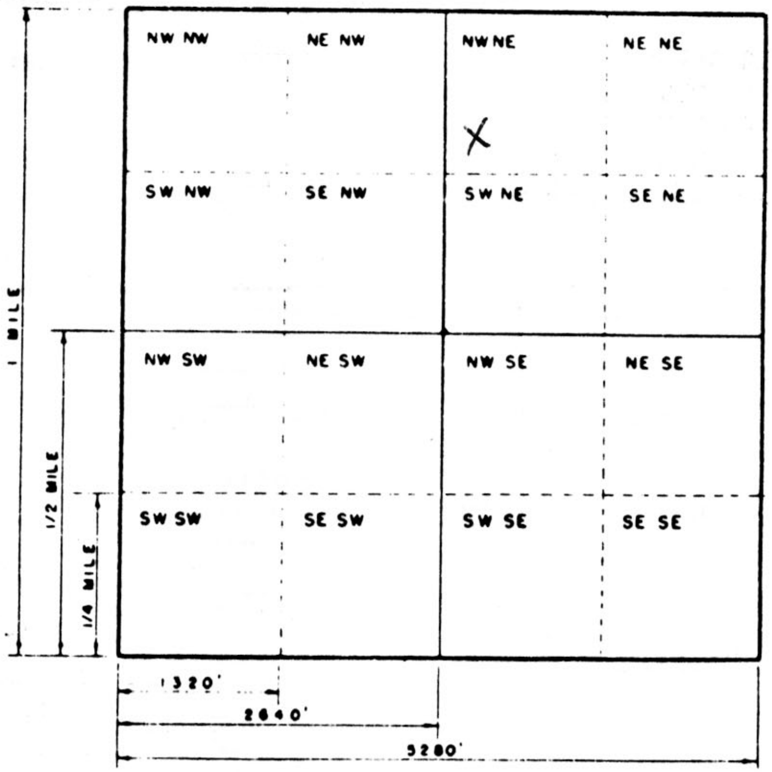
NOTE

Gallaries are spring infiltrated Water flows by gravity to City Reserver. During peak consumption a booster pump is used to meet the demand.

MORE ON BACK

MORE ON BACK wwc

(With an "X" mark the location of the well)



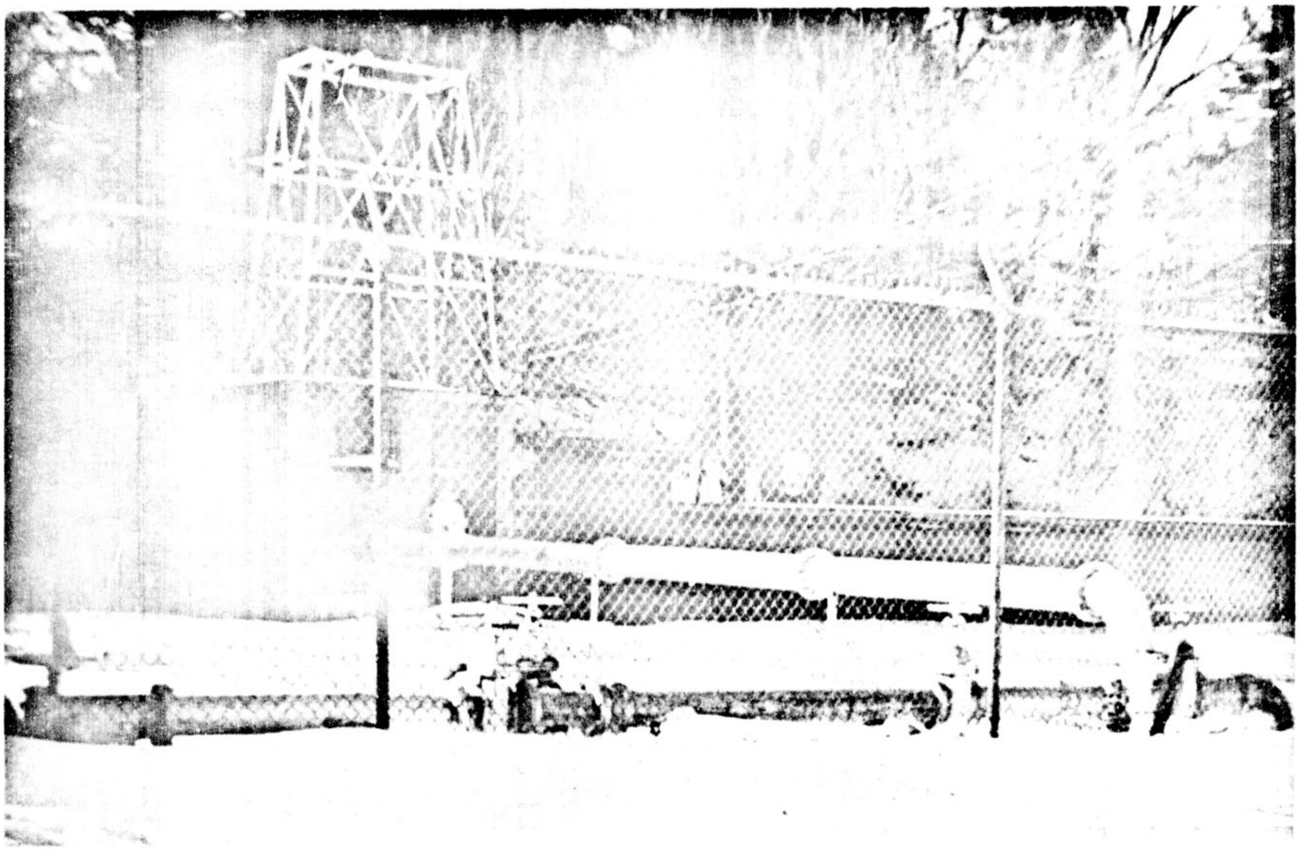
This drawing represents one square mile (a section).
Each small subdivision is a 40-acre tract.

I certify that I am familiar with the information contained on this registration, and that to the best of my knowledge and belief such information is true, concise and accurate.

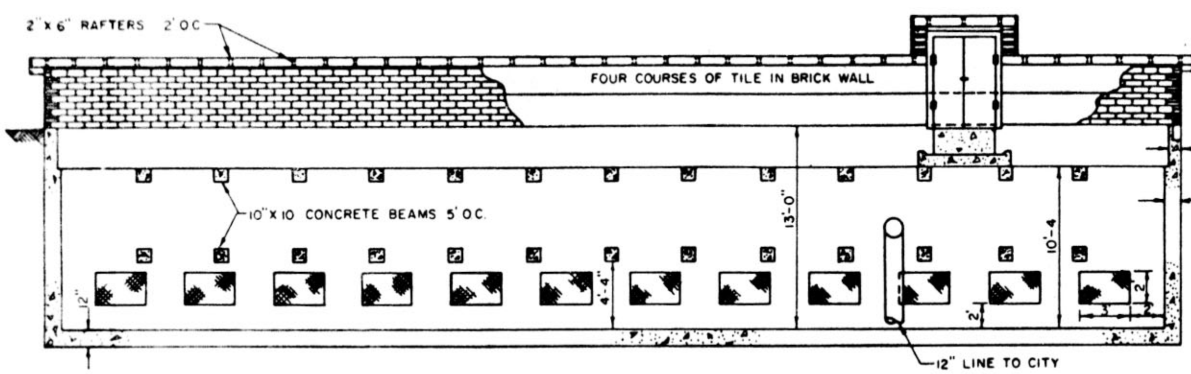
Glen R Beachler   Aug 31 1981
Well Owner's Signature   Date
Supt of Utilities

Both a Well Registration and Driller's Certificate must be completed in triplicate and in full. An incomplete or defective form will be returned. A non-refundable $7.50 fee (payable to the Director of Water Resources) must accompany your submittal. No fee is required to register: (1) a permitted well within a Ground Water Control Area; (2) a well constructed to replace a previously registered well; or (3) a well connected in a series with another well previously registered. Forward to:

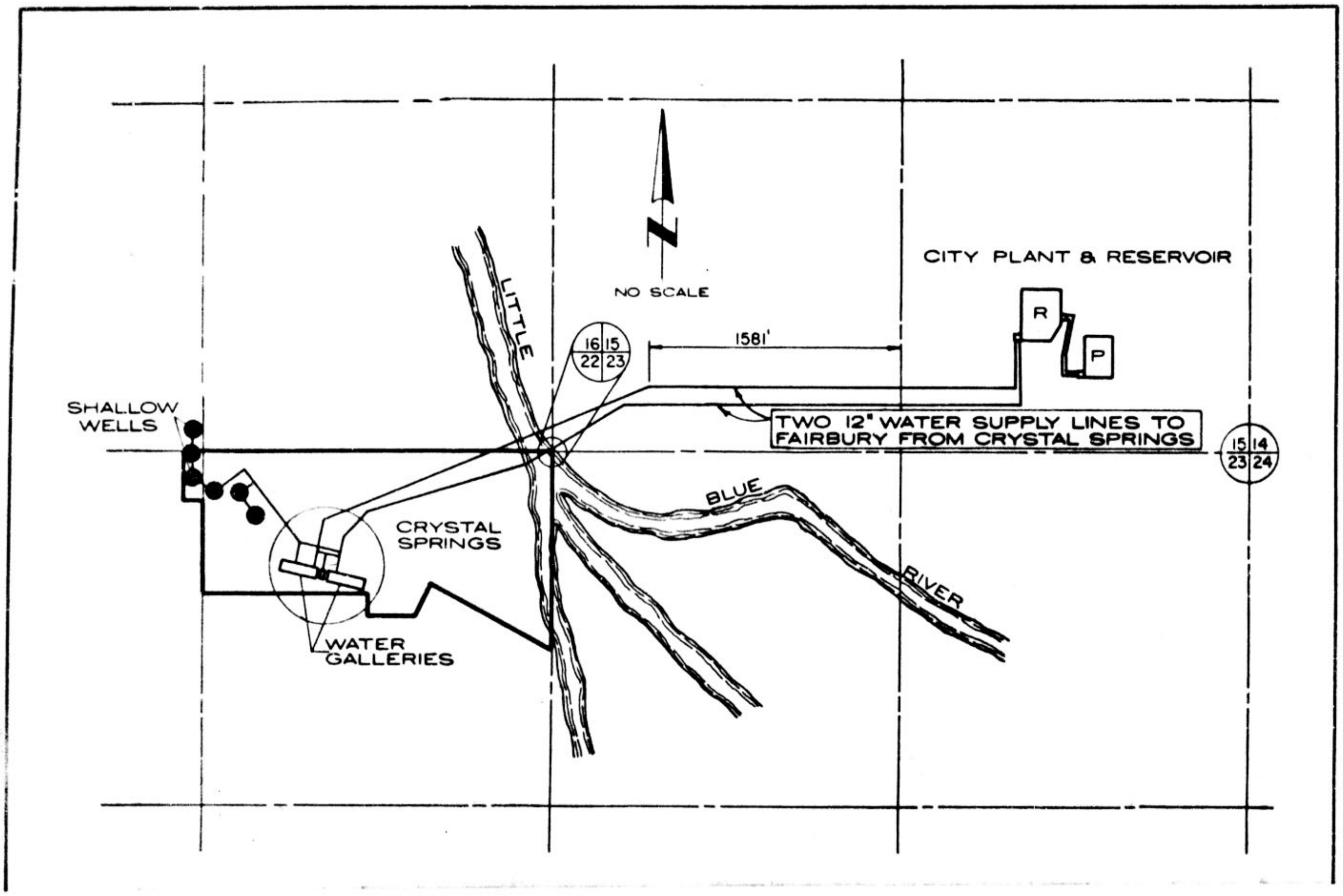
State of Nebraska
Department of Water Resources
301 Centennial Mall-South
P.O. Box 94676
Lincoln, Nebraska 68509



Crystal Springs infiltration galleries capture the flow of one of the largest of the many springs in this section of Nebraska



Infiltration galleries are of reinforced concrete and brick construction with galvanized screens at the inlet ports


NO SCALE
CITY PLANT & RESERVOIR
R
P
LITTLE
1581'
16 15
22 23
SHALLOW WELLS
TWO 12" WATER SUPPLY LINES TO FAIRBURY FROM CRYSTAL SPRINGS
15 14
23 24
BLUE
CRYSTAL SPRINGS
RIVER
WATER GALLERIES

DO NOT WRITE IN THIS SPACE

ORIGINALLY FILED: 4/23/70. 1

Registration No. G-32647 County Jefferson Date Filed 9/1/81

STATE OF NEBRASKA
DEPARTMENT OF WATER RESOURCES
WELL REGISTRATION

Type of well to be registered: (Check One)

- [ ] IRRIGATION
- [X] MUNICIPAL
- [ ] INDUSTRIAL
- [ ] Other ______

1. General information:
   A. Connected well
   Is this well connected to another well? [ ] Yes [X] No
   If yes, give registration number of previously registered well ______
   (If new installation consists of a series of wells with one outlet, complete registration forms and driller's certificates for each and submit $7.50)
   B. Replacement well
   Is this well to replace a permanently abandoned well? [ ] Yes [ ] No
   If yes, give registration number of abandoned well ______
   C. Permit No. G32647 4-23-70 ~~(required only in a Ground Water Control Area)~~

2. Name & address of well owner: CITY OF FAIRBURY
   612 D Street
   Fairbury, Nebraska

   Zip Code 683522399 Phone (402) 729-3030

3. Name & address of well driller: WILLIAMS DRILLING CO.
   Belvidere, Nebraska

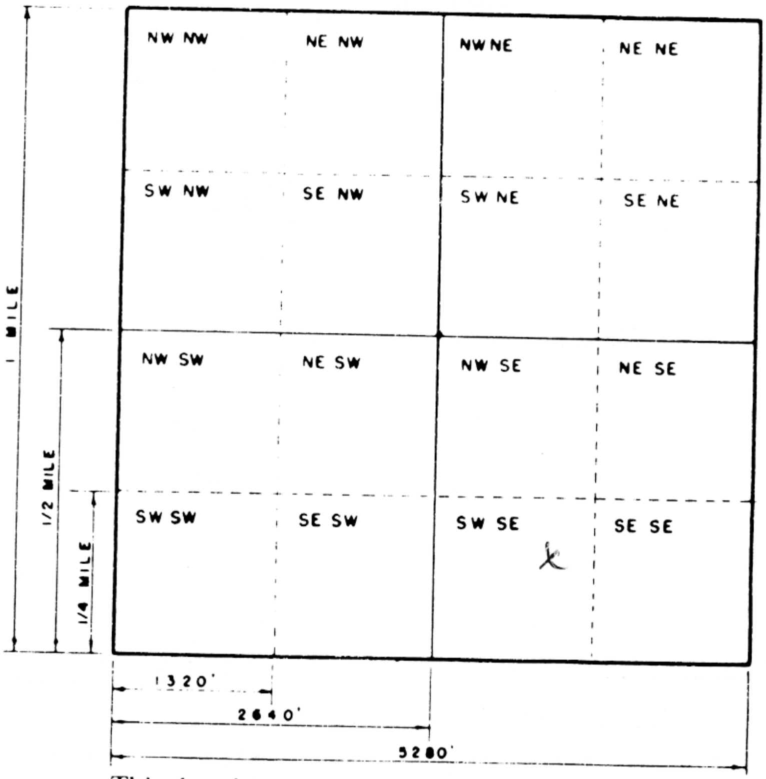
   Zip Code NA Phone: (____) NA

4. Location & purpose of the well: Well Designation: East WEll 70-1
   A. MUNICIPAL WATER SUPPLY ~~Name of Reservoir District~~ (Identify)
   B. SW ¼ of the SE ¼ of Section 13, Township 2N, Range 2 [X] E [ ] W, (check one)
   JEFFERSON County.
   C. The well is Apprx4000 feet from the nearest municipal, irrigation, or industrial well. The nearest well is owned by [ ] you [X] someone other than you. (check one)
   D. The well is intended to irrigate None acres of land, and it is intended to irrigate all or parts of the following land: ______
   OR
   E. The well shall be used for purposes of: MUNICIPAL WATER SUPPLY.

5. Well and pump specifications:
   A. Pumping rate under normal conditions: 1000 gallons per minute.
   B. Total well depth: 110 feet.
   C. Inside diameter of the casing: 18 inches.
   D. Static (non-pumping) water level in the well: 63 feet below ground surface.
   E. Depth of water under normal pumping conditions: 71 feet below ground surface.
   F. Pump column: Diameter 8 inches. Length 86 feet.
   G. The well was completed on or about April, 19 70.

MORE ON BACK 2-6-67 MORE ON BACK

(With an "X" mark the location of the well)



This drawing represents one square mile (a section).
Each small subdivision is a 40-acre tract.

I certify that I am familiar with the information contained on this registration, and that to the best of my knowledge and belief such information is true, concise and accurate.

Glen R Beadles — Aug 31 1981
Well Owner's Signature — Date
Supt of Utilities

Both a Well Registration and Driller's Certificate must be completed in triplicate and in full. An incomplete or defective form will be returned. A non-refundable $7.50 fee (payable to the Director of Water Resources) must accompany your submittal. No fee is required to register: (1) a permitted well within a Ground Water Control Area; (2) a well constructed to replace a previously registered well; or (3) a well connected in a series with another well previously registered. Forward to:

State of Nebraska
Department of Water Resources
301 Centennial Mall-South
P.O. Box 94676
Lincoln, Nebraska 68509

DO NOT WRITE IN THIS SPACE

Registration No. G-68253 County Jefferson Date Filed July 14, 1982 1

STATE OF NEBRASKA
DEPARTMENT OF WATER RESOURCES
WELL REGISTRATION

1. General information:
   A. Connected well
      Is this well connected to another well? [ ] Yes [x] No
      If yes, give registration number of previously registered well ______
      (If new installation consists of a series of wells with one outlet, complete registration forms and driller's certificates for each and submit $7.50)
   B. Replacement well
      Is this well to replace a permanently abandoned well? [ ] Yes [x] No
      If yes, give registration number of abandoned well ______
   C. Permit No. ______ (required only in a Ground Water Control Area)

Type of well to be registered (Check One)
[ ] IRRIGATION
[x] MUNICIPAL
[ ] INDUSTRIAL
[ ] Other ______

2. Name & address of well owner: CITY OF FAIRBURY FAIRBURY, NE 68352 Supt. of Utilities 612 "D" Street

   Zip Code ______ Phone (___) ______ 08671

3. Name & address of well driller: WILLIAMS DRILLING CO. INC. BELVIDERE, NE 68315

   Zip Code ______ Phone: (402) 768-6098

4. Location & purpose of the well: OK.
   A. 05 LITTLE BLUE Natural Resources District (Identify)
   B. SW ¼ of the SE ¼ of Section 13, Township 2, Range 2 [x] E. [ ] W. (check one)
      Jefferson County.
   C. The well is 940 feet from the nearest municipal, irrigation, or industrial well. The nearest well is owned by [x] you [ ] someone other than you. (check one)
   D. The well is intended to irrigate ______ acres of land, and it is intended to irrigate all or parts of the following land: ______
      OR
   E. The well shall be used for purposes of: Municipal water supply

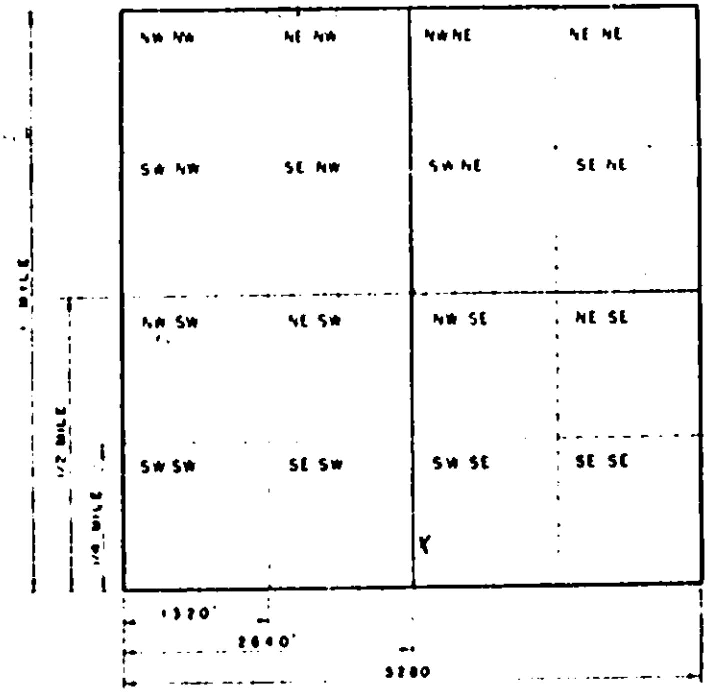
5. Well and pump specifications:
   A. Pumping rate under normal conditions: 1000 gallons per minute.
   B. Total well depth: 137'7" feet.
   C. Inside diameter of the casing: 16 inches.
   D. Static (non-pumping) water level in the well: 99'8" feet below ground surface.
   E. Depth of water under normal pumping conditions: 105'4" feet below ground surface.
   F. Pump column: Diameter 8 inches. Length 116 feet.
   G. The well was completed on or about July 30, 1982.

MORE ON BACK

6-3-82

MORE ON BACK

(With an "X" mark the location of the well)



This drawing represents one square mile (a section).
Each small subdivision is a 40-acre tract.

I certify that I am familiar with the information contained on this registration, and that to the best of my knowledge and belief such information is true, concise and accurate.

Allen R Beachler Supt of Utilities
City of Fairbury — July 7 1982
Well Owner's Signature — Date

Both a Well Registration and Driller's Certificate must be completed in triplicate and in full. An incomplete or defective form will be returned. A non-refundable $7.50 fee (payable to the Director of Water Resources) must accompany your submittal. No fee is required to register: (1) a permitted well within a Ground Water Control Area; (2) a well constructed to replace a previously registered well; or (3) a well connected in a series with another well previously registered. Forward to:

State of Nebraska
Department of Water Resources
301 Centennial Mall-South
P.O. Box 94676
Lincoln, Nebraska 68509

Revised April, 1976

Registration No. G-68253 County Jefferson Date Filed July 14, 1982

STATE OF NEBRASKA
CERTIFICATE OF WELL DRILLER

Permit No. .... (required only in a control area)

Name & Address of well driller: WILLIAMS DRILLING CO. INC.
BELVIDERE, NE 68315

Well Location:

05 Little Blue Natural Resources District

SW Quarter of the SE Quarter of Section 13, Township 2, Range 2 E,

Jefferson County, and owned by City of Fairbury

Drilling & construction specifications:

1. Date construction was begun: June 3, 19 82
2. Date construction was completed: June 3, 1982.
3. Diameter of the drilled hole: 30 inches.
4. Was the hole electronically logged? ☐ Yes ☒ No.
5. How is drilled hole sealed (not sealed)? w/clay pack & concrete. top to 20' concrete. 20' to 85' clay pack
6. Well casing & screen: 117' 7" 16" I.D. .375 wall, steel plain casing, 16" x 20' .080 slot Johnson 304 S.S. Screen
(Give type of casing, lengths and vertical position of plain and slotted segments, slot or perforation size.)
7. Is the well artifically gravel stabilized? ☒ Yes ☐ No

Pumping test information:

1. Pumping rate: 1000 gallons per minute.
2. Depth to water before pumping: 93' 8" feet.
3. Depth to water 105 feet after pumping 60 minutes.

DRILLING LOG ON BACK

DRILLING LOG ON BACK

DRILLING LOG

DEPTH IN FEET FROM	TO	MATERIAL DRILLED
0	6	Light Brown clay
6	16	Dark Brown clay
16	35	Med. sand & Gravel
35	44	Med. to coarse sand & Gravel
44	53	Med. sand & Gravel
53	81	Fine to med. sand & Gravel
81	93	Med. to coarse sand & Gravel
93	114	Med. sand & Gravel
114	126	Med. to coarse sand & Gravel
126	135	Med. sand & Gravel, White

Well Driller's Signature .... Date ....

STATE OF NEBRASKA
DEPARTMENT OF WATER RESOURCES
WATER WELL REGISTRATION

FOR DEPARTMENT USE ONLY

Registration No. G-96478 Sequence No. 109835 Registration Date: 6-10-98
Owner Code No. 8671 Receipt No. 96859 LITTLE BLUE NRD

1. Well Owner City of Fairbury Telephone Number (402) 729-2476
Address 612 D Street
City Fairbury State NE Zip Code 68352 +

2. Drilling Firm Sargent Drilling Telephone Number (402) 759-3902
Address PO Box 367 Contractor's License No. 39194 Pump Installer License No.
City Geneva State NE Zip Code 68361-0367 +

3. Permit Number(s) LBMA-0118

4. Purpose of well (indicate one): ___Dewatering (over 90 days) ___Domestic ___Geothermal ___Ground Heat Exchanger ___Ground Water Source Heat Pump ___Industrial ___Injection ___Irrigation ___Livestock ___Monitoring ___Observation X Public Water Supply (with spacing (46-638)) ___Public Water Supply (without spacing) ___Recovery ___Other ______ (indicate use)

5. Replacement and abandoned well information.
A. Is this well a replacement well? ___Yes X No
B. Registration number of abandoned well: ______
C. Replacement well is ______ feet from abandoned well.
D. Abandoned well last operated ______, 19___
E. Original well pump column size: ______ inches.
F. Abandoned well plugged ______, 19___

6. A. Well location: SE ¼ NE ¼ of Section 13, Township 2 North, Range 3 East/~~West~~ Jefferson County.
B. The well is 2110 feet from the North/~~South~~ section line and 1010 feet from the East/~~West~~ section line. (indicate one) (indicate one)
C. Street address or block, lot and subdivision, if applicable: ______
D. Location of water use, if applicable (give legal descriptions): ______
E. If for irrigation, the land to be irrigated is ______ acres.
F. Well reference letter(s), if applicable: ______

7. Pump Information.
Is pump installed at this time? X Yes ___No
If yes, complete items A through E.
If no, complete items A and D with estimated information for those wells in which pump will be installed.
A. Actual pumping rate, if applicable: 500 gallons per minute. Measured ☒ or Estimated ☐
B. Pump column diameter: 6 inches.
C. Length of pump column: 60 feet.
D. Pumping equipment installed: 11-3, 19 97.
E. Brand/Type: Sargent / turbine

8. Well Construction Information.

G-96478

A. Total well depth: 92 feet. B. Static water level: 38'6" feet. C. Pumping water level: 45 feet.

D. Construction began: 9-1, 19 97. E. Construction completed: 9-1, 19 97.

F. Bore hole diameter: 24 inches.

G. Casing: Diameter 15 3/4" ID 16" OD inches. Type of material: steel

Wall thickness: 3/8 inches. Joints--Welded/[illegible]

Length(s) and placement(s) depth from 0 ft. to 68 ft. from ______ ft. to ______ Guides at 20 f

H. Screen: 15 1/4 ID 16 OD in.: Type of material stainless steel

Screen openings (slot size): .080 Trade name: v-wire screen

Length(s) and placement(s) depth from 68 ft. to 88 ft. from ______ ft. to ______ Guides at 20 f

I. Gravel pack interval(s) from 50 ft. to 92 ft. from ______ ft. to ______ ft. Grade size: AA

J. Grouted/Sealed from 25 ft. to 50 ft., with chunk bentonite (type)

from 0 ft. to 25 ft., with cement grout (type)

K. Drilling method: reverse circulation L. Drilling fluid: n/a

M. Well development technique (total time and method): 36-hours pumping

N. Will chemicals, fertilizer or antifreeze be injected or utilized in the system? ___ Yes X No

If yes, what will be used: ______

9. Geologic Materials Logged

DEPTH IN FEET FROM	TO	DESCRIPTION	DEPTH IN FEET FROM	TO	DESCRIPTION
0	2	Clay			
2	5	Sand & gravel			
5	7	Clay			
7	13	Sand & gravel			
13	17	Clay			
17	20	Sand & gravel			
20	23	Med. gravel & coarse sand w/clay layers			
23	40	Coarse sand & coarse & med. gravel			
40	60	Coarse gravel & coarse sand			
60	86	Med. gravel & trace coarse sand			
86	89	Yellow shale			
89	100	White shale			

(Additional sheets may be submitted)

10. I am familiar with the information submitted on this registration, and to the best of my knowledge it is true.

[signature] P.A.

Water Well Contractor's Signature

12-29-97

Date

Gene D. Sifford

Water Well Owner's Signature

June 2, 1998

Date

Fairbury, NE Water Records
OA Project No. 016-3570

	East Well #1			East Well #2			East Well #3		
Date	**Static Water Level (ft)**	**Pumping Water Level (ft)**	**Drawdown (ft)**	**Static Water Level (ft)**	**Pumping Water Level (ft)**	**Drawdown (ft)**	**Static Water Level (ft)**	**Pumping Water Level (ft)**	**Drawdown (ft)**
3/2/2010	62.0	71.0	9.0	89.0	100.0	11.0	38.0	45.0	7.0
4/8/2010	62.0	70.0	8.0	89.0	100.0	11.0	37.5	44.5	7.0
5/28/2010	62.0	70.0	8.0	89.0	99.5	10.5	37.5	45.0	7.5
6/29/2010	62.0	71.0	9.0	89.0	100.0	11.0	38.0	45.0	7.0
7/30/2010	63.0	70.5	7.5	91.0	101.5	10.5	37.5	45.0	7.5
8/31/2010	63.0	70.5	7.5	91.0	100.5	9.5	38.0	45.5	7.5
9/17/2010	63.0	70.5	7.5	90.0	100.5	10.5	38.5	45.5	7.0
12/15/2010	62.0	70.5	8.5	89.0	100.0	11.0	37.5	45.0	7.5
3/1/2011	62.0	70.5	8.5	89.0	99.0	10.0	35.5	45.0	9.5
4/29/2011	62.0	70.0	8.0	89.0	100.0	11.0	37.0	44.0	7.0
5/16/2011	63.0	72.5	9.5	89.5	100.5	11.0	38.0	45.5	7.5
6/28/2011	62.5	71.0	8.5	89.5	100.5	11.0	37.5	45.0	7.5
7/11/2011	63.0	72.0	9.0	90.0	101.0	11.0	38.0	45.5	7.5
8/15/2011	64.0	71.0	7.0	91.0	101.0	10.0	38.5	45.0	6.5
9/26/2011	63.5	71.0	7.5	90.5	101.5	11.0	39.0	45.5	6.5
12/21/2011	63.0	70.5	7.5	90.0	101.0	11.0	38.0	45.0	7.0
2/16/2012	62.5	71.5	9.0	90.0	100.0	10.0	37.5	45.0	7.5
4/25/2012	62.5	71.5	9.0	90.0	100.5	10.5	37.5	45.0	7.5
5/30/2012	64.5	72.0	7.5	91.0	101.0	10.0	39.0	46.5	7.5
6/29/2012	66.0	74.0	8.0	91.5	102.0	10.5	40.0	47.0	7.0
7/20/2012	66.0	73.0	7.0	93.0	102.0	9.0	40.0	48.0	8.0
8/30/2012	66.0	74.0	8.0	93.0	103.0	10.0	41.5	49.0	7.5
9/27/2012	66.0	74.0	8.0	92.5	103.0	10.5	41.0	48.5	7.5
12/26/2012	64.5	72.0	7.5	91.5	103.0	11.5	40.0	47.0	7.0
2/26/2013	64.0	72.0	8.0	91.0	101.5	10.5	39.0	46.5	7.5
4/6/2013	64.0	71.5	7.5	91.0	101.0	10.0	39.0	46.0	7.0
5/31/2013	64.0	71.0	7.0	91.0	101.0	10.0	39.0	46.0	7.0
6/17/2013	64.0	71.0	7.0	91.0	101.5	10.5	39.5	47.0	7.5
7/24/2013	66.0	74.0	8.0	93.0	103.0	10.0	40.5	48.0	7.5
8/26/2013	66.0	75.0	9.0	92.0	103.0	11.0	41.0	48.0	7.0
9/20/2013	65.0	74.0	9.0	92.5	102.5	10.0	41.0	48.0	7.0
11/19/2013	64.5	73.0	8.5	91.5	101.0	9.5	40.0	47.5	7.5
2/27/2014	64.0	73.0	9.0	91.5	101.5	10.0	39.5	47.0	7.5
4/23/2014	64.0	73.0	9.0	91.5	102.0	10.5	39.5	47.5	8.0
5/28/2014	65.0	73.0	8.0	92.5	102.5	10.0	39.5	48.0	8.5
6/28/2014	65.0	73.5	8.5	92.5	102.5	10.0	39.5	48.5	9.0
7/28/2014	65.0	76.5	11.5	93.0	102.5	9.5	42.0	49.0	7.0
8/27/2014	66.0	74.0	8.0	93.0	102.5	9.5	41.0	49.0	8.0
9/10/2014	66.0	74.0	8.0	93.0	102.0	9.0	42.0	49.0	7.0
12/15/2014	65.0	74.0	9.0	92.0	102.0	10.0	40.5	49.0	8.5
2/17/2015	65.0	74.0	9.0	91.0	102.0	11.0	40.0	48.0	8.0
4/20/2015	65.0	72.0	7.0	91.5	101.5	10.0	40.0	47.0	7.0
5/5/2015	65.0	72.0	7.0	91.5	101.5	10.0	40.0	47.0	7.0
6/24/2015	65.0	71.0	6.0	91.5	102.0	10.5	40.0	47.0	7.0
7/28/2015	66.0	74.5	8.5	92.0	102.0	10.0	41.0	47.5	6.5
8/25/2015	66.0	73.0	7.0	92.0	102.5	10.5	41.5	48.0	6.5
9/24/2015	66.0	73.0	7.0	92.0	102.5	10.5	41.5	48.0	6.5
10/21/2015	66.0	73.0	7.0	93.0	103.0	10.0	42.0	49.0	7.0
2/18/2016	64.5	71.5	7.0	91.5	100.0	8.5	40.0	47.0	7.0
4/11/2016	65.0	73.0	8.0	91.5	101.0	9.5	40.5	47.0	6.5
5/16/2016	64.5	70.5	6.0	91.5	101.0	9.5	40.0	47.0	7.0
6/20/2016	65.0	74.5	9.5	91.5	101.0	9.5	41.5	49.0	7.5
7/18/2016	64.5	74.5	10.0	92.0	102.0	10.0	42.0	49.0	7.0
8/31/2016				93.0	102.0	9.0	42.0	49.0	7.0
11/7/2016	65.0	73.0	8.0	92.0	102.0	10.0	40.0	47.0	7.0
Average	64.3	72.3	8.1	91.2	101.4	10.2	39.5	46.9	7.3
Maximum	66.0	76.5	11.5	93.0	103.0	11.5	42.0	49.0	9.5
Minimum	62.0	70.0	6.0	89.0	99.0	8.5	35.5	44.0	6.5

APPENDIX "C"

Water Usage and Pumping Records

Fairbury, NE Water Records
OA Project No. 016-3570

Year	Month	Water Reservoir	East Well #1	East Well #2	East Well #3	Total Daily Use (gallons)
2012	January	22,423,000	892,000	709,000	1,699,000	25,723,000
	February	20,284,000	1,638,000	1,050,000	1,558,000	24,593,000
	March	23,034,000	1,867,000	872,000	1,510,000	27,283,000
	April	21,982,000	1,992,000	1,855,000	2,296,000	28,125,000
	May	22,629,000	8,184,000	6,053,000	9,461,000	46,327,000
	June	24,661,000	9,216,000	7,401,000	10,310,000	51,588,000
	July	26,416,000	10,094,000	10,264,000	12,318,000	59,092,000
	August	23,461,000	5,758,000	6,087,000	9,075,000	44,381,000
	September	20,888,000	4,484,000	5,342,000	8,869,000	39,583,000
	October	21,374,000	2,140,000	1,973,000	4,579,000	30,066,000
	November	20,220,000	1,152,000	931,000	1,842,000	24,145,000
	December	20,717,000	1,483,000	1,126,000	1,223,000	24,549,000
2013	January	21,200,000	1,175,000	812,000	480,000	23,667,000
	February	19,394,000	807,000	449,000	127,000	20,777,000
	March	21,000,000	841,000	782,000	792,000	23,415,000
	April	20,634,000	1,065,000	1,054,000	1,253,000	24,006,000
	May	21,884,000	1,297,000	898,000	1,804,000	25,216,000
	June	22,620,000	4,747,000	3,841,000	4,242,000	35,450,000
	July	26,163,000	7,946,000	8,077,000	7,521,000	49,707,000
	August	23,574,000	4,993,000	3,654,000	5,063,000	37,284,000
	September	22,554,000	3,347,000	3,465,000	5,040,000	34,406,000
	October	20,862,000	1,103,000	1,300,000	2,703,000	25,968,000
	November	19,475,000	657,000	761,000	960,000	21,853,000
	December	20,188,000	1,233,000	1,195,000	772,000	23,388,000
2014	January	20,355,000	1,780,000	1,918,000	1,297,000	25,350,000
	February	18,973,000	1,169,000	1,878,000	1,170,000	23,190,000
	March	21,597,000	1,110,000	2,362,000	925,000	25,994,000
	April	19,976,000	1,822,000	3,375,000	2,330,000	27,503,000
	May	22,813,000	4,473,000	7,256,000	5,936,000	40,478,000
	June	22,822,000	2,767,000	3,448,000	4,155,000	33,192,000
	July	24,045,000	4,953,000	9,571,000	4,257,000	42,826,000
	August	24,647,000	5,624,000	4,570,000	4,675,000	39,516,000
	September	21,387,000	2,789,000	3,142,000	4,268,000	31,586,000
	October	22,281,000	3,254,000	1,500,000	2,033,000	29,068,000
	November	21,741,000	1,170,000	729,000	934,000	24,574,000
	December	22,557,000	671,000	261,000	185,000	23,674,000

Fairbury, NE Water Records
OA Project No. 016-3570

Year	Month	Water Reservoir	East Well #1	East Well #2	East Well #3	Total Daily Use (gallons)
2015	January	22,257,000	1,410,000	960,000	272,000	24,899,000
	February	20,380,000	892,000	455,000	424,000	22,151,000
	March	22,901,000	1,534,000	888,000	483,000	25,806,000
	April	22,661,000	1,136,000	1,464,000	1,148,000	26,409,000
	May	14,256,000	3,589,000	3,629,000	4,189,000	25,663,000
	June	21,817,000	1,577,000	966,000	1,338,000	25,698,000
	July	23,051,000	4,745,000	2,281,000	3,531,000	33,608,000
	August	23,237,000	6,502,000	4,945,000	6,233,000	40,917,000
	September	20,266,000	4,413,000	3,433,000	6,740,000	34,852,000
	October	20,820,000	3,933,000	2,889,000	5,991,000	33,633,000
	November	18,950,000	1,183,000	1,230,000	770,000	22,133,000
	December	20,075,000	346,000	159,000	289,000	20,869,000
2016	January	19,942,000	265,000	468,000	131,000	20,806,000
	February	19,334,000	13,000	21,000	11,000	19,379,000
	March	20,822,000	387,000	244,000	195,000	21,648,000
	April	21,349,000	847,000	1,667,000	1,928,000	25,791,000
	May	21,863,000	1,675,000	1,961,000	1,479,000	26,106,000
	June	23,417,000	8,641,000	7,748,000	7,781,000	47,587,000
	July	25,000,000	4,514,000	6,475,000	8,323,000	44,312,000
	August	24,225,000	104,000	7,478,000	1,687,000	33,494,000
	September	21,909,000	0	6,205,000	1,691,000	29,805,000
	October	20,898,000	1,067,000	3,715,000	874,000	26,554,000
	November	21,410,000	2,763,000	455,000	445,000	25,073,000
	December	20,751,000	428,000	252,000	369,000	21,800,000
	Average	21,707,033	2,694,283	2,832,483	3,066,400	30,275,600
	Minimum	14,256,000	0	21,000	11,000	19,379,000
	Maximum	26,416,000	10,094,000	10,264,000	12,318,000	59,092,000

Fairbury, NE Water Records

OA Project No. 016-3570

Year	Month	Water Reservoir	East Well #1	East Well #2	East Well #3	Total Daily Use (gallons)
Annual Water Use Summary						
2012		268,089,000	48,900,000	43,663,000	64,740,000	425,455,000
2013		259,548,000	29,211,000	26,288,000	30,757,000	345,137,000
2014		263,194,000	31,582,000	40,010,000	32,165,000	366,951,000
2015		250,671,000	31,260,000	23,299,000	31,408,000	336,638,000
2016		260,920,000	20,704,000	36,689,000	24,914,000	342,355,000
	Average	260,484,400	32,331,400	33,989,800	36,796,800	363,307,200
	Maximum	268,089,000	48,900,000	43,663,000	64,740,000	425,455,000
Daily Water Use Summary						
	Average	713,045	88,760	93,359	100,843	995,195
	Minimum	0	0	0	0	0
	Maximum	1,266,000	825,000	749,000	797,000	2,381,000
	St. Dev.	119,858	117,162	120,203	130,353	334,067
	95% Conf.	952,761	323,085	333,765	361,549	1,663,328
	Summer Use (June through August; 2012-2016)					
	Total, gals	359,156,000	82,181,000	86,806,000	90,509,000	618,652,000
	Average Day (gpd)	748,242	171,210	180,846	188,560	1,288,858
	Average Day (gpm)	520	119	126	131	895

Average Day	691	GPM	Peak Day	1,653	24-hour (GPM)
(overall)*	258	GPM			
(overall)**	207	gpcd	(overall)	2,480	16-hour (GPM)

*Calculated with 3,863 persons (City only)

**Calculated with 4,815 persons (City & RWD) Peak/Avg Day factor 2.39

APPENDIX “D”

Water User and Rate Information

ORDINANCE NO. 3031

AN ORDINANCE AMENDING CITY OF FAIRBURY ORDINANCE NO. 2932 TO ESTABLISH WATER RATES; TO REPEAL CONFLICTING ORDINANCES AND SECTIONS; AND TO PROVIDE FOR THE EFFECTIVE DATE THEREOF.

BE IT ORDAINED BY THE MAYOR AND COUNCIL OF THE CITY OF FAIRBURY, NEBRASKA:

Section 1. That the rates, fees, charges and collections for the use of water sold by the Board of Public Works of the City of Fairbury ("Utility") be and hereby are those figures and terms set forth in the schedules incorporated by this Ordinance, which schedules and terms shall be on file in the office of the Municipal Clerk for public inspection at normal hours of operation. For all schedules below:

A. Customer Charge means a monthly fee that is charged to customers of the system based on size of service and/or meter regardless of usage.

B. Service under each schedule is subject to the **General Terms and Conditions** as stated in Section 5.

Section 2. Water Rates.

A. RESIDENTIAL WATER RATE

1. Applicability. To all residential customers in individually metered family residences for all domestic uses within the city limits including lawn watering.

2. Character of Service. The Utility shall endeavor to provide a dependable supply of potable water from available sources, in quantities and pressures adequate to meet the reasonable anticipated and projected needs of its customers.

3. Rate Schedules. The rates for service under this schedule shall be as follows:

Effective May 1, 2013

Meter Charge By Size	0.75" or Less	$	15.30
	1"	$	23.80
	1.25"	$	35.80
	1.5"	$	41.80
	2"	$	67.30
Commodity	CCF		$/CCF
First	10	$	1.0440
Next	40	$	1.0940
Excess		$	1.1940

Effective May 1, 2014:

Meter Charge By Size	0.75" or Less	$	15.30
	1"	$	23.80
	1.25"	$	35.80
	1.5"	$	41.80
	2"	$	67.30
Commodity	CCF		$/CF
First	10	$	1.3420
Next	40	$	1.3920
Excess		$	1.4920

B. GENERAL SERVICE WATER RATE

1. Availability. To any non-residential customer for water service inside the City limits where the customer does not qualify for service under another rate offered by the Water Utility. There is a rate for customers with City Sewer Service and a rate for customers without City Sewer Service. Not applicable to resale, supplemental, auxiliary or shared service.

2. Character of Service. The Utility shall endeavor to provide a dependable supply of potable water from available sources, in quantities and pressures adequate to meet the reasonable anticipated and projected needs of its customers.

3. Rate Schedules. The rates for service under this schedule shall be as follows:

GENERAL SERVICE WATER - WITH SEWER

Effective May 1, 2013:

Meter Charge By Size	0.75" or Less	$	14.55
	1"	$	23.00
	1.25"	$	32.90
	1.5"	$	38.55
	2"	$	65.75
	3"	$	105.83
	4"	$	168.35
Commodity	CCF		$/CCF
First	10	$	1.0440
Next	40	$	1.0940
Excess		$	1.1940

Effective May 1, 2014:

Meter Charge By Size	0.75" or Less	$	16.93
	1"	$	25.38
	1.25"	$	35.28
	1.5"	$	40.93
	2"	$	68.13
	3"	$	108.21
	4"	$	170.73
Commodity	CCF		$/CF
First	10	$	1.0440
Next	40	$	1.0940
Excess		$	1.1940

GENERAL SERVICE WATER - NO SEWER

Effective May 1, 2013:

Meter Charge By Size	0.75" or Less	$	14.55
	1"	$	23.00
	1.5"	$	38.55
Commodity	CCF		$/CCF
First	10	$	1.1178
Next	40	$	1.1678
Excess		$	1.2678

Effective May 1, 2014:

Meter Charge By Size	0.75" or Less	$	16.93
	1"	$	25.38
	1.5"	$	40.93
Commodity	CCF		$/CF
First	10	$	1.2783
Next	40	$	1.3283
Excess		$	1.4283

C. RESIDENTIAL – OUTSIDE CITY LIMITS WATER RATE

1. Applicability. To all residential and/or farm Utility customers located outside the City limits for all domestic and agricultural uses.

2. Character of Service. The Utility shall endeavor to provide a dependable supply of potable water from available sources, in quantities and pressures adequate to meet the reasonable anticipated and projected needs of its customers.

3. Rate Schedules. The rates for service under this schedule shall be as follows:

Effective May 1, 2013:

Meter Charge By Size	0.75" or Less	$ 15.30
	1"	$ 23.80
	1.25"	$ 35.80
	1.5"	$ 41.80
	2"	$ 67.30
Commodity	CCF	$/CCF
First	10	$ 1.094
Next	40	$ 1.146
Excess		$ 1.251

Effective May 1, 2014:

Meter Charge By Size	0.75" or Less	$ 15.30
	1"	$ 23.80
	1.25"	$ 35.80
	1.5"	$ 41.80
	2"	$ 67.30
Commodity	CCF	$/CCF
First	10	$ 1.2493
Next	40	$ 1.3013
Excess		$ 1.4063

D. GENERAL SERVICE – OUTSIDE CITY LIMITS WATER RATE

1. Availability. To all non-residential and/or farm Utility customers located outside the City limits where the customer does not qualify for service under another rate offered by the Utility. Not applicable to resale, supplemental, auxiliary or shared service.

2. Character of Service. The Utility shall endeavor to provide a dependable supply of potable water from available sources, in quantities and pressures adequate to meet the reasonable anticipated and projected needs of its customers.

3. Rate Schedules. The rates for service under this schedule shall be as follows:

Effective May 1, 2013:

Meter Charge By Size	0.75" or Less	$ 14.40
	1"	$ 24.20
	1.25"	$ 36.79
	1.5"	$ 42.25
	2"	$ 73.00
	3"	$ 111.10
	4"	$ 190.70
Commodity	CCF	$/CCF
First	10	$ 1.0940
Next	40	$ 1.1460
Excess		$ 1.2510

Effective May 1, 2014:

Meter Charge By Size	0.75" or Less	$ 7.13
	1"	$ 16.93
	1.25"	$ 29.52
	1.5"	$ 34.98
	2"	$ 65.73
	3"	$ 103.83
	4"	$ 183.43
Commodity	CCF	$/CF
First	10	$ 1.2493
Next	40	$ 1.3013
Excess		$ 1.4063

Section 3. Effective Date: The water rates and charges shall be effective on the dates noted. All other terms and conditions of this Ordinance shall be effective upon passage, approval and publication as provided by law.

E. MUNICIPAL SERVICE WATER RATE (Screen House services only)

1. Availability. To municipal Screen House services accounts for City of Fairbury only. Not applicable to resale, supplemental, auxiliary or shared service.
2. Rate Schedules. The rates for service under this schedule shall be as follows:

Effective May 1, 2013:

Customer Charge		$ 8.30
Commodity	CCF	$/CCF
First	10	1.0440
Next	40	1.0440
All		1.0440

Effective May 1, 2014:

Customer Charge		$ 9.30
Commodity	CCF	$/CCF
First	10	1.1745
Next	40	1.1745
All		1.1745

Section 5. GENERAL TERMS AND CONDITIONS:

1. Payment Schedules and Regulations.

All bills will be issued monthly, following consumption and reading of meters. Payment shall be made at the Fairbury Light and Water Office or designated points of collection. Courtesy disconnect notices will be mailed one day after the delinquent date shown on the monthly bill, and cut-off date will be in accordance with delinquent date shown on courtesy notice. The procedure for discontinuance of service shall be as set forth in Chapter 3, Article 401 of the Fairbury Municipal Code. It shall be the duty of the Fairbury Light and Water Superintendent to cause the service to be turned off and discontinued until such charges are paid. A charge of $30.00 shall be added to all bills as a reconnect charge. Reconnection shall be made after hours only by approval of the Superintendent of Utilities or his designated representative at rate of $80.00.

2. Tax Clause.

This rate may be increased by the amount of any new of increased governmental tax imposed and levied on the transmission, distribution, production or sale of water.

3. Special Terms and Conditions:

   a. Special Service requirements, if available, will be billed on an actual cost basis by the Utility.

   b. The Utility shall supply one water service to a property at one point of delivery designated by the Utility. For installation of additional water services to a property, the customer or owner shall pay the Utility an installation fee equal to the total cost of installing the service equipment except for metering equipment as supplied by the Utility. Distribution from the point of delivery to points of use on the customer's premises shall be the responsibility of the property owner.

   c. When water service is measured through more than one meter, the consumption registered on each meter will be billed separately unless installation is at the convenience of the Utility and as approved by the Superintendent of Utilities.

4. Restoration of Services.

   This pertains to all classifications. Any customer making a request for restoration of electric or water service within a 12-month period, in the same name or same customer, at the same address, shall pay the applicable connection charge prior to reconnection.

Section 6. Ordinance No. 2932 and all ordinances or part of ordinances in conflict herewith are hereby repealed.

Section 7. This ordinance shall be in full force and effect upon its passage, approval and publication as provided by law.

PASSED AND APPROVED THIS 7th_ DAY OF MAY, 2013.

____
Homer L. Ward, Mayor

ATTEST:

____
Sharyl Preston, City Clerk

Ronald R. Brackle

Attorney at Law

Legal Secretary:
Bobbi L. McDaniel

Fax: (402) 729-2607

417 "F" Street
P.O. Box 12
Fairbury, NE 68352-0012
(402) 729-2228

July 29, 1998

RECEIVED
JUL 30 1998

MIKE BEACHLER
Superintendent of Utilities
Board of Public Works
P.O. Box 554
Fairbury, NE 68352-0554

**RE: <u>ORIGINAL</u> WATER PURCHASE AGREEMENT
CITY/LBNRD
MY FILE: B 368 J2**

Dear Mike:

Enclosed herewith is the original of the above captioned document. In my opinion, since this is the original agreement it should be retained in the City's files rather than my file. I have retained a copy of the same in my file. I would like to think that in the very near future the LBNRD will pay the tapping fee mentioned in paragraph three in the amount of $40,000. If it's not received in a timely manner, please advise and I'll prod Michael D. ~~Onnen for the~~ payment.

Sincerely,

Ronald R. Brackle

Ronald R. Brackle

Encl.

6 j2.027
(B368)

WATER PURCHASE AGREEMENT

THIS AGREEMENT is entered into this the 2nd day of September ___________, 1997, between the CITY OF FAIRBURY, NEBRASKA, a Municipal Corporation, hereinafter called "City," and LITTLE BLUE NATURAL RESOURCES DISTRICT, a Political Subdivision, hereinafter called "District," WITNESS THAT:

WHEREAS, the District is organized and established under the provisions of Sections 2-3201 to 2-32,114, R.R.S., 1943, as amended of the Statute of the State of Nebraska, and has the power and authority to establish an improvement project area for the purpose of carrying out projects authorized by these statutes, and has the authority to make improvements and water purchases with relation thereto; and

WHEREAS, the District has established such improvement project areas for the purpose of constructing and operating water supply distribution systems serving rural water users within Thayer and Jefferson Counties of Nebraska, the boundaries of such established improvement project areas are shown on the map attached hereto marked "Exhibit A"; and

WHEREAS, the District has now established a new improvement project area in a portion of its District and further has contracted with a rural water district established by action of the Washington County, Kansas Board of Commissioners for the purpose of constructing and operating a new rural water supply distribution system in an area known as "LITTLE BLUE PUBLIC WATER PROJECT - SOUTH," which service area is hereto attached marked "Exhibit B", and incorporated by reference as if fully set forth, and

WHEREAS, the parties hereto have heretofore entered into a certain Water Purchase Contract, which was negotiated on the 16th day of March, 1976, with subsequent addendums accepted on the 30th day of May, 1978 and the 3rd day of July, 1979, for the purpose of supplying water to currently existing rural water systems developed by District, and after the effective date of this agreement, the above stated agreements shall terminate, and this agreement shall prevail, and

WHEREAS, the City owns and operates a water supply distribution system with a capacity currently capable of serving the customers of the District's water systems and the estimated number of water users to be served by said District as shown in the plans of the systems now on file in the office of the District, and

NOW, THEREFORE, in consideration of the foregoing and mutual agreements hereinafter set forth, City agrees to furnish and sell potable water to District, and District hereby agrees to purchase said water from City, pay the following described tapping fee, and perform the other terms and conditions as stated in this agreement during the term of this agreement as follows:

1. Effective Date of Agreement. This Agreement shall become effective on the 1st day of January, 1998 and shall run for the term herein specified unless changed or amended by the express mutual consent of the parties.

2. Term of Contract. All parties agree that this agreement shall extend for a period of Twenty-five (25) years from the effective date hereof and, thereafter, may be renewed or extended for such term or terms, as may be expressly agreed upon by the City and District.

Both parties hereby agree that all terms, covenants and conditions of this agreement are subject to review and renegotiation by either party at Five (5) year intervals during the term of this agreement, the first such renegotiation date to be January 2, 2003 and subsequent review dates to be at Five (5) year intervals thereafter.

3 Connection Fee/Tapping Fee. District agrees to pay a service extension connection fee or tapping fee to connect City's water system with the water system of District. Such fee shall be Forty Thousand Dollars ($40,000), and shall be paid on or before January 30, 1998.

38,500 cu. ft. or 288,750 per day
26.74 cu. ft. or 200.55

4. Quality and Quantity of Water. The City agrees to furnish the District at the points of delivery hereinafter specified, during the term of this contract or any renewal or extensions thereof, potable treated water meeting applicable purity standards of the State of Nebraska in such quantity as may be required by the District not to exceed a gross combined total to 38,500 cubic feet (cu. ft.) per day at a rate not to exceed a gross combined total of 26.74 cu. ft. per minute.

5. Points of Delivery and Pressure. City agrees to furnish water to the District at the City system's normal operating pressure of not less than Twenty (20) pounds per square inch to mainlines supplied by the District at "Points of Delivery" located at or near:

Point A. A meter pit located approximately One Hundred (100') feet west of the intersection of Tilden Street and State Highway # 136 of the City of Fairbury, Jefferson County, Nebraska; thence north thirty-five feet (35') north to the center line of the said State Highway # 136, Said point to be at or near Surveyor Station 37+61 and Thirty-five feet (35') North of the Center line of State Highway No. 136.

Point B. A meter pit located approximately One-half mile North of the Northwest Corner of Northgate's First Addition, near an extension of "E" Street to the City of Fairbury, Jefferson County, Nebraska.

If a greater pressure than that normally available at the point of delivery is required by the District, the cost of providing such greater pressure shall be borne by District. Emergency failures of pressure or supply due to main supply line breaks, power failure, flood, fire and use of water to fight fire, earthquake or other catastrophe shall excuse City from this provision for each reasonable period of time as may be necessary to restore service.

6. Metering Equipment. City agrees to retain ownership of, and operate and maintain the necessary metering equipment and meter pits located at or near the Points of Delivery for properly measuring the quantity of water delivered to District from City. Such metering equipment, including dual meters with outside readers, and the installation and maintenance thereof shall be at City's expense. City agrees to calibrate such metering equipment whenever requested by District but not more frequently than once every six (6) months

A meter registering not more than Two per cent (2%) above or below the test result shall be deemed to be accurate. The previous readings of any meter disclosed by test to be inaccurate shall be corrected for the Three (3) months previous to such test in accordance with the percentage of inaccuracy found by such tests. If any meter fails to register for any period, the amount of water furnished during such period shall be deemed to be the amount of water delivered in corresponding period immediately prior to the failure, unless District and City shall agree upon a different amount. An appropriate official of District shall, upon request, have access to the meters at all reasonable times for the purpose of verifying its readings.

7. Billing Procedures. The meters shall be read monthly at approximately the same date by City so as to cover approximately one-month intervals within the billing periods. City shall provide District at District's address, to-wit:

Little Blue Natural Resources District
P O Box 100
Davenport NE 68335

not later than the 10th day of each month with an itemized statement of the amount of water furnished by City to District during the preceding month.

8. Rates and Payment Dates.

a. City agrees that the water rate as charged by City shall be sufficient to collect the expense of the City associated with furnishing water to District, and these rates with respect to District, shall be fair, reasonable, and nondiscriminatory in that the rates charged by the City to the District during the term of this agreement shall be as follows:

1. at the inception, and for the first Three (3) years of this agreement, District agrees to pay to City for all water purchased in accordance with the prevailing water rate schedule in effect for residential users as provided for in the City's Water Rate Ordinance No. _____ established by City attached hereto marked "Exhibit C", and incorporated by reference as if fully set forth; and

2. from the third year through the sixth year of this agreement, District agrees to pay to City for all water purchased in accordance with the then prevailing water rate schedule in effect for residential users within the City of Fairbury, plus a Five Percent (5%) surcharge; and

3. after the sixth year of this agreement, District agrees to pay to City for all water purchased in accordance with the then prevailing water rate schedule in effect for residential users within the City of Fairbury, plus a Ten Percent (10%) surcharge for the remaining term of this agreement.

b. City shall give District thirty days advance notice before implementing any new rate change.

c. District agrees to pay City, not later than the Fifth (5th) day of each month, for water delivered and billed during the preceding billing period, in accordance with the then prevailing rate schedule established by ordinance of City.

9. Penalty For Surpassing Water Use Limitations. In the event District exceeds the amount or rate of water supply as described in Paragraph 4 above, for each billing period in which there is a contract violation involving an unauthorized overrun of either 26.74 cu. ft. per minute or 38,500 cu. ft. per day, City shall bill such overrun at twenty (20) times the then current purchase rate.

10. Regulatory Agencies. This agreement is subject to such rules, regulations or laws as may be applicable to similar agreements in this State. The City and District will collaborate in obtaining such permits, certificates, or other instruments as may be required to comply therewith.

11. Financing. The construction of the water supply distribution system by the District is being financed by a loan made or insured by, and a grant from, the United States of America, acting through the Rural Development of the United States Department of Agriculture, and the provisions hereof pertaining to the undertakings of the District are conditioned upon approval, in writing, of the State Director of the U.S.D.A. Rural Development.

12. Assignment. This agreement may be assigned by District to the United States of America or any agent thereof as collateral security for any loans made or to be made to said District in financing the construction, extension or repair and maintenance of the water supply of District. Except as above stated, this agreement shall not be sublet or assigned by either of the parties hereto without the express written consent of the other party.

13. Successors. In the event of any occurrence rendering the City or the District incapable of performing under this agreement, any successor of the City or District, whether the result of legal process, assignment, or otherwise, shall be bound to each and every term, covenant and condition of this agreement during the term thereof and shall assume all rights and liabilities of City or District hereunder.

14. Special Agreement: Jeopardy to City's Customers. The maximum daily amount of water supplied by City to District, as provided for in Paragraph 4 hereof, may be modified or altered by the express mutual agreement of the parties; PROVIDED, HOWEVER, that the amount shall never be more than City is able to supply without jeopardizing service to the other customers of the City. With respect to the interpretation of this paragraph, this decision shall be made at the sole discretion of City.

15. Special Agreement: Nonpayment of Bills. If District fails to pay any statement when due as provided for in Paragraph 8, District agrees to pay to City in addition to the principal amount due a finance charge of One per cent (1%) per month which shall be charged to any unpaid account on the last day of each month at 5:00 p.m., on the amount of the previous balance remaining unpaid at that time.

In addition thereto, a finance charge of Three-fourths (3/4) of One per cent (1%) shall be charged on the last day of each month thereafter at 5:00 p.m., on any amount of the previous balance remaining unpaid until said principal sum and accrued interest is paid.

16. Default. Time is of the essence of this agreement. If District fails to pay any amounts due under the terms of this agreement for a period exceeding Sixty (60) days, or if District fails to perform any of the other terms, covenants, and conditions of this agreement, or if District abandons the project, City shall have the right, after giving Fifteen (15) days advance written notice to the Treasurer of Little Blue Natural Resources District, Water Districts herein, and to U.S.D.A. Rural Development with its principal office located at 100 Centennial Mall North, Room 308, Federal Building, Lincoln, Lancaster County, Nebraska, and said defect remaining, to discontinue and to declare this agreement terminated.

PROVIDED, HOWEVER, that nothing contained within this agreement shall be construed to require City to give notice to District before charging the penalty rates as specified in Paragraph 9 of this agreement for any overruns of District, said amounts being considered by all parties hereto to be a basic covenant of this agreement.

In addition thereto, City shall have the right to take such intermediate steps without complete discontinuance or termination of this agreement, including but not limited to the right of discontinuing the furnishing of water service, so long as any part of the amount due remains unpaid. Such a discontinuance of water service shall not relieve District of liability for any minimum charge during the time water service is so discontinued.

The rights given hereto herein to City shall be cumulative and in addition to all other remedies available to City, either at law or in equity, and as otherwise provided in this agreement, for the breach of any other provisions of this agreement.

17. Special Agreement: Annexed Area. All water use customers located within the corporate limits of the City, or within the zoning area of the City as provided for in Section 16-901 R.R.S., 1943, as amended, at the option of City, shall receive water service from City, subject only to the rights and approval of the individual customer to receive service from City within City corporate limits or City zoning area.

18. Special Agreement: Water Project Area. Attached hereto marked "Exhibit A and Exhibit B" and incorporated by reference as if fully set forth, are maps of the proposed service area of District to be served by City with water, pursuant to the terms and conditions of this agreement. City shall be under no obligation to supply District with water to be used outside this water project service area. Modifications of the service area by District after the execution of this agreement shall be only with the express mutual consent of City.

19. Repairs. City agrees to maintain and make any repairs necessary to City's capital improvements required to provide service to District. District agrees to maintain and repair District's capital improvements which include all District mainlines and facilities beyond the City's water measuring devices.

20. Additional Work. The cost of any additional work requested by District or City for District's benefit shall be done at the rate (regularly going hourly) of City for such labor, trucks, and associated materials. Nothing contained herein shall be construed to require City to perform such additional work.

21. Special Agreement: Meter Test. Either party at any time may request a meter test. Said meter test shall be conducted by City or City's agent or engineer. In the event a test is requested by District, District shall be notified in advance of the date and time of the test and may have a representative present at such test. In the event District demands a meter test and said meter, after testing, shows to be accurate within Two per cent (2%), the District shall bear the cost of such test. If meter inaccuracy exceeds Two per cent (2%) to the detriment of District, then City shall bear the costs of such test.

Nothing contained herein shall prohibit District from conducting an independent meter test. In the event District desires an independent meter test, District shall pay all costs connected with such test and shall notify City in advance of the date and time of the test, and shall allow a representative of City to be present at such test.

22. Special Agreement: Exclusive Service. During the term of this agreement, District agrees that City shall have the exclusive rights to supply District with District's water needs during the term of this agreement.

23. District Responsibility. Nothing contained herein shall be construed to require City to supply, participate in, or construct any lines from the point of delivery to the Water Supply Project area. The District shall be responsible for the installation and maintenance of a backflow prevention device at each "Point of Delivery" from the City's water system. It is to be expressly understood that all costs for construction, maintenance or repairs of said water district lines and facilities from the "Point of Delivery" on shall rest solely with the District.

24. Governing Law. The situs of this agreement shall be the State of Nebraska, and this agreement shall be interpreted and enforced in accordance with the laws of such state.

25. Partnership. It is hereby acknowledged that there is no partnership between the City and the NRD which would extend the City's liability to any claim of damage from the District or one of it's rural water users.

26. Hold Harmless. The District agrees to hold the City harmless and indemnify the City and its representatives from any and all liabilities, suits, judgments, and damages to persons or property claims of any nature arising out of or in connection with the Project, actionable negligence of the City excluded.

27. Plans. Plans for the construction of all Project lines and facilities were developed by the firms of Bartlett & West, Consulting Engineers, P.A., 5835 SW 29th Street, Topeka, Kansas, and HWS Consulting Group, Inc., 825 J Street, Lincoln, Nebraska. Copies of such engineering plans and any updates or amendments thereto are retained on file at the office of District.

This agreement was prepared by the District with the assistance of its legal counsel.

IN WITNESS WHEREOF, the parties hereto, acting under authority of their respective governing bodies, have caused this Agreement to be duly executed in quadruplicate, each of which shall constitute an original.

CITY:

CITY OF FAIRBURY, NEBRASKA

ATTEST:

By____________________

Title Mayor

____
City Clerk

DISTRICT:

By resolution of the Board of Directors of the District, the foregoing instrument and all terms and conditions as set forth herein, was approved and executed on the 26th day of August, 1997.

LITTLE BLUE NATURAL RESOURCES DISTRICT

By____________________
Chairman of Board of Directors

ATTEST:

____
Secretary

LITTLE BLUE PUBLIC WATER PROJECT

By____________________

Title Chairman

ATTEST:

____
Secretary

LITTLE BLUE PUBLIC WATER PROJECT - SOUTH

By____________________

Title Chairman

ATTEST:

____
Secretary

This contract is approved on behalf of the U.S.D.A. Rural Development on this the 23rd day of July, 1998.

By____________________

Title Business + Community Program Director

EXHIBIT A

LITTLE BLUE PUBLIC WATER PROJECT SERVICE AREA

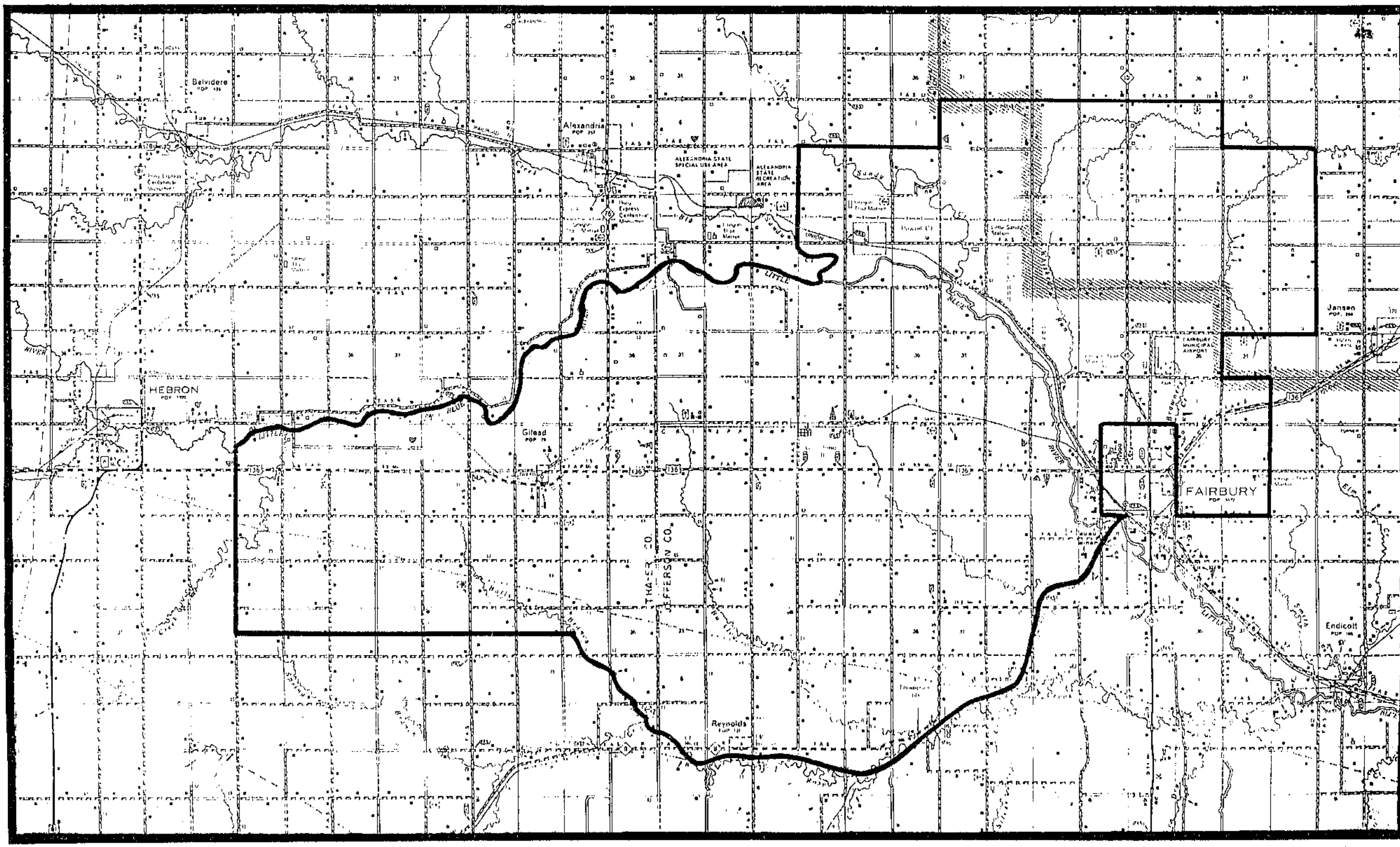


EXHIBIT C

ORDINANCE NO. 2720

AN ORDINANCE AMENDING ORDINANCE NO. 2670 AND ESTABLISHING WATER RATES FOR THE CITY OF FAIRBURY, NEBRASKA

BE IT ORDAINED BY THE MAYOR AND COUNCIL OF THE CITY OF FAIRBURY NEBRASKA:

Section 1. Water rates for the City of Fairbury, Nebraska, are hereby established as follows:

Water Rates effective with first billing after the dates shown below

	Jan. 1, 1997	Oct. 1, 1998	Oct. 1, 1999	Oct. 1, 2000
Residential				
Commodity, $/ccf - Month				
First 10 ccf Per ccf	$0.3350	$0.3518	$0.3693	$0.3878
Balance Per ccf	0.4050	0.4253	0.4465	0.4688
Customer Charge, Per Month				
3/4 " Service	$7.50	$7.88	$8.27	$8.68
1 " Service	12.00	12.60	13.23	13.89
1.5 " Service	22.00	23.10	24.26	25.47
2 " Service	35.00	36.75	38.59	40.52
3 " Service	54.00	56.70	59.54	62.51
4 " Service	92.00	96.60	101.43	106.50
6 " Service	184.00	193.20	202.86	213.00
8 " Service	331.00	347.55	364.93	383.17
General Service				
Commodity, $/ccf - Month				
First 50 ccf Per ccf	$0.2740	$0.2877	$0.3021	$0.3172
Balance Per ccf	0.3140	0.3297	0.3462	0.3635
Customer Charge, per Month				
3/4 " Service	$7.80	$8.19	$8.60	$9.03
1 " Service	12.50	13.13	13.78	14.47
1.25 " Service	17.70	18.59	19.51	20.49
1.5 " Service	23.00	24.15	25.36	26.63
2 " Service	36.00	37.80	39.69	41.67
3 " Service	54.00	56.70	59.54	62.51
4 " Service	92.00	96.60	101.43	106.50
6 " Service	184.00	193.20	202.86	213.00
8 " Service	331.00	347.55	364.93	383.17

Section 2. Ordinance No. 2670 is hereby amended and all ordinances or parts of ordinances in conflict are hereby repealed.

Section 3. That this ordinance shall take effect and be in full force from and after its passage, approval, and publication or posting as required by law.

Passed and approved this 19th day of August, 1997.

Gene D. Siefford, Mayor

Lila Hannappel
City Clerk

APPENDIX “E”

ISO Report – April 2016

1000 Bishops Gate Blvd. Ste 300
Mt. Laurel, NJ 08054-5404

t1.800.444.4554 Opt.2
f1.800.777.3929

June 27, 2016

Mr. Collin Bielser, Administrator
Fairbury
PO Box 554
612 D St.
Fairbury, Nebraska, 68352

RE: Fairbury, Jefferson County, Nebraska
Public Protection Classification: 04/4X
Effective Date: October 01, 2016

Dear Mr. Collin Bielser,

We wish to thank you Mr. Jeff Sweetser and Chief Chris Goeking for your cooperation during our recent Public Protection Classification (PPC) survey. ISO has completed its analysis of the structural fire suppression delivery system provided in your community. The resulting classification is indicated above.

If you would like to know more about your community's PPC classification, or if you would like to learn about the potential effect of proposed changes to your fire suppression delivery system, please call us at the phone number listed below.

ISO's Public Protection Classification Program (PPC) plays an important role in the underwriting process at insurance companies. In fact, most U.S. insurers – including the largest ones – use PPC information as part of their decision- making when deciding what business to write, coverage's to offer or prices to charge for personal or commercial property insurance.

Each insurance company independently determines the premiums it charges its policyholders. The way an insurer uses ISO's information on public fire protection may depend on several things – the company's fire-loss experience, ratemaking methodology, underwriting guidelines, and its marketing strategy.

Through ongoing research and loss experience analysis, we identified additional differentiation in fire loss experience within our PPC program, which resulted in the revised classifications. We based the differing fire loss experience on the fire suppression capabilities of each community. The new classifications will improve the predictive value for insurers while benefiting both commercial and residential property owners. We've published the new classifications as "X" and "Y" — formerly the "9" and "8B" portion of the split classification, respectively. For example:

- A community currently graded as a split 6/9 classification will now be a split 6/6X classification; with the "6X" denoting what was formerly classified as "9."
- Similarly, a community currently graded as a split 6/8B classification will now be a split 6/6Y classification, the "6Y" denoting what was formerly classified as "8B."
- Communities graded with single "9" or "8B" classifications will remain intact.
- Properties over 5 road miles from a recognized fire station would receive a class 10.

PPC is important to communities and fire departments as well. Communities whose PPC improves may get lower insurance prices. PPC also provides fire departments with a valuable benchmark, and is used by many departments as a valuable tool when planning, budgeting and justifying fire protection improvements.

ISO appreciates the high level of cooperation extended by local officials during the entire PPC survey process. The community protection baseline information gathered by ISO is an essential foundation upon which determination of the relative level of fire protection is made using the Fire Suppression Rating Schedule.

The classification is a direct result of the information gathered, and is dependent on the resource levels devoted to fire protection in existence at the time of survey. Material changes in those resources that occur after the survey is completed may affect the classification. Although ISO maintains a pro-active process to keep baseline information as current as possible, in the event of changes please call us at 1-800-444-4554, option 2 to expedite the update activity.

ISO is the leading supplier of data and analytics for the property/casualty insurance industry. Most insurers use PPC classifications for underwriting and calculating premiums for residential, commercial and industrial properties. The PPC program is not intended to analyze all aspects of a comprehensive structural fire suppression delivery system program. It is not for purposes of determining compliance with any state or local law, nor is it for making loss prevention or life safety recommendations.

If you have any questions about your classification, please let us know.

Sincerely,

Dominic Santanna

Dominic Santanna
Manager -National Processing Center

cc: Mr. Jeff Sweetser, Water Superintendent, Fairbury Water Department
Mr. Nels Sorensen, Sheriff, Jefferson County Sheriffs Office
Chief Chris Goeking, Chief, Fairbury Fire Department

INSURANCE SERVICES OFFICE, INC.

HYDRANT FLOW DATA SUMMARY

City Fairbury

County Nebraska(Jefferson), State NEBRASKA (26) Witnessed by: Insurance Services Office Date: Apr 1, 2016

TEST NO.	TYPE DIST.*	TEST LOCATION	SERVICE	FLOW - GPM Q=(29.83(C(d²)p^0.5)) INDIVIDUAL HYDRANTS			TOTAL	PRESSURE PSI STATIC	RESID.	FLOW - AT 20 PSI NEEDED **	AVAIL.	REMARKS***	MODEL TYPE
1		West of H & Arcade	Fairbury Water Department, main zone	710	0	0	710	122	85	1000	1200		
10.0		9th & Hubble	Fairbury Water Department, main zone	750	0	0	750	58	44	2250	1300		
11		20th & H St.	Fairbury Water Department, main zone	1910	0	0	1910	50	35	2500	2800		
2.0		2nd St. & H St.	Fairbury Water Department, main zone	770	0	0	770	120	70	1750	1100		
3.0		4th St. & C St.	Fairbury Water Department, main zone	790	790	0	1580	124	91	2000	2900		
3.1		4th St. & C St.	Fairbury Water Department, main zone	790	790	0	1580	124	91	4500	2900		
4.0		4th St. & E St.	Fairbury Water Department, main zone	1910	0	0	1910	121	92	2250	3700		
5.0		5th St. & E St.	Fairbury Water Department, main zone	500	0	0	500	119	98	2500	1200		
6.0		5th St. & E St.	Fairbury Water Department, main zone	500	0	0	500	119	98	1750	1200		
7.0		12th St. & G St.	Fairbury Water Department, main zone	340	0	0	340	92	82	3500	1000		
8.0		8th & F St.	Fairbury Water Department, main zone	500	500	0	1000	98	82	1000	2400		
9.0		8th & K St.	Fairbury Water Department, main zone	480	480	0	960	64	40	3000	1300		

THE ABOVE LISTED NEEDED FIRE FLOWS ARE FOR PROPERTY INSURANCE PREMIUM CALCULATIONS ONLY AND ARE *NOT* INTENDED TO PREDICT THE MAXIMUM AMOUNT OF WATER REQUIRED FOR A LARGE SCALE FIRE CONDITION.

THE AVAILABLE FLOWS ONLY INDICATE THE CONDITIONS THAT EXISTED AT THE TIME AND AT THE LOCATION WHERE TESTS WERE WITNESSED.

*Comm = Commercial; Res = Residential.

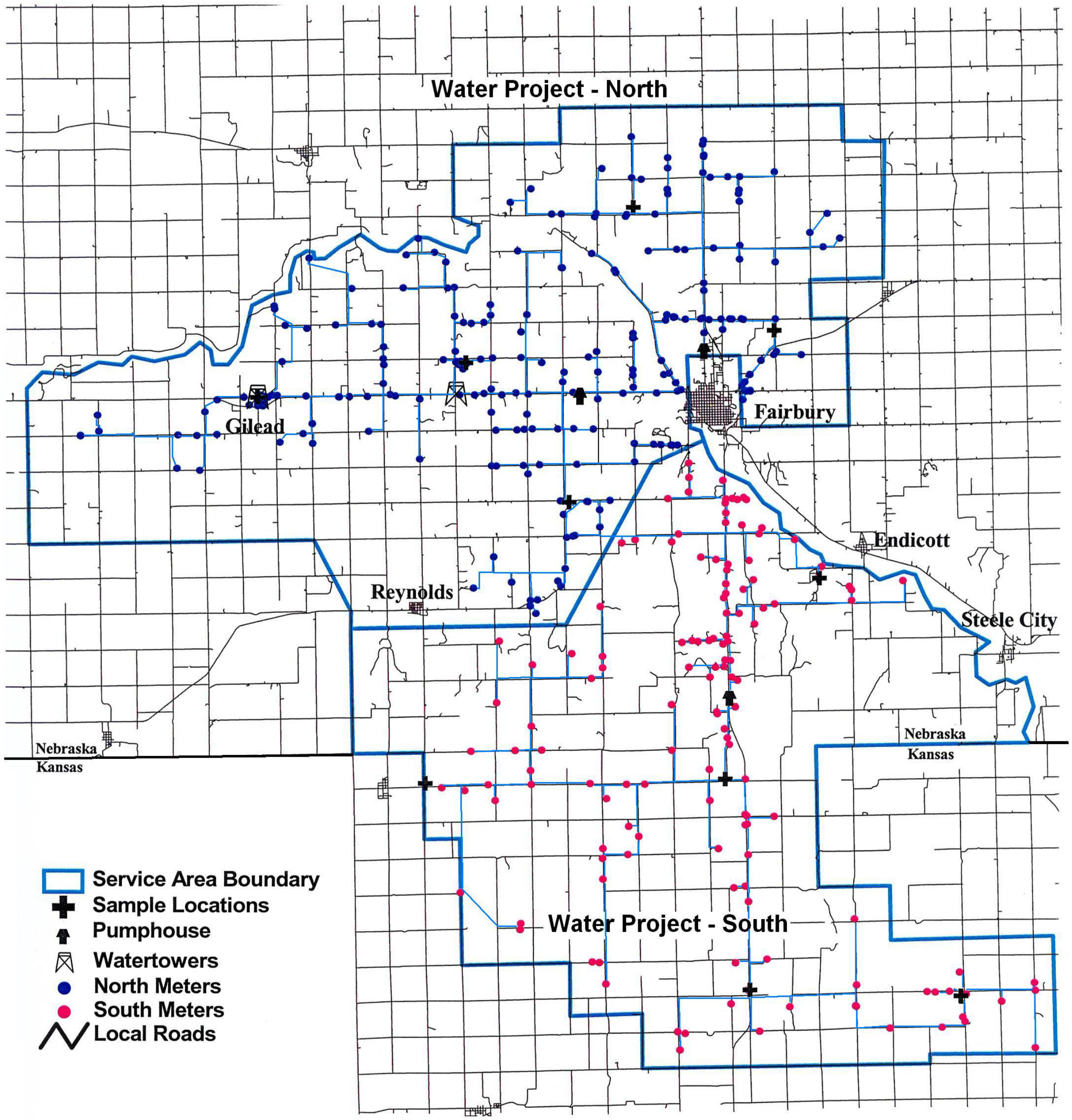
**Needed is the rate of flow for a specific duration for a full credit condition. Needed Fire Flows greater than 3,500 gpm are not considered in determining the classification of the city when using the Fire Suppression Rating Schedule.

*** (A)-Limited by available hydrants to gpm shown. Available facilities limit flow to gpm shown plus consumption for the needed duration of (B)-2 hours, (C)-3 hours or (D)-4 hours.

APPENDIX “F”

Little Blue Natural Resources District System Information and Service Agreement

Little Blue Natural Resources District
Rural Water Districts



APPENDIX "G"

Existing and Proposed High Service Pump Performance Data

6" 5824

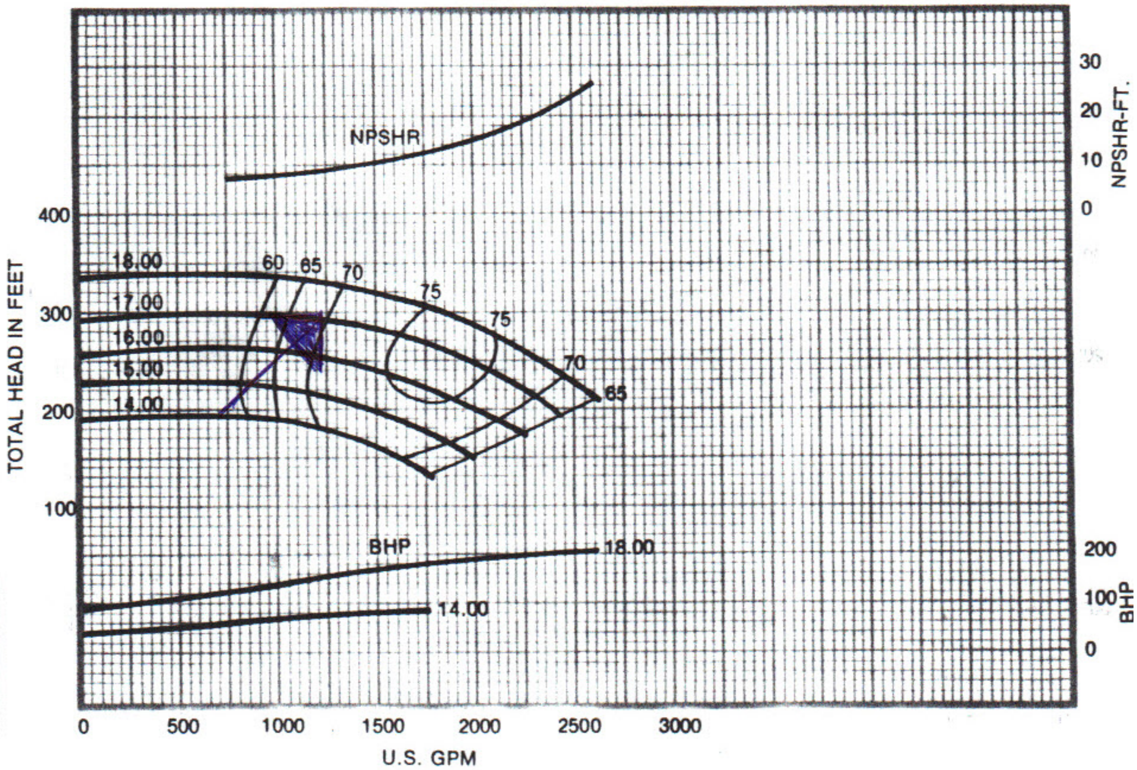
1770 RPM

IMPELLER D6D1AM

SUCTION SIZE 8"

EYE AREA 51.6 SQ. IN.

MAX. SPHERE 7/8"



8" 5824

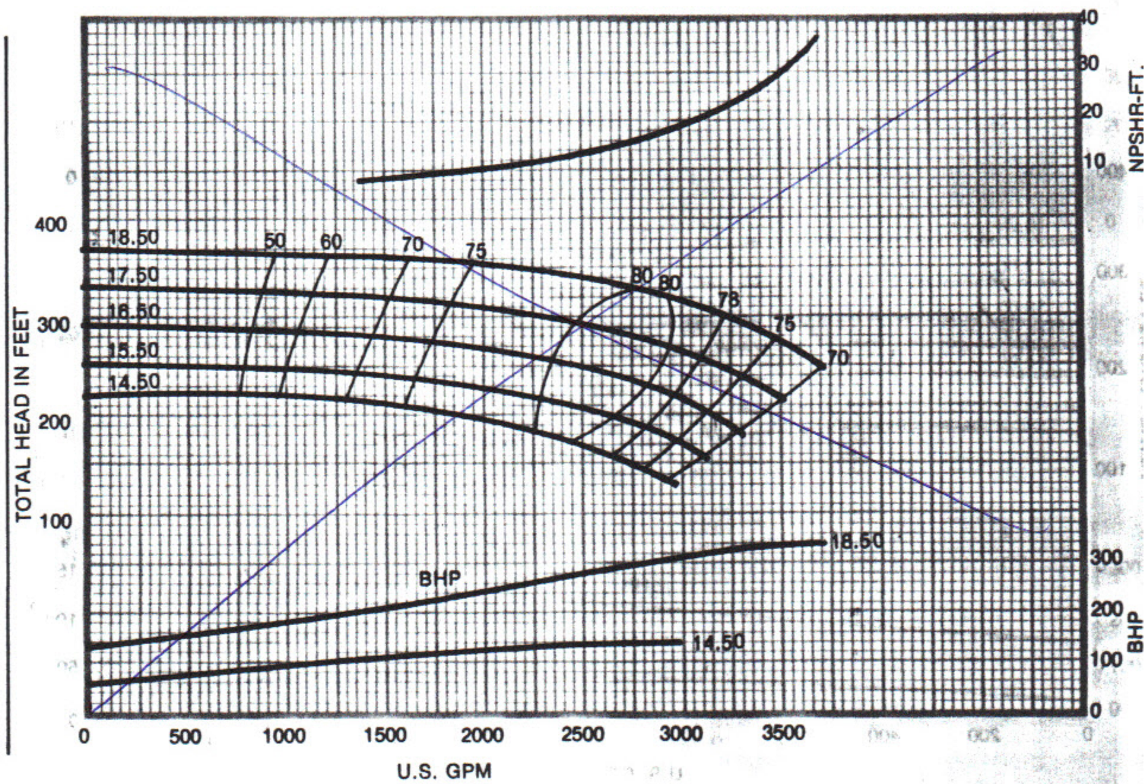
1770 RPM

IMPELLER D8D1G

SUCTION SIZE 10"

EYE AREA 62.8 SQ. IN.

MAX. SPHERE 11/16"



Customer :
Project name : Default

Pump Performance Datasheet

Encompass 2.0 - 17.1.4.0

Item number	: Fairbury NE High Service Pump	Size	: 6"1922B
Service	: Fairbury NE High Service Pump Replacement	Stages	: 1
Quantity	: 1	Based on curve number	: 24-6x8x17B-1750 Rev 11/15/12
Quote number	: 355668	Date last saved	: 08 May 2017 10:09 AM

Operating Conditions

Flow, rated	: 1,200.0 USgpm
Differential head / pressure, rated (requested)	: 300.0 ft
Differential head / pressure, rated (actual)	: 302.1 ft
Suction pressure, rated / max	: 0.00 / 0.00 psi.g
NPSH available, rated	: Ample
Frequency	: 60 Hz

Performance

Speed, rated	: 1750 rpm
Impeller diameter, rated	: 13.75 in
Impeller diameter, maximum	: 15.00 in
Impeller diameter, minimum	: 11.00 in
Efficiency	: 79.16 %
NPSH required / margin required	: 16.30 / 0.00 ft
nq (imp. eye flow) / S (imp. eye flow)	: 15 / 139 Metric units
Minimum Continuous Stable Flow	: 593.0 USgpm
Head, maximum, rated diameter	: 359.3 ft
Head rise to shutoff	: 16.86 %
Flow, best eff. point	: 1,292.9 USgpm
Flow ratio, rated / BEP	: 92.82 %
Diameter ratio (rated / max)	: 91.67 %
Head ratio (rated dia / max dia)	: 76.72 %
Cq/Ch/Ce/Cn [ANSI/HI 9.6.7-2010]	: 1.00 / 1.00 / 1.00 / 1.00
Selection status	: Acceptable

Liquid

Liquid type	: Water
Additional liquid description	:
Solids diameter, max	: 0.00 in
Solids concentration, by volume	: 0.00 %
Temperature, max	: 68.00 deg F
Fluid density, rated / max	: 1.000 / 1.000 SG
Viscosity, rated	: 1.00 cP
Vapor pressure, rated	: 0.34 psi.a

Material

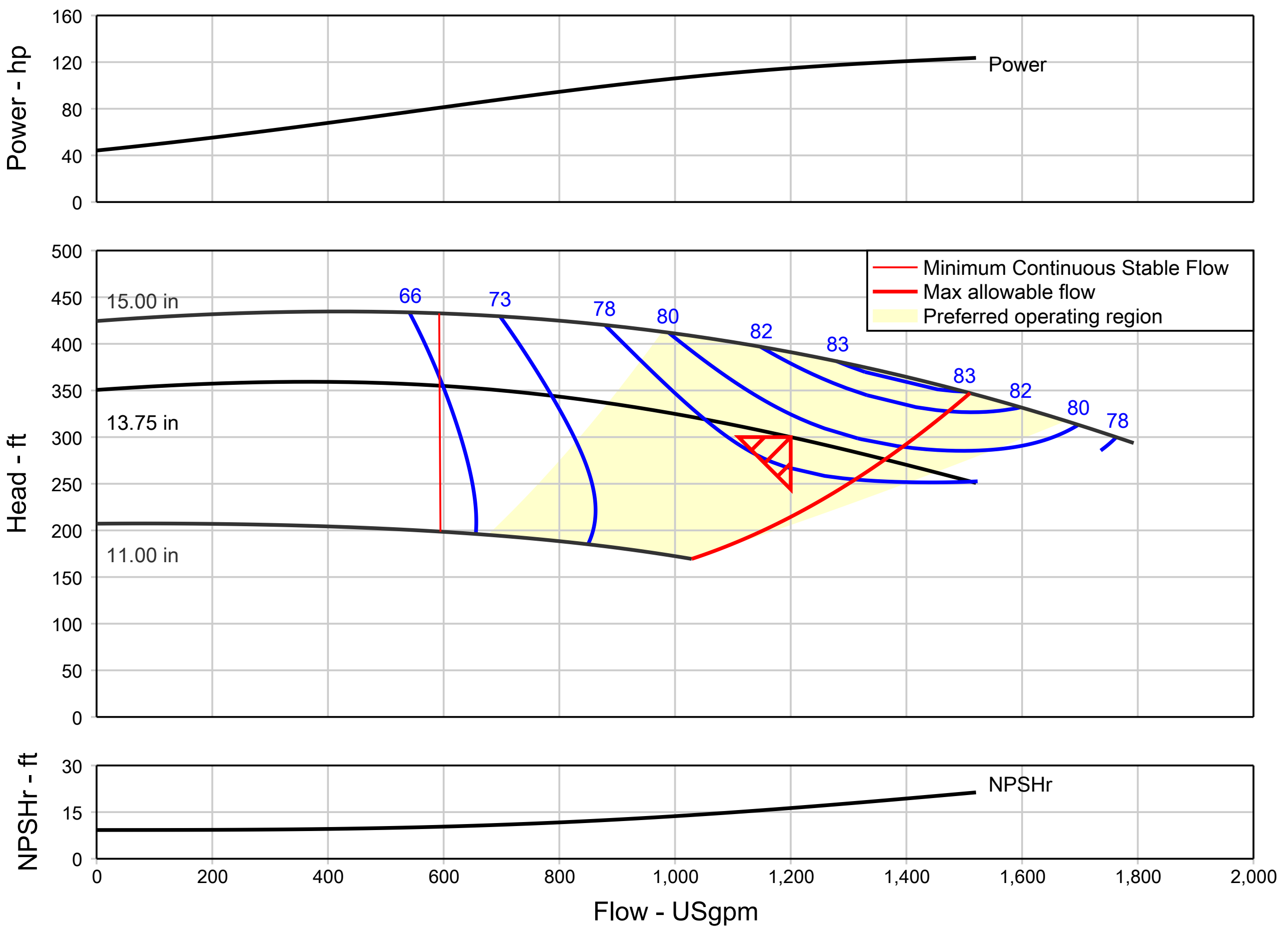
Material selected	: Standard

Pressure Data

Maximum working pressure	: 155.5 psi.g
Maximum allowable working pressure	: 250.0 psi.g
Maximum allowable suction pressure	: 250.0 psi.g
Hydrostatic test pressure	: N/A

Driver & Power Data (@Max density)

Driver sizing specification	: Max Power
Margin over specification	: 0.00 %
Service factor	: 1.00
Power, hydraulic	: 90.90 hp
Power, rated	: 115 hp
Power, maximum, rated diameter	: 124 hp
Minimum recommended motor rating	: 150 hp / 112 kW

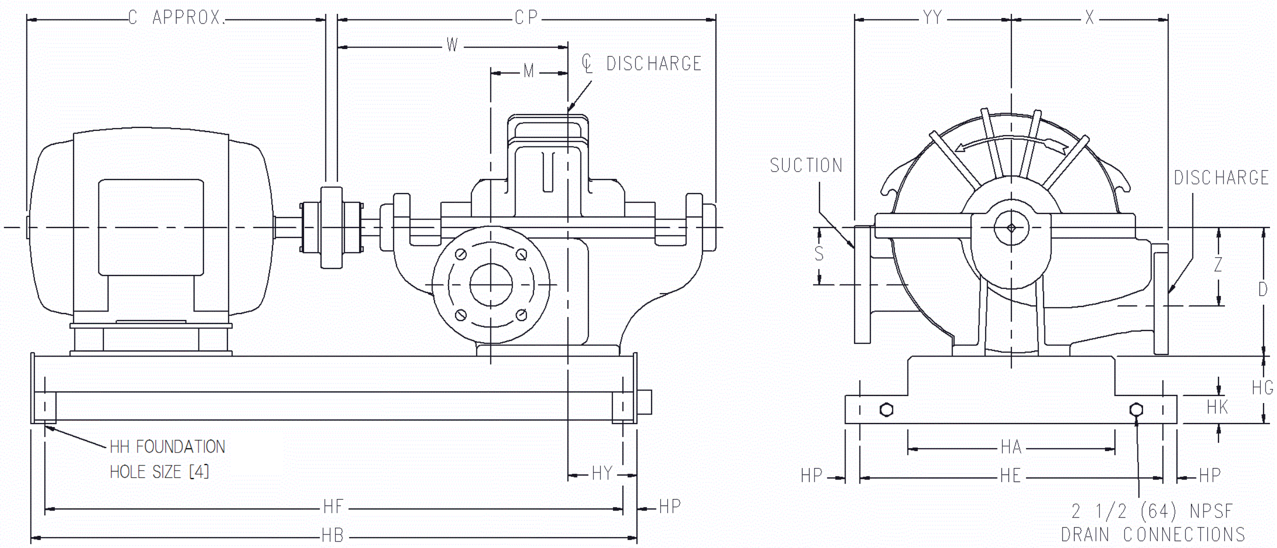


BERT GURNEY & ASSOCIATES INC
4428 S 108 ST · OMAHA, NE 68137

PHONE: · FAX:

PENTAIR

General Arrangement Drawing



RIGHT–HAND PUMP

C	D	M	S	W	Z	CP	HY	X	YY	HA	HB	HE	HF	HG	HH	HK	HP
34.00	14.75	11.00	7.00	24.50	9.00	38.00	4.00	16.00	16.50	22.00	64.50	29.13	62.88	4.50	0.75	2.00	0.81

Notes:
All dimensions are in inches.
Dimensions may vary ± 1/2" (13mm) due to normal manufacturing tolerances.
Discharge and suction flanges - ANSI Standard flat face.

Pump Data			
Pump series	1900	Power series	5
Model	1920	Discharge size	6.00 in
Size	6"1922B	Suction size	8.00 in
Flow	1,200.0 USgpm	Impeller diameter	13.75 in
Head	300.0 ft	Pressure rating	250.0 psi
RPM	1750 rpm	Temperature rating	68.00 deg F
Rotation	Right	Connection suc/disc	125#/250#
Paint	Standard	Base type	Steel Drip Rim Base
Liquid type	Water	Coupling type	Rubber-in-shear

Motor Data			
Horsepower	150 hp	-	-
Phase	3	Efficiency (%)	95.8
Hertz	60 Hz	Rating	premium
Volts	460	Enclosure	ODP
RPM	1800 rpm	Manufacturer	US Motors
Frame	444TS		

Pump Materials of Construction			
Pump material	Bronze fitted	Shaft	Steel, AISI C1045
Casing	Cast iron, ASTM A48	Shaft sleeve	Stainless steel, 316
Casing wear ring	Stainless Steel, AISI 416	Gland	-
Impeller	Bronze, ASTM B584	Sealing type	Mechanical
Impeller wear ring	Bronze	Sealing material	Ceramic
Flush lines	1/4" Copper Tubing, from volute to stuffing boxes		

Estimated Weights	
Pump	1,030.0 lb
Driver	1,100.0 lb
Base type	386.0 lb
Coupling	60.00 lb
Total	2,576.0 lb

Additional Options

Lead free construction

-
-
-
-
-
-
-

Quote Information	
Customer	-
Customer quote	355668
Job name	Default
Market	-

PENTAIR

Quote item	038
Quote date	28 Apr 2017

APPENDIX “H”

- **Trouble Shooting Fire Hydrant Problems**
- **Water Distribution Flushing Programs**
- **Question of the Month: How Do We Maintain Our Water Well?**

Troubleshooting Fire Hydrant Problems

Although a fire hydrant's primary purpose is public fire protection, usually a hydrant is the property or responsibility of a water utility. However, during emergencies, the hydrant is operated by members of a fire department rather than by water utility personnel. The utility should schedule regular and frequent inspections of hydrants to ensure they are in good working condition. Hydrants are diverse, requiring detailed maintenance as specified by the manufacturer, but some problems are universal. Should your hydrants have problems, the following troubleshooting tips may provide a solution.

The fire hydrant is one of the most important parts of a water distribution system, but is often one of the most ignored.

Photo courtesy of Mueller Co.

This guide is an excerpt of the Fire Hydrant Reference Material, *a copyrighted publication of Mueller Co., and is reproduced by permission.*

Problem: Pulsation or chatter during opening and flow of water from hydrant.

- ► ***Cause:*** Loose condition in stem at lower valve plate nut.
- ■ ***Corrective Action:*** Tighten lower valve plate nut and secure with SS lock washer.
- ► ***Cause:*** Loose condition in stem caused by more than one extension being used.
- ■ ***Corrective Action:*** Replace multiple extension stems with single extension stem.
- ► ***Cause:*** Excessive looseness at the safety coupling due to overtightening or high number of open/close cycles.
- ■ ***Corrective Action:*** Replace safety coupling and pins.

Problem: Hard turning of operating nut during hydrant operation.

- ► ***Cause:*** Debris or foreign material in operating mechanism of hydrant within the bonnet.
- ■ ***Corrective Action:*** Disassemble operating nut, hold-down nut, and anti-friction washer. Clean, lubricate, and assemble with new anti-friction washer (ensure washer is placed on operating nut's top surface). Check for damaged O-rings, which seal oil in the reservoir, at bottom of bonnet. Replace if necessary. Fill bonnet with fresh oil.
- ► ***Cause:*** Hydrant has been struck, possibly bending stem.
- ■ ***Corrective Action:*** Check upper stem and coupling(s) for damage. Replace if necessary.

Problem: Hydrant slams shut while being closed.

- ► ***Cause:*** Play in stem due to wear on stem couplings.
- ■ ***Corrective Action:*** Inspect the safety/extension coupling for damage and ensure couplings are installed with the correct end up.
- ► ***Cause:*** Loose main valve assembly.
- ■ ***Corrective Action:*** Remove main valve assembly and tighten lower valve plate nut, securing with SS lock washer.

Problem: Excessive external leakage at the drain area of the hydrant when main valve is open.

- ► ***Cause:*** Damaged or worn drain valve facings.
- ■ ***Corrective Action:*** Replace drain valve facings.
- ► ***Cause:*** Damaged upper seat ring O-ring.
- ■ ***Corrective Action:*** Replace upper seat ring O-ring.

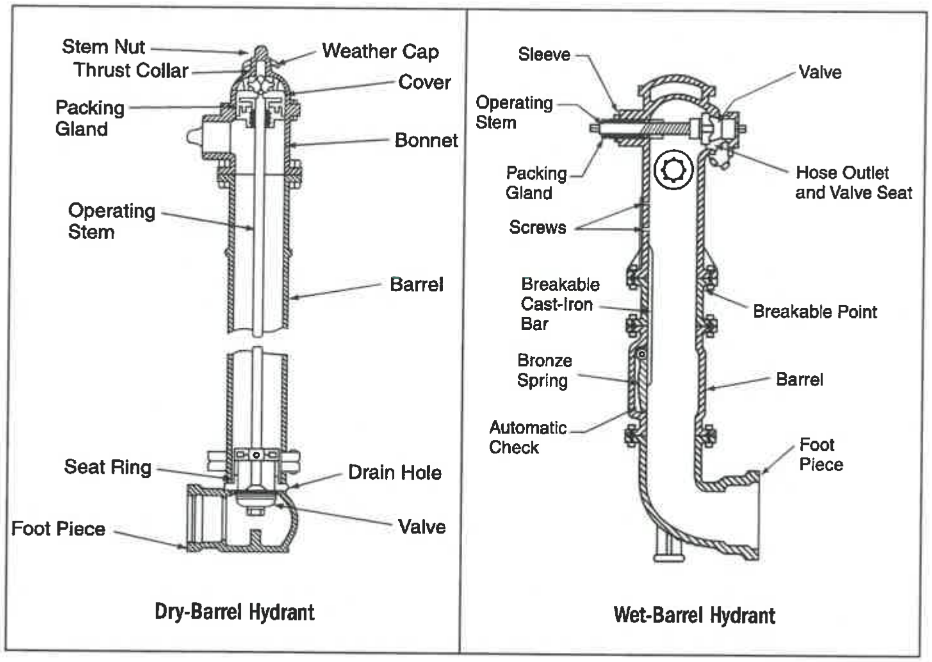
Problem: External leakage at the drain valve area when main valve closed and barrel has drained.

- ► ***Cause:*** Damaged lower seat ring O-ring.
- ■ ***Corrective Action:*** Replace lower seat ring O-ring.

Problem: Internal leakage in the upper barrel when main valve is closed.

- ***Cause:*** Damaged main valve or seat ring.
- ***Corrective Action:*** Replace main valve and/or seat ring.
- ***Cause:*** Leakage through center of main valve around stem because of loose lower valve plate nut.
- ***Corrective Action:*** Tighten lower valve plate nut and secure with SS lock washer.
- ***Cause:*** Damage to copper sleeve on stem hitting bottom of bonnet, preventing full main-valve closure.
- ***Corrective Action:*** Inspect upper stem and replace if sleeve is damaged.
- ***Cause:*** O-rings on seat ring may be damaged.
- ***Corrective Action:*** Replace O-rings.

continued on page 28



Dry- and wet-barrel hydrants are the two most common types. Dry-barrel hydrants are primarily used in freezing climates; the barrel is filled with water only when the main valve is open. Wet-barrel hydrants are completely filled with water at all times, so they cannot be used in climates where temperatures fall below freezing.

Hydrant (from page 27)

(from page 27)

- ▶ *Cause:* Damaged main valve or seat ring.
- ■ ***Corrective Action:*** Replace main valve or seat ring.

Problem: Opens hard in cycles.

- ■ ***Corrective Action:*** Check for bent stem or operating nut drilled off center.

Problem: Oil filler plug will not come out.

- ▶ *Cause:* Corroded or painted over.
- ■ ***Corrective Action:*** Clean paint from oil filler plug, lubricate, and use easy-out to remove. ***Do not*** use a torch to heat the bonnet and filler plug, as this will only cause damage to the O-rings within the bonnet.

Problem: Oil stain on bonnet.

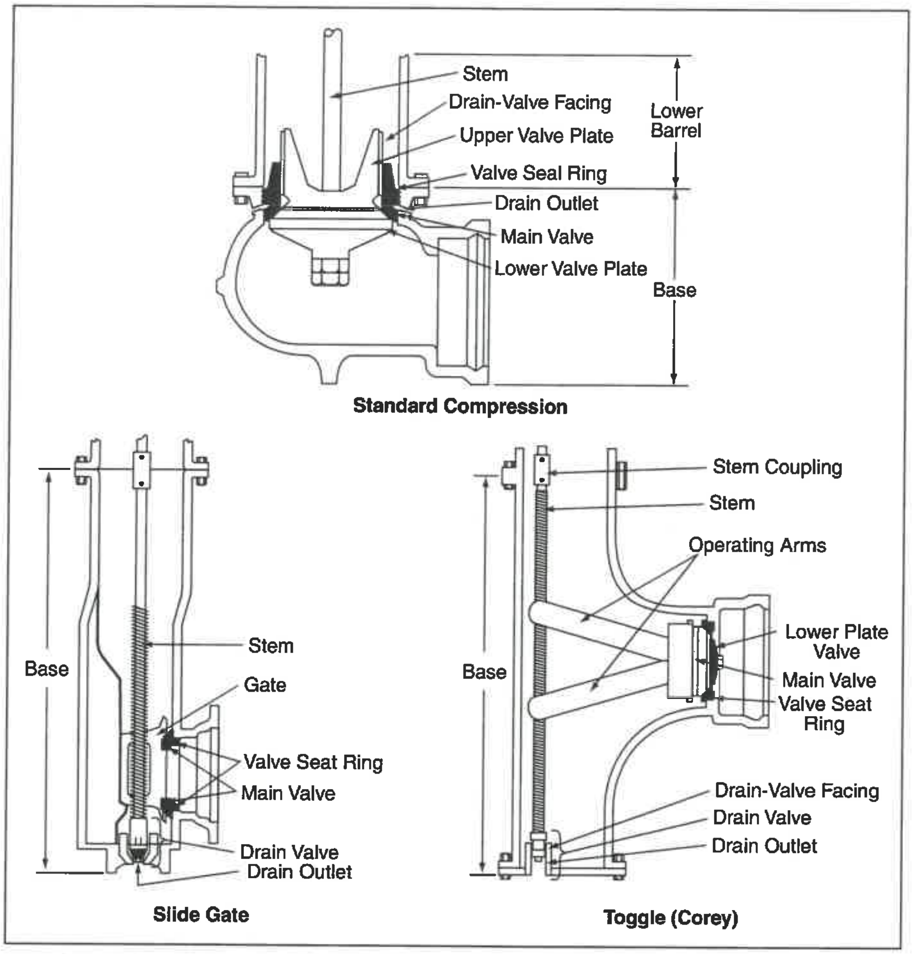
- ■ ***Corrective Action:*** Overfilled oil reservoir occurs when oil reservoir is filled when hydrant is in open position. Fill oil reservoir only when hydrant is in the closed position and fill until it overflows out of the oil filler hole. Wipe excess clean with rag.

Problem: Nozzles facing in the wrong direction.

- ■ ***Corrective Action:*** Loosen safety flanges, or breakaway bolts. Turn operating nut in the opening direction. Water pressure against the main valve will raise the upper barrel, releasing the pressure from the O-ring or gasket. This will allow turning the upper barrel without damage to the flange gasket. Tighten bolts and pressurize the barrel, checking for leaks.

Problem: Hydrant opens but will not close.

- ▶ *Cause:* Safety coupling is broken or loose.
- ■ ***Corrective Action:*** Remove bonnet and upper barrel and replace safety coupling.
- ▶ *Cause:* Cap nut on lower valve plate may be broken or loose.
- ■ ***Corrective Action:*** Remove main valve assembly and tighten or repair, securing with SS lock washer.



The type of main valve classifies dry-barrel hydrants: standard compression (the valve closes with the water pressure against the seat to help provide a good seal), slide gate (the valve is a simple gate valve), and toggle or Corey (the valve closes horizontally, and the barrel extends well below the branch line).

Problem: Loss of oil from the reservoir in the bonnet.

- ▶ *Cause:* Leakage between bonnet O-ring and stem sleeve.
- ■ ***Corrective Action:*** Replace O-ring in the bonnet and upper stem if sleeve has been damaged. Fill bonnet with fresh oil.

Problem: Drain holes leak when hydrant is fully open.

- ▶ *Cause:* Drain valve facings are damaged.
- ■ ***Corrective Action:*** Remove main valve assembly and replace drain valve facings.
- ▶ *Cause:* Top O-ring on seat ring may be damaged.
- ■ ***Corrective Action:*** Remove main valve assembly and replace top O-ring.

Problem: Drain holes leak when hydrant is fully closed.

- ▶ *Cause:* Damaged main valve.
- ■ ***Corrective Action:*** Remove main valve and replace if damaged.
- ▶ *Cause:* Bottom O-ring on seat ring may be damaged.
- ■ ***Corrective Action:*** Remove main valve assembly and replace bottom O-ring.

Problem: Hydrant will not drain.

- ▶ *Cause:* Drain holes may be plugged with debris.
- ■ ***Corrective Action:*** Loosen cap and open hydrants until cap squirts water from nozzle. Tighten cap and leave hydrant open 2–3 turns to force-flush drain holes. Allow flushing for 2–3 minutes or until holes are cleared and hydrant is draining properly.

- *Cause:* Not all hydrants are required to drain.
- ***Corrective Action:*** Ensure that hydrant installed is a draining hydrant.

Problem: Hydrant will not open.

- *Cause:* Corrosion or paint has locked operating nut to bonnet, hold-down nut, or upper stem.
- *Corrective Action:* Disassemble, clean, lubricate, and reassemble.
- *Cause:* Debris in shoe of hydrant.
- *Corrective Action:* Remove main valve assembly, flush hydrant using isolation valve. Reassemble and test hydrant.
- *Cause:* Hydrant opens opposite direction and paint has covered indication on bonnet or weather cap.
- *Corrective Action:* Locate opening direction and attempt to open again.

Problem: Hydrant will not close after hydrant extension put on.

- *Cause:* Safety/extension coupling misplaced or upside down.
- *Corrective Action:* Check for placement of extension coupling and safety coupling. Relocate to correct position if misplaced. ***(Safety coupling always goes on top.)***

Problem: Flow from hydrant is low.

- *Cause:* Hydrant not fully open or isolation valve is not fully open.
- *Corrective Action:* Check for number of turns when opening hydrant. Also, ensure that isolation valve is fully open, using the formula for amount of turns to open or close all gate valves: ***3× nominal size of valve + (2 or 3) turns.***

Problem: Hydrant will not close after main valve replacement.

- *Cause:* Seat ring not tightened properly.
- *Corrective Action:* Remove bonnet and retighten main valve assembly.
- *Cause:* Damaged seat ring or O-rings on replacement.
- *Corrective Action:* Remove main valve assembly and check for damaged O-rings or seat rings

Problem: Operating nut turns, but hydrant will not open.

- *Cause:* Operating nut is locked to upper stem and safety coupling is broken.
- *Corrective Action:* Remove bonnet and upper barrel. Remove operating nut from upper stem, clean, lubricate, and reassemble. Replace safety coupling.

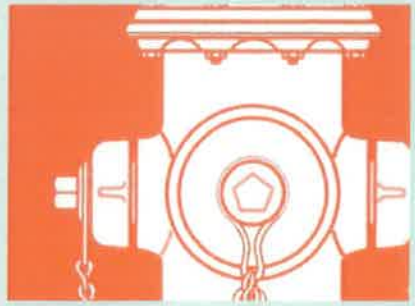
Inspections Play a Vital Role in Fire Hydrant Maintenance

All dry- and wet-barrel fire hydrants should be inspected regularly, at least once a year, to ensure their satisfactory operation. The following inspection guidelines will help keep hydrants functioning at peak efficiency.

Dry-Barrel Hydrant Inspection Procedure

1. Check the hydrant's appearance. Remove obstructions around it. If paint is needed, either paint the hydrant or schedule it for painting. Check to see whether the hydrant needs to be raised because of a change in the ground-surface grade. If adjustments are needed, schedule the work.
2. Remove one outlet-nozzle cap and use a listening device to check for main valve leakage.
3. Using a plumb bob, check for the presence of water or ice in the hydrant barrel.
4. Replace the outlet-nozzle cap. Leave it loose enough to allow air to escape.
5. Open the hydrant only a few turns. Allow air to vent from the outlet-nozzle cap.
6. Tighten the outlet-nozzle cap.
7. Open the hydrant fully. Check for ease of operation. Certain water conditions may cause hard-water buildup on the stem threads of toggle and slide-gate hydrants and on the threads of wet-top hydrants. Opening and closing the hydrant repeatedly usually removes this buildup. If the hydrant has no threads in the water, but operates with difficulty, check the lubrication before proceeding with the inspection. Other problems that may make operation difficult are stuck packing and bent stems.
8. With the hydrant fully open, check for leakage at flanges, around outlet nozzles, at packing or seals, and around the operating stem. Repair as needed.
9. Partially close the hydrant so the drains open and water flows through under pressure for about 10 sec, flushing the drain outlets.
10. Close the hydrant completely. Back off the operating nut enough to take pressure off of the thrust bearing or packing.
11. Remove an outlet-nozzle cap.
12. Attach a section of fire hose or other deflector to protect the street, traffic, and private property from water expelled at high velocity.
13. Open the hydrant and flush to remove foreign material from the interior and lead.
14. Close the hydrant. Remove the deflector and check the operation of the drain valve by placing the palm of one hand over the outlet nozzle. Drainage should be sufficiently rapid to create noticeable suction. For no-drain hydrants, pump the water from the barrel.
15. Using a listening device, check the main valve for leakage.
16. Remove all outlet-nozzle caps, clean the threads, check the condition of the gaskets, and lubricate the threads. (Graphite powder in oil works well, as do several of the never-seize compounds.) Check the ease of operation of each cap.
17. Check outlet-nozzle-cap chains or cables for free action on each cap. If the chains or cables bind, open the loop around the cap until they move freely. This will keep the chains or cables from kinking when the cap is removed during an emergency.
18. Replace the caps. Tighten them, and then back off slightly so they will not be excessively tight. Leave them tight enough to prevent their removal by hand.
19. Check the lubrication of operating-nut threads. Lubricate per the manufacturer's recommendations.
20. Locate and exercise the auxiliary valve. Leave it in the open position.
21. On traffic-model hydrants, check the breakaway device for damage.
22. If the hydrant is inoperable, tag it with a clearly visible mark and notify the fire department. This may save fire fighters valuable time in an emergency. Schedule the hydrant for repair.

Wet-Barrel Hydrant Inspection Procedure



1. Check the hydrant's appearance. Remove obstructions around it. If paint is needed, either paint the hydrant or schedule it for painting. Check to see whether the hydrant needs to be raised because of a change in the ground-surface grade. If adjustments are needed, schedule the work.
2. Remove outlet-nozzle caps and check for valve-washer leakage.
3. Install a test outlet-nozzle cap.
4. Open each valve and test for ease of operation. If stem action is tight, open and close several times until opening and closing actions are smooth and free.
5. Clean the cap and nozzle threads. Inspect and replace damaged cap gaskets. Lubricate the nozzle threads. (Graphite powder in oil works well, as do several of the never-seize compounds.)
6. Check the outlet-nozzle-cap chains and cables for free action on each cap. If the chains or cables bind, open the loop around the cap until they move freely. This will keep the chains or cables from kinking when the cap is removed during an emergency.
7. Replace the caps. Tighten them, and then back off slightly so they will not be excessively tight. Leave them tight enough to prevent their removal by hand.
8. Locate and exercise the auxiliary valve. Leave it in the open position.
9. If the hydrant is inoperable, tag it with a clearly visible mark and notify the fire department. This may save firefighters valuable time in an emergency. Schedule the hydrant for repair.

*This is an excerpt from **Installation, Field Test, and Maintenance of Fire Hydrants (M17)**. The AWWA Standards Committee on Fire Hydrants is revising the manual and anticipates a 2006 publish date.*

Question of the Month

ADVICE FOR SMALL SYSTEMS

Do You Have Any Fire Hydrant Testing/Maintenance Recommendations? BY PAT KLINE

QUESTION: **My local fire department allows firefighters to test fire hydrants for operability without regard for the distribution system that supplies the hydrants. Do you have recommendations for proper fire hydrant testing or maintenance practices that protect water mains?**

ANSWER: When the public sees a fire hydrant, there's a perception of safety—the reliable protection of life and property that a hydrant provides. Fire hydrants are often the only visible sign of a water utility's presence in a community and can affect the community's perception of the utility's effectiveness, management, and reliability. Improper hydrant operation or maintenance can affect the reality of the protection provided the community.

HYDRANT BASICS

There are two types of fire hydrants: wet-barrel hydrants and dry-barrel hydrants. Because they're always filled with water, wet-barrel hydrants are used in areas where freezing rarely, if ever, occurs. They may also be used indoors—the hydrants you see inside shopping malls are frequently wet-barrel hydrants. Dry-barrel hydrants are designed to drain after the water supply is shut off.

No matter which type is involved, firefighters are concerned with two things about a community fire hydrant: the flow from the hydrant and whether the hydrant will open. Distribution system operators are concerned about the same things and about the effect on water quality and customer service that operating the hydrant may have. To foster top fire and top water service, help the firefighters with their concerns and educate them about the water quality consequences of hydrant operation so they'll understand yours.

COMMON CONCERNS

Incorrectly operating a hydrant can cause problems. If a hydrant is opened too quickly, negative pressure may cause backflow conditions, allowing contaminants to enter a distribution line. If a hydrant is closed too quickly, water hammer conditions can be severe enough to harm the hydrant and the distribution system. Water hammer not only creates a lot of noise (think of how loud the pipes sound if they rattle in your home's walls), but can also be dramatic enough to burst pipes, damage supports, and blow out connections and joints.

Opening fire hydrants when flow testing them can cause material in pipelines to break loose and be carried in the flow into customers' homes. Firefighting can cause low pressure for customers in the area of a fire. Moreover, heavy fire hydrant use causing temporary pressure losses can lead to the backflow of contaminants into the distribution system.

Hydrants are generally designed to be operated by one person using a special 15-in. wrench. Wrench extenders, cheater bars, or two-person operation can damage the threads on a hydrant, making a tight connection between the nozzles and the attaching hose impossible to achieve.

RESOURCES

AWWA M17: *Installation, Field Testing, and Maintenance of Fire Hydrants*

AWWA Standard C502-05, Dry-Barrel Fire Hydrants

AWWA Standard C503-05, Wet-Barrel Fire Hydrants

AWWA Standard C651-05, Disinfecting Water Mains

AWWA, *Water Distribution Operator Training Handbook*

Skousen, P. L., *Valve Handbook*, McGraw Hill Publishers

A rigid diverter should never be used on any type of hydrant. A rigid diverter consists of a pipe screwed onto the hydrant outlet, extending out to a desired length, and bending up to 90 degrees to change the direction of the water flow before discharging full flow into the atmosphere. Rigid diverters can cause huge amounts of torque that can damage both wet-barrel and dry-barrel hydrants. However, damage to the fire hydrant and the distribution system isn't the only concern—destruction to a hydrant from too much torque can happen so quickly and violently that workers may be seriously harmed. If a flexible hose is used to direct the flow from a hydrant, the end of the hose from which the water flows should be restrained to prevent operator injury.

Anyone operating a hydrant should be familiar with the drain requirements associated with the hydrant. In general, dry-barrel fire hydrants should be fully opened, because the drain operator and the main valve are connected. If a dry-barrel fire hydrant is only partially opened for flushing, water may be forced through the drains and cause erosion around the base of the hydrant. The caps shouldn't be tightened until the hydrant is finished draining. A person operating a hydrant may feel a vacuum at the nozzle when the hydrant is draining; once the vacuum stops, the hydrant is drained and the caps may be tightened.

TIPS AND TRICKS

Common sense, observation, and good recordkeeping are the key components to hydrant inspection. Although hydrants may be operated by members of the fire department, it's generally the water utility's responsibility to maintain them in working order. Each hydrant should be clear of vegetation, landscaping, or other obstruction. A stethoscope or other lis-

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tening device may be used to discover main valve leaks. A weighted cord may be used to check for water standing in the barrel of the hydrant (if applicable). Unscrew the cap slightly to allow air to vent, then tighten the cap and open the hydrant fully. Check for leaks around the operating stem, nozzles, seals, packing, and flanges. O-rings should be replaced as necessary. Note any wear around all seals and threads, and lubricate these parts before reassembly to ensure smooth hydrant operation. Partially close the hydrant until the drain opens, and then flush the drain for a few seconds under pressure. Exercise the watch valve, but remember to leave it in the open position.

You may also want to consider painting each hydrant based on the hydrant's individual flow capacity, to make it easier for firefighters to use the hydrant that's appropriate to a fire. Because hydrants must be visible at all times, they should be painted colors that are visible day and night. A good coating system to use is the uniform color-coding system that is consistent with the scheme set forth in NFPA 291, *Recommended Practice for Fire Flow Testing and Marking of Hydrants*:

- Class AA hydrants with a flow capacity of 1,500 gpm are painted light blue.
- Class A hydrants with a flow capacity of between 1,000 and 1,499 gpm are painted green.
- Class B hydrants with a flow capacity of 500 to 999 gpm are painted orange.
- Class C hydrants with a flow capacity of less than 500 gpm are painted red.

This color scheme signifies only the approximate capacity of the individual hydrant when tested alone, but not the capacity when more than one hydrant in the vicinity is in use.

The most vital thing to remember about hydrant inspection is that if a hydrant isn't operational, make sure it's fixed quickly! Mark the hydrant in some way to alert others that it can't be used. Some utilities, such as Tacoma Water, have a goal of hydrant repair within 24 hours and hydrant replacement within 72 hours of notification. Keep your hydrants happy!

BY MELINDA FRIEDMAN
GREGORY J. KIRMEYER
EDWARD ANTOUN

DEVELOPING AND IMPLEMENTING a Distribution System Flushing Program

Utilities have long implemented flushing programs in one form or another and to varying extents within the distribution system. Generally, these programs have been established as corrective measures in response to customer complaints or to expel contaminants inadvertently introduced into the system.

FLUSHING PROGRAMS—AN IMPORTANT PART OF MANY DISTRIBUTION SYSTEM MAINTENANCE PROGRAMS—CAN IMPROVE DISTRIBUTION SYSTEM WATER QUALITY, REDUCE CUSTOMER COMPLAINTS, AND INCREASE WATER SAVINGS.

WORKSHOP IDENTIFIES FOUR-STEP FLUSHING PROGRAM

Participants in the March 1998 AWWA Research Foundation (AWWARF) study "Guidance Manual to Maintain Distribution System Water Quality" included utility representatives, consultants, members of the Project Advisory Committee, and members of the project team. Together, they devised a four-step flushing program that would meet the needs of utilities (Kirmeyer et al, 2000). The steps are as follows:

- Step 1—Determining the appropriateness of flushing as part of a utility maintenance program
- Step 2—Planning and managing a flushing program
- Step 3—Implementing a flushing program and data collection
- Step 4—Evaluating and revising a flushing program

Although the magnitude and frequency of flushing programs will vary from utility to utility, workshop participants agreed that flushing was one of many tools that should be considered best management practices for maintaining water quality in distribution systems. The group also concurred that flushing is an important part of a good distribution system maintenance program.

A full report of this project, Guidance Manual for Maintaining Distribution System Water Quality *(catalog number 90798), is available from AWWA Customer Service (1-800-926-7337). Reports are free to AWWA Research Foundation subscribers by calling 303-347-6121.*

STEP 1—DETERMINING THE APPROPRIATENESS OF FLUSHING AS PART OF A UTILITY MAINTENANCE PROGRAM

Should a utility consider routine flushing? The questions that follow can help utilities assess the appropriateness of a flushing system.

- Does the utility utilize an unfiltered surface water supply?
- Does the utility utilize an undisinfected groundwater supply?
- Does the utility use a water source with elevated iron and/or manganese?
- Does the utility experience positive coliform results or elevated levels of heterotrophic plate counts (HPCs)?
- Does the utility chloraminate?
- Is the utility planning to implement a treatment change that will alter the chemistry of the water?
- Does the utility experience frequent customer complaints related to water quality?
- Does the utility have difficulty maintaining a disinfectant residual in portions of the distribution system?
- Is the system lacking an aggressive valve/hydrant/tank exercising program?
- Would the utility consider the water entering the distribution system to be corrosive?
- Does sediment accumulate in storage reservoirs?

If any of these questions apply to a utility, it is probable that distribution system water quality improvements would be realized from implementing a routine flushing program. If the answer is "yes" to more than one of the assessment questions, not only should the utility consider implementing a routine flushing program, but it is probable that the system will benefit from more frequent flushing compared with a utility that answers "yes" to only one of the questions.

Systems that answer "no" to all of the questions should be able to document that the water quality issues listed are not occurring. It is not satisfactory just to assume that disinfectant residuals are maintained throughout the system on a year-round basis. Instead, monitoring should be conducted to document the microbial and chemical quality of the water, both seasonally and spatially. Suggested monitoring programs to evaluate the need for flushing and the effectiveness of existing flushing programs are discussed later in this article.

Assess the feasibility of flushing. After a utility has determined that distribution system water quality improvements could be realized from flushing, it is important to assess the feasibility of actually conducting an effective flushing program. The utility should consider the following questions prior to initiating flushing.

- Will hydraulic constraints prevent the achievement of desired flushing velocities?
- Is enough water available to flush at desired velocities for desired durations?
- What are the requirements for disposing of the water?
- What is the estimated cost (labor, power, equipment, and so forth) for conducting flushing?
- Is flushing the solution to distribution system water quality concern(s), or is it only part of the solution?
- What other operation/maintenance practices should be considered to address the specific water quality concern(s)?
- Does the entire system need to be flushed, or can water quality goals be achieved by focusing on certain portions of the system?

The answers should help the utility determine the degree of planning and level of effort that will be required to conduct an effective flushing program. If the level of effort is high and the potential water quality benefits are low (based on responses to questions in the previous section), then flushing may not be the best approach for maintaining water quality within a specific system. Other approaches, such as source water treatment, booster disinfection, pipe cleaning/lining, or increased tank fluctuations, may also address water quality concerns. A combination of approaches is often the most effective method of maintaining water quality throughout the distribution system.

Depending on a utility's water quality goals and treatment practices, measuring the disinfectant residual should be on the list of water quality parameters for a routine baseline monitoring program.

STEP 2—PLANNING AND PROGRAM MANAGEMENT

Planning the flushing program is probably the most important step toward obtaining the desired water

ADDITIONAL SAFETY CONSIDERATIONS

• Ensure the flushing crews are properly equipped with personal protective equipment and the correct tools for flushing operations. These tools should be well-maintained and replaced when necessary.

• Use the appropriate size crew for flushing operations. This typically involves a two-person crew. Individuals working alone are not efficient for flushing operations because of the distances between hydrants, valves, and so forth. While waiting for a main to clear, other crew members can be preparing the next section of main for flushing. They can also perform valve and hydrant maintenance work.

• Many of the valves that will be operated during flushing operations are located within paved portions of active streets. One crew member should control traffic while other crew members are operating distribution system valves.

• Traffic signs, cones, flags, and/or vehicles with warning lights should be used as necessary to divert traffic around flushing activities.

• Brightly colored safety vests should be worn by all crew members, especially when they perform the work at night.

• Keep the public away from ongoing flushing activities. Children are attracted to such activities and are vulnerable to injury.

• Use written procedures throughout the flushing operations to minimize unsafe situations and help coordinate the activities of the various crews involved.

• Open hydrant valves completely to prevent water discharging through the barrel drain at pressure, undermining the hydrant support.

• Open and close hydrants and valves slowly to prevent the development of dangerous pressure surges. A general rule of thumb is that for every 1 fps (0.3 m/s) sudden decrease in flow velocity within a water main, a pressure rise of 50 to 60 psi (345 to 414 kPa) can be expected. Likewise, sudden increases in velocity can result in the development of low or negative pressure surges.

• Use well-restrained energy dissipators designed for that purpose to prevent damage to private and public property.

• Discharge flushing water directly to a sanitary or storm sewer whenever possible to avoid flooding of streets and underground electrical vaults. Where street flooding is unavoidable, use signs, flags, and other items to direct traffic appropriately.

quality goals while minimizing unnecessary costs and undesirable secondary effects.

Determine flushing objectives. Flushing objectives may involve both water quality and hydraulic/maintenance considerations. It is imperative to decide what the water quality objectives are prior to flushing because the flushing approach used will likely vary depending on the specific water quality goal. Water quality concerns that can potentially be addressed through flushing include removal of accumulated silt/sediment from distribution system piping, reduction of chlorine demand throughout the distribution system, reduction of disinfection by-product (DBP) precursor materials, removal of accumulated biofilm, removal of contaminated water from a portion of the system, prevention of nitrification episodes, and reduction of customer complaints.

A flushing system can also address the following hydraulic/maintenance considerations: testing the structural integrity of the system under controlled (versus emergency) conditions, giving crews an opportunity to "operate" the system, providing opportunities to audit the system and associated appurtenances, and testing the hydraulic capacity of the system.

Depending on the utility-specific water quality objectives and hydraulic/maintenance considerations, one or more flushing approaches may be appropriate. These are described here.

Three flushing techniques are available. There are basically three flushing methods: unidirectional, conventional, and continuous blowoff. Each approach has a specific use and can help to meet certain water quality goals. In addition, each approach can be implemented on a comprehensive, systemwide basis or on a narrower "spot" basis. This largely depends on the configuration of the system within the area of interest and the water quality goals for that particular area. The term "comprehensive" indicates that the flushing campaign addresses the entire system, whereas "spot" flushing is typically used to target an acute problem in an isolated area of the system or in an area where chronic water quality problems because of low demand and other causes have led to repeated customer complaints.

Spot flushing is typically implemented more frequently than com-

Distribution system maps can be used to identify flushing loops, valves to be opened or closed, locations of pump stations and hydrants, pressure-reducing valves, and other facilities.

prehensive flushing. Because spot flushing focuses more on replacing the bulk water (versus cleaning the pipe), water quality benefits typically last only a short time. However, in the absence of any flushing program, it may still be beneficial to conduct spot flushing at dead ends. Flushing an area with low demand on a monthly or quarterly basis, for instance, can be considered spot flushing. A brief discussion of flushing approaches, advantages, and disadvantages is provided here.

Unidirectional flushing (UDF). According to Antoun et al (1997), UDF consists of isolating a particular pipe section or loop, typically through closing appropriate valves, and creating a single-direction flow. It is carefully engineered with consideration to the size of the flushing crew, duration of flushing, equipment availability, and location of water sources such as water treatment plant, storage tanks, and booster stations. UDF can be implemented as a comprehensive, systemwide flushing effort to prevent water quality deterioration or on a spot basis in response to a specific water quality concern.

The term "unidirectional" is often associated with a velocity of ≥ 5 fps (1.5 m/s) (Oberoi, 1994), which is thought to be adequate for the removal of biofilm and corrosion products and other debris attached to the pipe walls. However, the concept of isolating pipe segments and flushing in a sequential manner from the source to periphery (i.e., unidirectional) can be practiced at lower velocities to achieve different water quality goals, such as removing loose sediments, restoring chlorine residual, and reducing tastes and odors.

Utilities must take the initiative to determine the most appropriate velocities for meeting their individual water quality goals. An AWWARF study (number 2606) titled "Establishing Site-specific Flushing Velocities" is currently under way both to characterize accumulated materials and to determine required velocities for lifting, scouring, and removing contaminants from the distribution system.

UDF can lead to both water quality and hydraulic improvements. Benefits associated with a systemwide UDF program may include the following:

- reducing the management hours required to oversee the program implementation, because all the needed information is presented on the flushing maps and accompanying step-by-step flushing instructions;
- allowing for simultaneous implementation of preventive maintenance activities;
- using less water than conventional flushing (savings of greater than 40% by some estimates) (Oberoi et al, 1997);
- standardizing procedures, which provides a uniform basis of comparison with future flushing events;
- reducing troubleshooting efforts because of searches for closed valves that are supposed to be open; and
- allowing chloraminated systems to quickly and effectively implement flushing during conversion to free chlorine or to prevent the onset of nitrification.

Conventional flushing. Conventional flushing is usually implemented with little, if any, preplanning. Conventional flushing consists of opening hydrants in a specific area of the distribution system until preselected water quality criteria are met. These criteria could include detectable disinfectant residual, reduction/elimination of color, reduction in turbidity, and so forth. It is important to note that valve isolation is not part of conventional flushing. Consequently, flushing velocities are not maximized, because water to the hydrant often flows from several mains with the resultant velocity in each individual main remaining low. In contrast, by using valve isolation for UDF, water is forced through a single main at higher velocities. Further, because the water used to flush a particular main during conventional flushing may not originate from a segment that has already been flushed, the cleaning efficiency is not maximized, and contaminants can be transported from one main to another. The primary water quality improvements that can be achieved through conventional flushing may include restoration of disinfectant residual and expulsion of some of the poor water quality in specified areas of the system.

If these are the primary water quality goals within a specific portion of the system, conventional flushing may be adequate. Conventional flushing typically requires less planning than UDF; however, the opportunity to combine flushing with valve inspection/exercising programs is diminished. Additionally, conventional flushing has resulted in the following water quality problems: increased customer complaints during and immediately after implementation, a considerable waste of water, short-lived water quality benefits, and the potential for increased coliform occurrences following this type of flushing.

Continuous blowoff. For utilities that have numerous dead ends and severe water circulation problems, continuous blowoff, or bleeding of water, may be conducted to force a low velocity flow through a small portion of the system. Typically, because of hydraulic restrictions associated with the use of blowoff valves on dead-end lines, velocities of less than 1 fps (0.3 m/s) are attained. Therefore, unless used in conjunction with hydrants, adequate velocities may not be achieved to remove accumulated sediments or to provide scouring. The use of continuous blowoffs can help utilities restore disinfectant residuals and reduce water age. Obviously, this practice can result in the use of large quantities of water, without providing a solution to the cause of the water quality problem. Although continuous blowoff may be necessary to reduce detention time, more permanent solutions should be considered, such as looping dead ends or installing smaller-diameter pipes in lieu of larger pipes to meet future demands.

Preliminary program development will vary. Depending on the type of flushing program to be carried out, the degree of planning and program development will vary. This section of the article focuses on developing a UDF program, because it is widely accepted that a UDF program will produce the greatest long-term water quality improvements. Additionally, the UDF approach likely requires the greatest level of planning. The information provided here can be scaled down to assist utilities with developing the other types of flushing programs as well.

Obtain maps and review hydraulic models. The first step in developing a UDF program is to gain a thorough understanding of the distribution system's hydraulics and flow patterns. If a calibrated hydraulic model is not available, it will be necessary to obtain and review distribution system maps along with sewer and stormwater maps. The distribution system maps will be used to identify flushing loops, valves to be opened or closed, locations of pump stations and hydrants, pressure-reducing valves, plus other distribution system facilities. The sewer and stormwater maps will be needed to identify the locations to which the flushed water will be discharged. At this stage, it should be verified that adequate water and pressures are available to attain desired flushing velocities to meet water quality goals.

Develop a list of stakeholders. Once flushing loops have been identified, it will be very beneficial to develop a list of stakeholders that may be affected by flushing activities or that can facilitate the successful implementation of a flushing program. Such stakeholders may include preventive maintenance program directors, fire department(s), sewer/stormwater departments, customer service/public education departments, adjacent/interconnected water systems, and the water quality department/laboratory.

The flushing program should be reviewed with potential stakeholders to avoid problems that can be associated with crossing interagency "turf" boundaries and to obtain concurrence regarding water disposal issues, hydrant use, and so forth. Additionally, any requirements associated with treating the flushed water before discharging it to storm sewers or fish-bearing streams should be clearly identified. Potential parameters of concern with regard to disposal issues are discussed in the section titled Collect Data to Assess Program Success. Additionally, the *Guidance Manual for Disposal of Chlorinated Water* (Tikkanen et al, 2001) addresses the disposal of chlorinated water in compliance with federal, state, and provincial regulations, while minimizing the impact of these requirements on operations.

Combine flushing program with other preventive maintenance programs. A flushing program should not be a stand-alone effort that requires additional crews for a single purpose. Rather, implementation of a flushing program should be coordinated with other distribution system preventive maintenance programs. In this way, labor savings can be realized, and a more comprehensive view of actual hydraulic conditions of the system can be attained. Combining maintenance programs can help the utility meet numerous water quality, operational, and maintenance goals. Additional maintenance programs that could be carried out simultaneously include tank cleaning; valve/hydrant exercising, survey, and inventory; fire department hydrant testing; sewer flushing; and street sweeping/inlet cleaning.

Notify the public. Citizen sensitivity to apparent waste by a public agency, the sight of a water utility crew letting hydrants run into the street, and the potential for discolored water during the flushing event can trigger numerous complaint calls. Therefore, public notification is essential to implementing and maintaining an effective flushing program. It is important for the public to understand the reasons that flushing is conducted, such as improving water quality, decreasing the reliance on chemical treatment and chemical use within the distribution system, improving system hydraulics, ensuring that water can and will be made available in emergency situations, and so on. Most people can appreciate these objectives and will be supportive of the utility's efforts.

REFINING AND EVALUATING A FLUSHING PROGRAM

Utilities may want to consider the following questions to evaluate and refine their own flushing programs.

WERE WATER QUALITY OBJECTIVES MET?

- Document improvements in water quality (e.g., improved chlorine residual, decreased turbidity, fewer customer complaints, less time to reach water quality objectives from year to year).
- If objectives were not met, was the situation improved or worsened?

WHAT WERE THE ESTIMATED COSTS/SAVINGS ASSOCIATED WITH THE PROGRAM?

- Assign actual costs when possible (e.g., labor, power, equipment, disposal requirements, planning/notification efforts).
- Estimate savings from conducting maintenance activities simultaneously.

WERE THERE POSITIVE SECONDARY EFFECTS BECAUSE OF THE FLUSHING PROGRAM?

- Were operating costs perhaps reduced (e.g., lower chemical dosage requirements, reduced power costs from decreasing pipe friction, improved valve/meter/hydrant life)?
- Was customer perception improved?
- Is there potential for increased industrial use as a result of water quality improvements?

WERE THERE NEGATIVE SECONDARY EFFECTS FROM THE FLUSHING PROGRAM?

These might include stirred-up portions of the system in uncontrolled fashion, increased chlorine residual that resulted in customer complaints, release of bacteria into the water column, exposed new surface of tubercles, and negative public perception/waste of water.

A good public notification program will educate and inform not only customers but other utility staff (especially field crews that will have direct contact with the public), regulators, and other stakeholders. Adequate notice should be given whenever possible using a variety of mediums to reach as many parties as possible. Depending on the size of your utility, one or more of the following notification methods may be more appropriate: mailer/bill inserts, newspaper notices, television and/or radio announcements, door hangers, telephone calls, electronic postings, and posting signage in the neighborhood during flushing.

All utilities should identify sensitive users, such as hospitals, high-tech industries with onsite water treatment requirements, and kidney dialysis patients, and try to accommodate their needs. In these instances, adequate notice of flushing is imperative. Perhaps flushing could be conducted at night to minimize effects on sensitive users, or, potentially, the utility could alter the point of service to the customer.

Utilities should also give customers an opportunity to provide feedback regarding the immediate effects of flushing on water quality at the tap, problems that may be experienced, or potential observations related to water quality improvements since flushing has been implemented. This type of information can be used by the utility to better plan its programs and to evaluate the effects and benefits of flushing.

STEP 3—PROGRAM IMPLEMENTATION AND DATA COLLECTION

Once a utility has identified water quality and hydraulic objectives, potential constraints to flushing, sensitive users, several methods for notifying the public and other stakeholders, and other preventive maintenance programs that can be combined with a flushing program, the actual flushing program can be implemented.

Developing and implementing a UDF program involves dividing system into loops. The first step is to divide the distribution system into individual loops. These are sections within the distribution system, starting at the water source(s) and ending at the system's periphery, to be flushed in sequence. Each loop consists of a manageable section, the size of which is determined with consideration to flushing crew size, duration of flushing, equipment availability, and location of water sources such as water treatment plant, storage tanks, and booster stations. The goal is to complete flushing each individual loop or multiple loops during the crew's predetermined work shift. This will allow for reopening all valves used for isolation while flushing the particular loop, which avoids keeping normally open valves closed for extended periods. An experienced two-person crew can often flush 1 mi (1.6 km) of pipe per day using a UDF approach.

Following loop delineation, desired flushing velocities must be determined. For practical reasons, large transmission mains with diameters greater than 24 in. (600 mm) are generally not flushed. Under the strictest definition of UDF, flushing velocities throughout the system must be ≥ 5 fps (1.5 m/s) (Oberoi, 1994). However, a unidirectional approach can be used at different velocities, depending on the desired water quality goals and system constraints, which may limit attainable velocities.

The next task in developing a UDF program is to prepare step-by-step flushing procedures, which provide precise instructions with regard to the sequence of valve and hydrant opening and closing. For each loop, an average of 10 to 12 steps can be developed. Depending on the complexity of the system, each step can be complemented with an individual map that clearly illustrates, in color, the valve and hydrant status (open or closed) during each step. Individual maps for each loop can be laminated and used by the flushing crew. Maps may be developed from geographic information system (GIS) coverages, computer-assisted design files, or even by scanning hard copies of maps that are not available electronically.

Prior to program implementation, it is recommended that a "worst case" loop scenario be tested to assess the extent of repairs, if any, that may be required during program implementation. Ideally, the repair crew should preconduct preventive maintenance activities for those valves and hydrants to be exercised during UDF implementation.

The final step is program implementation. This should be carried out with consideration to public and flushing crew safety. An effective UDF program requires not only good design but also proper execution. Some of the key techniques for an effective program include the following:

- Flushing should progress from the water treatment plant or well to the system's periphery.
- Flushing should progress from larger to smaller mains.
- As previously indicated, flushing velocities should ideally be at least 5 fps (1.5 m/s) if pipe scouring is desired.
- Valves and hydrants should be exercised prior to flushing (together with a vigorous maintenance program) to minimize interruptions during flushing.
- Crews should be properly trained and equipped.
- Flushing should ideally be performed during late-night and early-morning hours (11 p.m. to 5 a.m.) to minimize effects on customers and take advantage of high pressures.

Take safety into consideration. Safety is of paramount importance during flushing operations. Poor safety practices can result in damage to property and injury to both crew members and the general public. This is especially true with flushing velocities ≥ 5 fps (1.5 m/s). As with any field operation, there are a number of general safety considerations to be incorporated into flushing program activities.

Foremost is an active safety program to ensure employees are knowledgeable about typical water utility procedures and associated hazards. This program should include a system for rewarding employees for good safety records and encouraging suggestions for improving on-the-job safety. Additional safety considerations are provided in the sidebar on page 50.

Collect data to assess program success. A data collection program enables the utility to determine whether flushing objectives are being met and to assess secondary effects that may have occurred as a result of flushing. The program assumes that flushing is being carried out as an active maintenance practice to improve distribution system water quality. Data collection has been divided into three categories: baseline, during flushing, and post flushing.

Baseline. "How do I document the effectiveness of a flushing program?" was one of the most common questions posed at the flushing workshop. The answer may well be in monitoring. It is recommended that utilities conduct rigorous baseline monitoring throughout the distribution system—from source to periphery—including reservoirs, sample stands, inlets, and dead ends, to assess water quality conditions prior to implementing flushing. Collection of baseline data will help the utility to identify problem areas of the system that can most benefit from flushing, potentially avoiding the expense associated with flushing all portions of the distribution system. Parameters that are of concern to the utility should be monitored on a seasonal basis. Historical data can also be used to help set a baseline condition. Depending on the individual utility's water quality concerns and treatment practices, the following list of water quality parameters should be considered for a routine baseline monitoring program: disinfectant residual; color; pH/alkalinity; coliform; iron/manganese; DBPs; disinfectant/corrosion control dosages at the treatment plant; water quality–related customer complaints; turbidity; temperature; inhibitor concentration; HPC (using R2A media); conductivity; and ammonia, nitrate, and nitrite (for chloraminating utilities).

Several of these parameters can be analyzed onsite with only minimal cost to the utility. Monitoring frequency will vary based on available budget, the size of the system, and water quality variability throughout the system. Monitoring should be conducted on a seasonal basis at a minimum. Once problem areas are identified, flushing loops can be developed, and velocities can be selected to produce the desired water quality results.

It is recommended that utilities avoid implementing more than one system change at a time. For example, it may be difficult to assess the effects of a new flushing program on distribution system water quality if a treatment change—such as switching disinfectants—is made simultaneously.

Changes in bulk water chemistry can affect scales accumulated on pipes, and it may be difficult to separate out the effect of flushing at a certain velocity to achieve scouring versus the effect of softened scales because of changes in water chemistry.

Data related to costs, including labor, equipment, water use, and public notification, should also be diligently tracked so that a cost–benefit assessment can be conducted and the flushing program can be refined as needed. An AWWARF study (number 2605) titled "Cost–Benefit Analysis of Flushing" is currently under way to help utilities assess individual flushing programs.

During flushing. Water quality data collected during flushing should focus on the specific water quality objective (e.g., disinfectant residual, pH, turbidity). Parameters should be measured in the field. The data should be collected at the beginning, middle, and end of a flush. Data collected from the beginning of a flush should be taken after the hydrant barrel has been cleared. The time to reach the desired water quality goal (or time to clear) should be recorded, and this can be used as the flush endpoint. Ideally, at least one pipe volume will be discharged from the system prior to ending the flush. This will allow all suspended material to be removed from the main. Pressure and flow data should also be collected during a flush, and pressures should be checked upstream of the flush to ensure that pressures of at least 20 psi (138 kPa) are being maintained. In addition to pressures and flows, valve/hydrant locations and conditions should be recorded to update distribution system maps.

Additionally, data should be collected so that chlorinated water can be disposed of properly. Depending on local or regional requirements, dechlorination or pH adjustment may be necessary, and there may be limits to solids content and dissolved oxygen levels that can be discharged to fish-bearing streams. Appropriate data should be collected so that treatment of the discharged water can be accomplished effectively. Data related to downstream flows into storm or sanitary sewers should also be collected.

After flushing. Post flushing data collection has been divided into short-term and long-term monitoring. Short-term monitoring is necessary to assess secondary effects (positive and negative) that can be attributed to the flushing. It is recommended that the following parameters be measured upstream of the flushed area and from within the flushed vicinity: HPC (R2A media), turbidity, disinfectant residual, coliform, corrosion products, color, and other parameters of specific interest.

It is possible that flushing will have "stirred things up," although practicing UDF rather than conventional flushing and discharging at least one complete pipe volume should minimize this problem. However, it is incumbent on the utility to ensure that flushing activities have not inadvertently exposed customers to temporarily high levels of HPCs, coliform, and so forth.

Long-term post flushing is the same as baseline monitoring and should be continued at the same locations so that the benefits/drawbacks of flushing can be assessed.

Take the time to manage data. Each utility must take the time to record and evaluate the data collected before, during, and after flushing. Only by evaluating the data collected will the utility be able to justify the expense associated with a routine flushing program. Data analysis will also enable the utility to refine the flushing program, potentially reducing costs and water use, while still achieving the desired water quality improvements. Flushing data that should be routinely analyzed relates to water quality, flows and pressures, maintenance issues, customer complaints, and costs.

Comparison of short-term and long-term (baseline) water quality data from year to year will help to determine whether flushing has led to improved water quality conditions on a systemwide basis or just within specific problem areas. The time needed to reach water quality objectives (or time to clear) during the flush should be compared from year to year to determine whether required flush times have decreased. This type of analysis is especially important for utilities that are only flushing dead ends.

If time to clear is not decreasing over time, it is likely that no long-term benefits are being realized from the flushing program. Additional operational, maintenance, or source water treatment approaches may be necessary to improve water quality conditions. The type, number, and location of customer complaints should be reviewed as well, to determine whether flushing has improved certain water quality conditions at the tap or, conversely, created customer dissatisfaction. Additional information related to evaluating/refining a flushing program is provided under step 4.

Some flushing crews carry laptop computers in the field, and data can be instantly entered for later evaluation by the appropriate personnel. Data related to hydrant/valve location, position, and condition can be entered into the system's GIS or

A data collection program enables the utility to determine whether flushing objectives are being met and to assess secondary effects that may have occurred as a result of flushing.

hydraulic models to refine the calibration process.

STEP 4—EVALUATE PROGRAM AND REFINE IT AS NEEDED

Utilities should be able to justify the need for their flushing program (or, conversely, to justify the lack of a flushing program). It is possible that all anticipated benefits may not be realized instantly, and experimentation with velocities, duration, and frequency may be required to develop a program that is within budgetary constraints yet produces documentable improvements in water quality. For many utilities, maintaining a disinfectant residual throughout the system is justification enough for conducting routine flushing. For some utilities, knowing that it is doing everything possible to prevent water quality degradation and to maintain water quality conditions as close as possible to those at the point of entry is of great enough benefit to their customers that the flushing program is worth the time and expense. To conduct such an evaluation, it will be necessary to carefully document the costs, potential savings, benefits, and problems, as well as the secondary effects that can result from a flushing program. See the sidebar on page 53 for more information on evaluating and refining a flushing program.

It is up to the utility to assess the advantages and disadvantages associated with its individual flushing program and to make the necessary changes in program procedures so that negative secondary effects can be minimized. For example, public education/notification efforts may need to be increased if the public complains about wasted water. A UDF approach may be required if conventional flushing results in uncontrolled "stirred up" water in other portions of the system. Flushing times may not be adequate if scoured bacteria are not being discharged from the system. Velocities may be too high if tubercles are being exposed, causing red water problems.

FLUSHING PROGRAM BENEFICIAL TO MOST UTILITIES

The workshop participants agreed that a routine flushing program is part of a good overall maintenance program. However, utilities should not rely on flushing as a cure for chronic problems. Adequate source water treatment may be necessary to permanently prevent certain types of water quality deterioration.

Also, not all utilities will require flushing. However, before flushing is excluded from a maintenance program, these utilities should have an aggressive water quality monitoring program (well beyond that required by regulations) that documents that water quality conditions are optimized throughout the system.

If conducted in conjunction with other preventive maintenance practices, flushing may not require drastic increases in operating/maintenance budgets. In fact, savings may actually be realized.

The flushing approach, velocity, frequency, and duration will be specific to individual water quality concerns, hydraulic conditions, source water treatment, and system design. Utilities should select a flushing velocity based on specific water quality objectives. Experimentation with velocities, duration, and frequency should be part of a flushing refinement program.

Planning, public notification, and communication with stakeholders should be a mandatory aspect of all flushing programs. Many of the negative secondary effects discussed in this article can be avoided through proper notification of potentially affected agencies and customers.

Data collection before, during, and after flushing is imperative to understanding the benefits, costs, and secondary effects that occur because of flushing. If adequate data are not collected, program refinement and a cost–benefit analysis cannot be conducted.

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If you have a comment about this article, please contact us at journal@awwa.org.

Question of the Month

How Do We Maintain Our Well?

by John Stubbart

Q

The source of drinking water for our small system is two wells. We constantly perform preventive maintenance on our other system components, including chlorination equipment, storage tank, valves, and hydrants, based on standard operating procedures (SOPs) that we've compiled from information from manufacturers and books. However, there is not much material on how to monitor and maintain the wells. Can you advise us?

A. A production well is made up of two main components: the well and the pump/motor. A scheduled, budgeted process of testing, inspection, and maintenance to maintain well performance and water quality is needed to avoid catastrophic failure or complete rehabilitation of the well or its components. The key to maintenance is collecting the right data to monitor changes and help make decisions about your well's condition.

In *Taking Stock of Your Water System, A Simple Asset Inventory for Very Small Drinking Water Systems,* the US Environmental Protection Agency states that the useful life of a well is about 25 years. Pumps should last about 10 years. Just how long your well and pump last is subject to design and water quality, but the projected life span is a benchmark for capital budgeting. Knowing the history of any well problems and pump replacements will help determine the life expectancy of your well and pump.

Well Construction Information

Record keeping is essential to effective well maintenance. The first thing you need is information on the construction of your well so you can have a benchmark for the data you collect during the years of operation. If you don't already have it in your records, obtain a copy of the well completion report that the well driller filed with the local health department after drilling the well. This report provides construction information and describes the soil and geologic conditions around your well, along with other pertinent information (Figure 1).

The completion report should also contain a cross-sectional drawing of your well and related performance documents, which can be compared to your current well configuration and pump performance.

Well Logs

As wells age they sometimes develop hydraulic problems. Symptoms of problems include sand or turbidity in the pumped water, loss of flow, sudden changes in water quality, gradual drop in flow performance, and water level fluctuations (static and dynamic).

Well water quality changes can be seen in variability of color and turbidity. Indicators of biofouling include sudden slugs of brown, black, or red water, and unexpected and unexplained changes in water treatment performance, such as increased chlorine demand, short pump life, or a drop in flow performance and rise in well water level.

Typical water quality tests are for bacteria, iron, manganese, water hardness, sulfides, and other water constituents that cause problems with plugging, staining, water color, and taste and odor. These should be conducted annually or when a change is noticed with the well flow or water quality to assist in troubleshooting your problem.

To determine the health of your well and aquifer, monitor and record the following information weekly:

Flow

- Gal/min flow (gpm)
- Flow total from water meter on wellhead
- Visual inspection of first water (color, odor, grit)
- Listen and check meter for water flowing back into the well

Water level

- Static, level when the well is not pumping, at rest
- Dynamic, level during pumping (drawdown)

John Stubbart is the AWWA small systems manager. Reach him on the Small Systems Helpline at (303) 347-6191 or smallsystems @awwa.org.

Wellhead

- Sanitary seal condition (look for any holes or means of contamination in the well at the wellhead)
- Signs of corrosion on the wellhead piping and equipment
- Leakage in wellhead piping
- Check for proper operation of blowoff valve and other valves at the wellhead

Surface drainage should be directed away from the well casing, and surface water should not collect near the well. The well itself should not be located downhill from any source of pollution. Keep hazardous chemicals, such as paint, fertilizer, pesticides, and motor oil, far away from your well. Also, make sure the screen vent is clear.

Pump Logs

Records will also help you evaluate pump performance. A decrease in flow and an increase in amperage could indicate that the pump bearing is failing. If the flow and the amps are both decreasing, the impeller may be wearing down. If the water level and the flow are dropping, the well screen may be fouling or the water table in the aquifer is dropping.

Monitor and look for changes in the following for submersible or line-shaft pumps:

- Power supply; volts (before and during load), amp load, hertz
- Flow, gpm and total
- Flowmeter (note changes in meter function)
- Hours run, expected life of pump components
- Pressure (in psi) at wellhead
- Start/stop cycles (if possible)

Line-shaft pumps also should be checked and maintained for

- lubrication of the motor and
- line-shaft lubrication (drips per min).

Well Driller: ____________________

Driller's Address: ____________________

Driller's Telephone Number: __________ Well ID Number: __________

Construction Date (completion): ____________________

Surveyed Elevation of Wellhead: ______ Longitude: _____ Latitude: ______

Static Water Level: ____________________ (from surveyed measuring point)

Test Pump Rate: __________ Drawdown (ft): __________

Well Bore Diameter: __________ Depth: __________

Solid Casing Diameter: __________ Length: __________

Screened Casing Diameter: __________ Length: __________

Pump Intake Depth: __________ Air Line Depth: __________

Motor HP: _____ Motor Volts: _____ Motor Amps: _____ Motor Efficiency: _____

Pump Type: __________ Model #: __________ Rated Flow: __________

Attach a cross-section drawing of the well and pump with dimensions.

Figure 1. Sample well completion report

Regularly monitor these indicators to detect changes that signal the onset of well deterioration. If enough parameters are amiss, then you will have to consider well rehabilitation, which is the process of removing the effects of past deterioration to restore or improve well performance and water quality.

With enough of the right data, you or your consultant can determine the condition of your pumps and adjust the operations and maintenance schedule or plan for new equipment.

Monitoring Is Maintenance

Well monitoring *is* your maintenance program. It should be a combination of

- monitoring of indicators to forecast possible well deterioration;
- controlling well and pipeline fouling in its early stages through preventive treatment, such as well chlorination, pump removal, video inspections of the well, and cleaning; and
- planning and budgeting for repair, replacement, and rehabilitation of the well and pump.

A good well-monitoring/maintenance program helps ensure your well operates efficiently and produces the best water quality possible. Benefits include

- Longer pump and motor life
- Reduced chance of well failure
- Fewer crisis pump repairs
- Predictable pump replacement or well rehabilitation
- Lower peak power use
- Lower well lifetime costs
- Better water quality by preventing the pumping of contaminated groundwater, especially brackish water

For More Information

Opflow published a two-part series, "Water Well Rehabilitation," in January and February 2002, and the AWWA Bookstore has numerous related products available, including

- AWWA Standard A100, Water Wells
- M21, *Groundwater*, third edition
- M50, *Water Resources Planning*
- *Water Pumps and Pumping Systems*

Also, new AWWA Standards on submersible pumps and line-shaft pumps will be published next year.

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You don't wait for the oil light to come on in your car to get an oil change. Why maintain your wells any differently? BY JIM BAILEY AND ANDREAS WICKLEIN

CONSIDER A CAR-CARE APPROACH TO IMPROVE WELL PERFORMANCE

LONG-TERM WELL MAINTENANCE IS probably the most neglected component of well field operations. When a well isn't producing enough water to meet supply demands, the owner assumes the pump is the problem and calls a pump contractor or driller. If the pump isn't the problem, the next step is a quick rehabilitation and returning the well on-line.

This approach to managing well performance is like operating a car without ever changing the oil—until the warning light comes on—which shortens the car's life span and increases maintenance costs. Fortunately, well owners in the United States, Canada, and Europe are opting for a more holistic approach to well operation and maintenance by managing the entire lifecycles of their wells to optimize long-term performance.

Key factors that influence well performance include design, construction, operation, biological and mechanical plugging, and maintenance. The extra attention and money expended to address these factors will result in wells with maximized production capacity and minimized repair downtimes.

In well design and construction, it's best to maximize the screen or water-producing interval of the well to the entire thickness of the aquifer and to match the screen slot size with the formation material. This may require drilling a little deeper than anticipated or collecting additional formation samples, but the payoff is a more efficient well.

A common error in new well construction is insufficient development time. New well development is essentially the same as rehabilitation of an old well. The goal is to get enough energy into the surrounding formation to remove finer-grained material and develop a zone of relatively unobstructed pore spaces, allowing water to flow as directly as possible into the well. The more laminar flow is obstructed, the more the well is stressed and the less efficiently it will operate.

PHOTOGRAPH: NATIONAL GROUND WATER ASSOCIATION

Alan Eades (left) of Eades Well Drilling and Pump in Hobbs, N.M., consults driller's assistant Neal Heard as their down-the-hole hammer drills a residential well. The well totaled 224 ft deep and yielded 60 gpm.

PLUGGING PROBLEMS

For best results, pumps should be located above the uppermost screen or screens to promote flow along the entire screen length, which reduces entrance velocities or stress. A pumping test of at least 24 hr—ideally 72 hr—is required to determine the optimal long-term pumping rate. The operational pumping rate should minimize drawdown caused by well inefficiencies and provide for long-term safe yield from the aquifer.

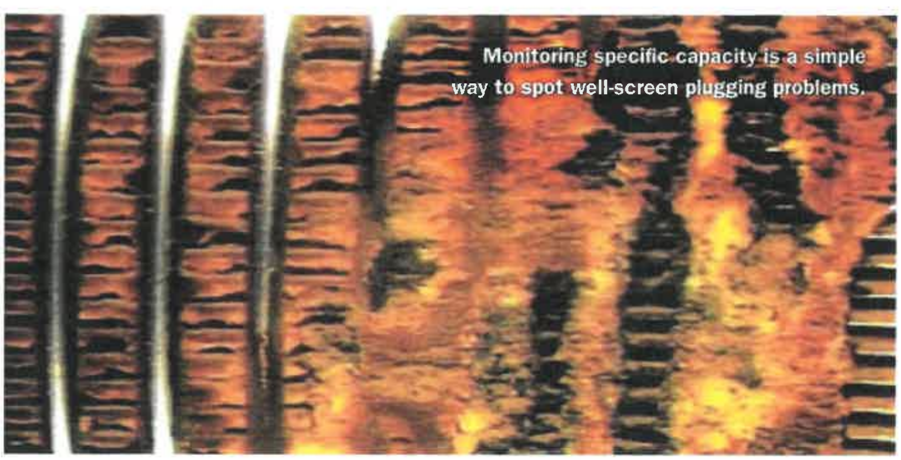
An aquifer's natural microbiology usually proliferates when a well is installed and operating. The available supply of food or dissolved minerals greatly increases around the borehole of the well and screen interval because of increased flow velocity and turbulence. This allows for more rapid growth of biological deposits or formation of mineral encrustations that can plug screen openings and the pore spaces near the screen and borehole. Operation also pulls fines in from surrounding formations, which plug the pore spaces and eventually reduce the open area for water to enter the well.

In most wells, the primary water-producing zone isn't uniformly distributed across the entire length of a screen interval. For example, in a 20-ft screen interval, a significant portion of the well's capacity might come from a 10-ft section of the screen. This zone suffers the most functional impairment from biological and mechanical plugging. Likewise, impairment of the localized zone pushes other portions of the water-bearing zone to supply water to maintain the desired capacity. Ultimately, added stress on the well reduces efficiency and increases biological and mechanical plugging problems. One of the best ways to minimize plugging is to recognize and repair problems early.

Monitoring specific capacity is a simple, reliable way to spot plugging problems. A well's specific capacity equals the discharge rate or gpm divided by the water level drawdown or feet. A well with a pumping rate of 100 gpm and 10 ft of drawdown has a specific capacity of 10 gpm/ft of drawdown. By keeping track of the specific capacity over time, a well owner can assess when conditions are beginning to affect well performance and schedule maintenance accordingly.

If plugging conditions aren't addressed early, the loss rate in specific capacity will increase faster over time, and the lost specific capacity will become more difficult to regain. A good rule of thumb is to initiate maintenance when specific capacity declines by about 10 percent.

Ideally, well maintenance shouldn't wait until there's a loss in specific capacity. Like regular oil changes in a car, regular well maintenance extends well life and results in lower long-term operational costs. When a well pump is pulled, a video inspection can help determine if biological plugging is occurring and if rehabilitation is necessary. A periodic pumping test will help determine if the well has lost efficiency, which—if there's no biological plugging—could indicate mechanical plugging from the migration of fines.



Monitoring specific capacity is a simple way to spot well-screen plugging problems.

TIME TO REHABILITATE

Most well owners must eventually address well performance and rehabilitation. To maintain long-term performance and well life, rehabilitation should be planned at regular intervals. Primary rehabilitation options fall into three categories

- Chemical—acids, bases, dispersants, antibacterial agents
- Mechanical—surging, brushing, jetting, freezing
- Impulse generation—detonation cord, impulse generators

Before selecting a particular method, the contractor should assess the well's condition and prepare a rehabilitation plan. Remember, a successful rehabilitation project typically isn't related to one particular rehabilitation method. Rather, it's a process that includes using approaches from the categories outlined above.

The contractor should monitor the rehabilitation work throughout the process to evaluate progress and document when further efforts aren't necessary. Concluding the rehabilitation work too soon will result in a less efficient well and one that will likely need additional rehabilitation much sooner.

A NEW REHABILITATION ALTERNATIVE

Impulse generation has shown significant results when used in old well rehabilitation and new well development. The principle effect of this process lies in the managed sudden release of a compressed gas that produces an elastic impulse and a secondary expansion of the gas bubbles, which cause the formation material and well screen to vibrate, loosening mechanically plugged sediment and biological deposits. The impulse generator is inserted and positioned in the well screen or water-producing

When a well pump is pulled, a video inspection can help determine if biological plugging is occurring and if rehabilitation is necessary.

An impulse generator uses compressed gas to loosen mechanically plugged sediment and biological deposits.

zone, and, through a pressurized hose, temporal impulses of high-pressure nitrogen are released. The impulse generator is equipped with a valve system that releases the accumulated energy (200 psi to 1,200 psi) in millisecond bursts through a large cross-sectional area.

Recent independent research by the Ground Water Research Center in Dresden, Germany, compared the ability of various well rehabilitation technologies to affect the gravel pack and surrounding formation materials. The technologies evaluated included high- and low-pressure water jetting, sonic devices, and impulse-generation devices. The study focused on each method's ability to generate energy at various distances into the formation surrounding a well. The impulse generator proved the most effective technology concerning penetration depth and energy measured beyond the well screen.

Impulse generators can be used in various well types, including vertical and horizontal stainless steel screened wells, perforated or slotted steel casing wells, uncased open-hole wells, and PVC-lined wells. The technology's advantages include

- a wide range of applications.
- effectiveness.
- a powerful impulse simultaneously sustained throughout the well screen or screens that provides good coverage.
- fast, cost-efficient operation.
- no harmful side effects or by-products.

This impulse generation method has been used in Germany for several years. It's one of the primary methods the city of Berlin uses to maintain more than 850 wells.

The impulse generation method has also been used in the United States for new well development and rehabilitation. For example, the city of Coeur d'Alene, Idaho, built a 24-in.-diameter well for water supply purposes. Initial well capacity was about 2,200 gpm. In less than one year, the city noticed declining specific capacity, with the pumping rate eventually lowered to about 1,600 gpm with 90 ft of drawdown. After initial assessment, the city determined that the well hadn't been adequately developed. Subsequent redevelopment was completed in three phases, with each phase consisting of the following steps:

- 30-min pumping tests to determine specific capacity
- impulse technology with simultaneous pumping
- isolation pumping and surging through the screen interval
- sediment removal from the well bottom

Specific capacity values were used to gauge progress after each phase of the redevelopment process, and water quality was monitored with an Imhoff cone during each phase to observe turbidity and the volume of sediment being removed from outside the well screen. The rehabilitation work succeeded in returning well yield to nearly the original capacity and improving well efficiency to a pumping rate of 2,100 gpm with 30 ft of drawdown. Specific capacity improved from 18 gpm/ft to 70 gpm/ft.

In addition, the city of Salisbury, Md., has used impulse generation technology on several wells. One well constructed in 1983 had an original specific capacity of about 31 gpm per ft of drawdown and a yield of 1,000 gpm. The well's construction included a 12-in. casing and stainless steel screen to a depth of 64 ft, with a screen interval consisting of one continuous length of wire-wrapped screen from 44 ft to 64 ft. A 2006 pumping test indicated that the specific capacity had declined to 3 gpm/ft and the pumping capacity was less than 100 gpm.

Video inspection of the well showed extensive biological plugging of the screen slots throughout the screen interval. The rehabilitation plan included

- brushing of the well casing
- high-pressure water jetting
- impulse generation technology
- mechanical surging and pumping

The initial brushing and high-pressure jetting improved specific capacity from 3 gpm/ft to about 10 gpm/ft. Impulse generation technology further rehabilitated the well by loosening fines and biological deposits outside the screen and in the surrounding formation. After three rounds of impulse technology consisting of mechanical surging and pumping, specific capacity improved to 20 gpm/ft.

PHOTOGRAPHS: KLEINFELDER

http://dx.doi.org/10.5991/OPF.2013.39.0057

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Most wells eventually lose capacity and experience lower pumping water levels, resulting in increased pumping costs. Implementing a time-based maintenance program can avoid potential problems. Ongoing performance monitoring can signal when it's time for rehabilitation to maintain or restore performance. BY RAY REECE, BILL PREHODA, AND RANDY MOORE

MAINTENANCE WELL ASSET MANAGEMENT INCREASES SERVICE LIFE

***Editor's Note:** This is the second of a three-part series of articles based on a series of AWWA webinars on distribution system issues. The first article, which appeared in the September 2013 issue, described what biofilms are, what problems they create, how they relate to coliforms, and how to evaluate them. This article reviews water well rehabilitation technologies and discusses how they can be incorporated into a well asset management program. The final article, which will appear in the November 2013 issue, will cover new leak-detection technologies coming to the United States. For more information, visit www.awwa.org/webinars.*

WATER WELLS, like other distribution system assets, require periodic maintenance and rehabilitation. An effective condition assessment can help you select the proper rehabilitation technology (or technologies) from a wide array of options.

It's possible to develop a sustainable well asset management program and, with some rehabilitation technologies, install hardware in the well that allows periodic maintenance without removing the pump. Based on the condition assessment and ongoing monitoring data, a cleaning schedule can be established to maintain performance and water quality.

PHOTOGRAPHS: SUBSURFACE TECHNOLOGIES

Effective well performance monitoring and regular condition assessments allow personnel to select the most effective rehabilitation technology. With some technologies, such as carbon dioxide, hardware installed at the wellhead allows the cleaning technology to be installed into the well while the pump is in place.

WELL PLUGGING

Nearly all wells experience plugging, which can result in lost capacity, water quality changes or deterioration, increased pumping costs, and possible increased treatment costs. Most well plugging is caused by naturally occurring groundwater bacteria and biofilm that deposit minerals in pore spaces, gravel pack, and well screen intervals.

Run to failure often has been the accepted approach to well rehabilitation and maintenance. Run to failure means wells are operated until the production rate declines, the well begins to pump sand, or water quality declines to an unacceptable level from customers' or regulatory compliance perspectives.

A customized, sustainable asset management program employs rehabilitation technology to restore a well to or near its original design parameters based on a full condition assessment. Then, based on each well's specific characteristics, a time-based preventive maintenance program should be developed and implemented to maintain well performance and water quality, extend the well's service life, and reduce or eliminate the need for future rehabilitations.

EFFECTIVE REHABILITATION

Well rehabilitation requires several steps to be successful. The following nine-step process will assure effective rehabilitation:

- Conduct an accurate pre-rehabilitation pump test using a calibrated flow device, such as a manometer and orifice system, to determine the current performance of the well and pump.
- Use an adequate pump-removal rig to safely remove pumping equipment.
- Inspect and repair the pump. When the rehabilitation is complete, replace the pump.
- Video-inspect the well to confirm its construction and identify integrity concerns within the casing or screen intervals.
- Conduct pretreatment using mechanical tools (wire or polypropylene brushing).
- Based on information obtained in the condition assessment, apply the appropriate rehabilitation technology.
- Redevelop the well using a down-hole airlift or pump-equipped double-disk swab made specifically for this type of work. Removing plugging materials is critical to the rehabilitation effort's longevity.
- Conduct a post-development video inspection to confirm cleaning results and inspect the casing/screen for integrity.
- Install pumping equipment with optional in-hole preventive maintenance tools.
- Conduct a post-rehabilitation pumping test to confirm well and pump performance conditions, set a benchmark

CASE STUDIES

CUSTOMIZED STRATEGIES RESTORE WELL PERFORMANCE

Each well is unique and requires an effective condition assessment to determine the optimum rehabilitation technology or technologies. The following case studies demonstrate that each well requires a customized rehabilitation strategy to restore performance and water quality.

Wells 29/29A. Well 29 is a vertical, screened well that taps a shallow sand aquifer. With an original design of 1,400 gpm, pumping Well 29 resulted in entrained sand caused by high-velocity water entering and clogging the well, which reduced capacity. Although rehabilitations using surge blocks with simultaneous air pumping regained some capacity, rehabilitations couldn't remove all of the clogging sand. Therefore, a new well was drilled.

Well 29 was replaced by Well 29A, which was designed to operate at 1,000 gpm or less to reduce entrance velocities and limit sand migration while retaining short-term peak-production capabilities of 1,400 gpm. Periodic pumping tests to monitor performance confirm Well 29A's ability to maintain the designed pumping rate. Periodic well rehabilitation focuses on physical energy to mobilize and remove sand.

Well 29A rehabilitations have included surging with simultaneous pumping and pressurized nitrogen. Nonphosphate surfactants have been used during surging to help mobilize fines. During rehabilitation, daily monitoring of the discharge flow rate and water levels allow personnel to track the rehabilitation's efficacy and a particular technique's effectiveness. Using high-pressure nitrogen at Well 29A has helped loosen compacted sediments and potential cementation of sediments. By removing the surge equipment, conducting high-pressure nitrogen pulses at about 1,200 psi, and reinstalling the surging equipment, nitrogen can be used during the surging process. A combination of rehabilitation techniques is helping Well 29A regain and maintain well capacity.

Well 29A and Well 27 are located in a two-well wellfield. Although several years older than Well 29 and constructed similarly in the same aquifer, Well 27 requires periodic rehabilitation but doesn't need to be replaced, illustrating that similarly constructed wells in the same area may react differently over time.

Well 42A. Vertically screened Well 42A taps a shallow sand and gravel aquifer. The well is 70 ft deep with 15 ft of 12-in.-diameter 60-slot screens originally rated at 300 gpm. The well has a history of severe iron- and manganese-related bacteria biofouling. A pre-rehabilitation video showed significant biofilm on the screen, which was in good condition. Pre-rehabilitation pumping tests revealed significant capacity loss caused by biofouling.

Effective well performance monitoring and regular condition assessments allow personnel to select the most effective rehabilitation technology.

for future comparisons and monitoring, and produce a final report that includes all results and performance factors associated with the condition of the well and pump.

ASSET MANAGEMENT

Because most wells eventually lose capacity and experience decreased water levels and increased pumping costs, ongoing performance monitoring can signal when it's time for rehabilitation to restore performance and water quality. Sustainable well asset management programs can be developed that avoid the practice of running to failure.

With certain well rehabilitation technologies, such as carbon dioxide, hardware installed at the wellhead allows the cleaning technology to be installed into the well while the pump is in place. When the hardware is installed, mini-cleanings can be performed per a time-based program to maintain well performance:

- A pretreatment (short) pump test determines pre-maintenance performance of the well and pump.
- Maintenance treatment is applied, with the pump in place.
- Post-application, the pump is operated to remove disrupted material from the well until satisfactory water is produced, followed by a pump test and report.

The benefits associated with this asset management approach include

- a significantly extended asset life cycle.
- reduced and/or maintained operational costs.
- improved well performance, consistency, and maintenance.
- predictable costs (flat and fixed annual fee for budgeting).
- consistent water quality by maintaining production from the proper zones.
- improved knowledge of well and system conditions with annual maintenance and associated reports.
- proactive well maintenance, instead of crises repairs or maintenance when wells are run to failure.
- time-based maintenance cleanings to keep well surfaces clean and maintain performance.

AN OUNCE OF PREVENTION

Most wells experience decreased performance and water quality over time. Effective well performance monitoring and regular condition assessments allow personnel to select the most effective rehabilitation technology. Develop an ongoing sustainable well management program by conducting periodic cleanings—with the pump in place—that will maintain well performance and water quality, eliminating the run-to-failure practice.

After wire brushing loosened biofouling from the screen, the material was pumped out so subsequent procedures didn't push the material into the aquifer. Next, pressurized carbon dioxide was injected. The well, including the nearby test well, was sealed with a packer to prevent short circuiting of the carbon dioxide. Over two days, 4,000 lb of carbon dioxide were injected to dislodge clogging material, in this case biofouling.

The final technique used surging with simultaneous pumping to remove material dislodged by the carbon dioxide treatment. Because of the action of the carbon dioxide injection, surging duration is usually less (2–3 days in this case) than when carbon dioxide isn't used.

A post-rehabilitation video of the Well 42A screen revealed dramatic cleaning results. The post-rehabilitation pumping test revealed the initial carbon dioxide treatment restored the well's original capacity. Although subsequent rehabilitations didn't restore original capacity, the design rate was maintained but with greater water-level drawdown.

Because more frequent rehabilitations were needed for Well 42A, a permanent stainless steel injection pipe was installed to allow periodic carbon dioxide injections without having to remove the pump. To date, yearly injections have maintained Well 42A's capacity.

Well 100. A 126-ft deep vertical well that taps a sand and gravel aquifer, Well 100 has a design pumping rate of 1,200 gpm. Performance monitoring over time revealed that Well 100 had lost capacity because of small amounts of sand migration, iron biofouling, and iron oxyhydroxide precipitation. A recent pre-rehabilitation video survey showed minor biofouling and iron precipitate as well as a casing perforation (up to 1 in.) attributed to corrosion. The casing perforation, if unchecked, would allow entrainment of sand and gravel in the pump, possibly causing the well to collapse. The ultimate solution would be to redrill the well and provide corrosion protection. However, in the interim, a liner screen was installed to allow the well's continued use.

Before the liner screen was installed, the well was rehabilitated because performance monitoring showed decreased well capacity. Future liner-screen rehabilitations will be more difficult because of additional well losses associated with having two screens.

Well 100 rehabilitation was initiated with a surge block outfitted with a submersible pump for simultaneous pumping. Nonphosphate surfactants (to mobilize fines) and hydrochloric acid (to dissolve precipitates) were also used during rehabilitation.

After rehabilitation, a 40-ft, 125-slot telescoping liner screen with a K-packer was installed within Well 100. Post-rehabilitation pumping test results revealed capacity had increased from the pre-rehabilitation level. Although the liner screen caused some expected capacity loss, Well 100 is operating at its 1,200-gpm design capacity.

APPENDIX “I”

Proposed Elevated Tank Mixing Information

TIDEFLEX MIXING SYSTEM (TMS)

PRELIMINARY DESIGN REPORT

Tank Name: 1.0MG Elevated Tank

Water Utility/Owner: City of Fairbury, NE

Consultant: Olsson Associates

CONTENTS

TMS - GENERAL ARRANGEMENT DRAWING

TMS - MIXING ANALYSIS

WATER AGE ANALYSIS

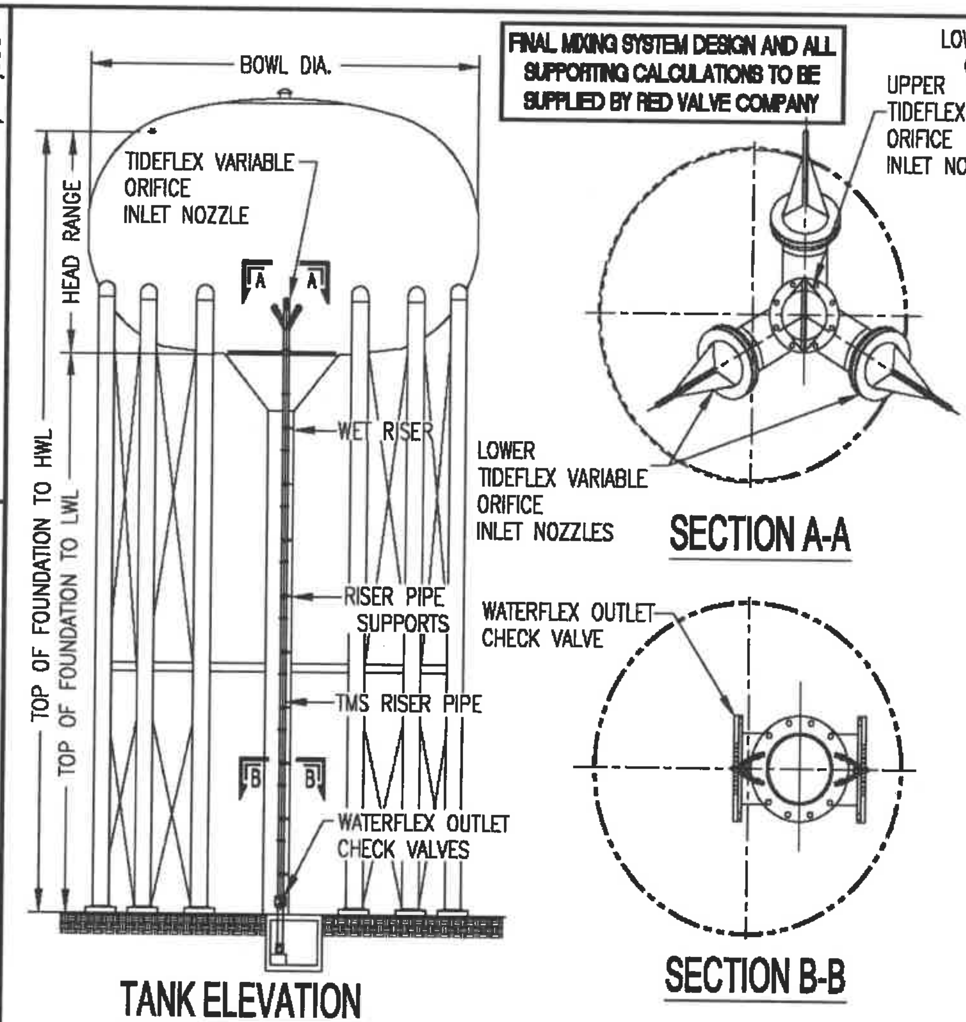
MANIFOLD HYDRAULICS / SYSTEM HEAD CURVE- FILLING CYCLE

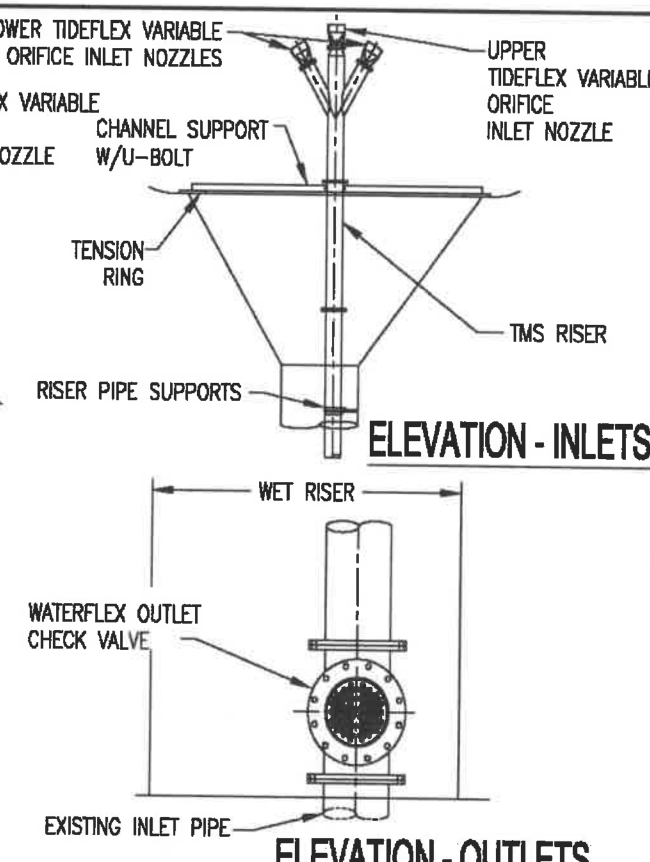
MANIFOLD HYDRAULICS / SYSTEM HEAD CURVE- DRAW CYCLE

ANALYSIS BY:
Michael Duer, P.E.

Tideflex Technologies
A Division of Red Valve Company,® Inc.

June 13, 2017





NOTES:

1. DO NOT USE THIS DRAWING FOR CONSTRUCTION. DRAWING INTENDED AS A GENERAL REPRESENTATION ONLY.
2. QUANTITY, SIZE, ELEVATIONS, LOCATIONS, AND DISCHARGE ANGLES OF TIDEFLEX INLET NOZZLES AND/ OR OUTLET CHECK VALVES ARE TANK-SPECIFIC BASED ON HYDRAULICS, MIXING AND TURNOVER CRITERIA.
3. CARBON AND STAINLESS PIPE SECTIONS MAY BE SUPPLIED WITH PLAIN ENDS TO BE BUTT WELDED IN THE FIELD.

S.O.#: QUOTE #:

NOT FOR CONSTRUCTION

REV	BY	DATE	DESCRIPTION

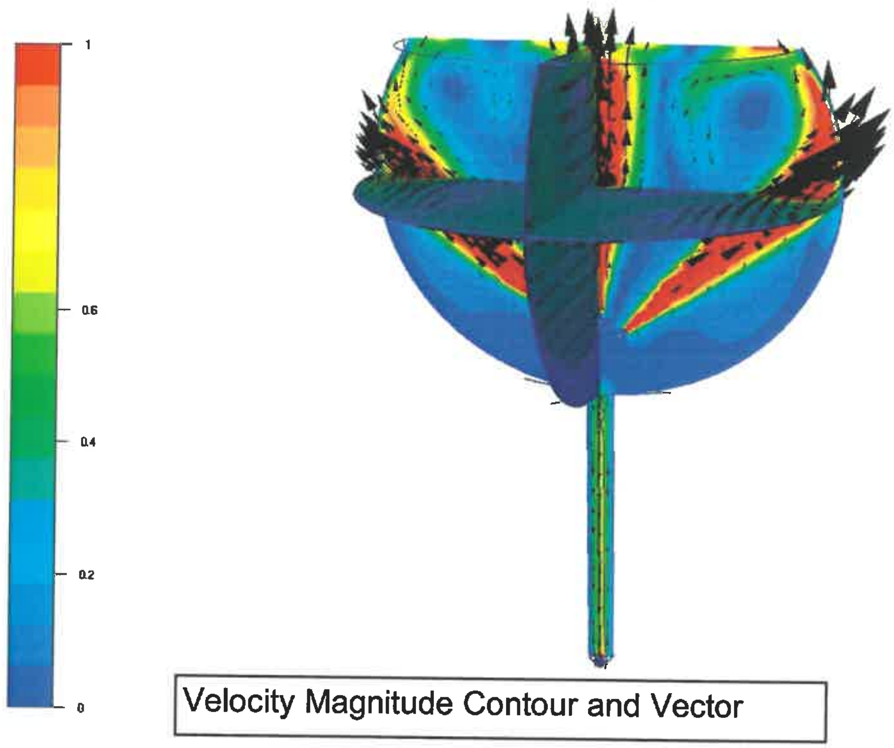
Tideflex Technologies
A Division of Red Valve Company, Inc.
TIDEFLEX TECHNOLOGIES
TIDEFLEX MIXING SYSTEM
700 N. BELL AVENUE
CARNEGIE, PA 15106 USA
PHONE: 412-279-0044
FAX: 412-279-5410
WEBSITE: WWW.TIDEFLEX.COM
EMAIL: INFO@TIDEFLEX.COM

TMS GENERAL ARRANGEMENT FOR ELEVATED TANK WITH WET RISER

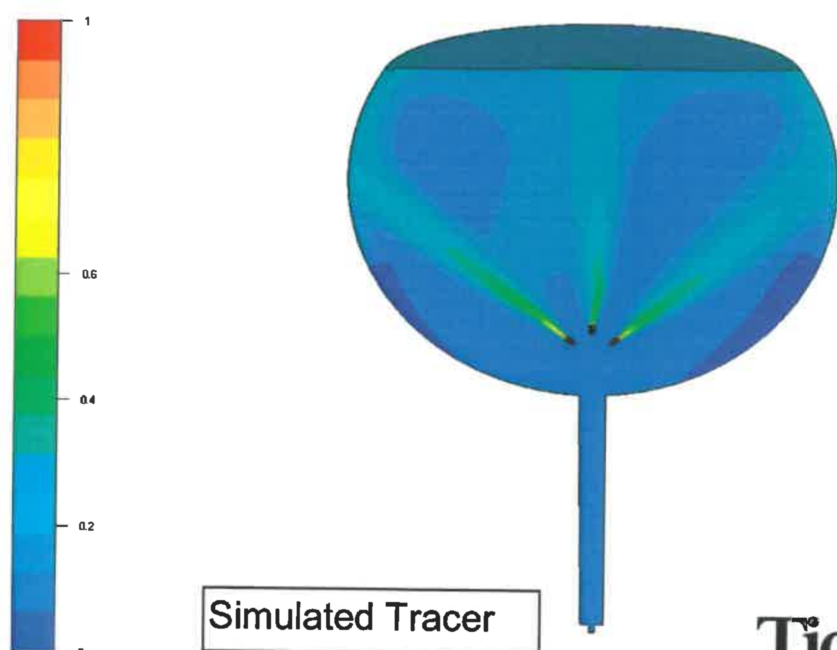
CONSULTANT:
APPLICATION: (TMS) TIDEFLEX MIXING SYSTEM
SCALE: FULL PLOT:
DWG. BY: G.MARRA DATE: 5/1/07
DWG. NO. TMS-ELV3
SHEET 1 OF 1

Computational Fluid Dynamics (CFD) Modeling

Below are CFD images showing representative velocity magnitude and simulated tracer images of this TMS configuration in an elevated tank



CFdesign for Windows 6.0



Tideflex
Technologies
A Division of Red Valve Company, Inc.

TIDEFLEX RESERVOIR MIXING ANALYSIS

1.0MG Elevated Tank
City of Fairbury, NE

The Reservoir Mixing Analysis (RMA) is to be supplied to the water utility/owner as it provides guidance on the tank turnover/fluctuation required to ensure complete mixing with the TMS installed. Maintaining water quality in tanks and reservoirs is a combination of achieving complete mixing AND tank turnover to minimize water age. It is critical to achieve complete mixing to prevent a localized increase in water age (and associated water quality problems) due to short-circuiting and dead zones.

The RMA calculates the dependent variables and uses the mixing time formula to calculate the "Theoretical Mixing Time" (MT) at various filling flow rates. The MT is the fill time required to achieve complete mixing. The required drawdown (in feet), % turnover, and the required volume exchange (in gallons) are calculated based on these mixing times. These values are shown in the "Guide to Tank Fluctuation and Turnover" section of the RMA. A slightly greater drawdown/turnover is typically recommended to be conservative.

Within the "Guide to Tank Fluctuation and Turnover" is a "Minimum Tank Fluctuation Target". This is applicable for tanks that operate in fill-then-draw. This is the minimum amount the tank should be drawn down on the draw cycles to ensure complete mixing on the fill cycles. This data is intended to be used by operators in conjunction with SCADA and strip charts (where applicable) to verify adequate tank turnover and to determine "pump on" and "pump off" set points (where applicable). For tanks that operate in simultaneous fill and draw, the "Theoretical Mixing Time" (fill time required to achieve complete mixing) should be used to ensure the minimum fill time required is achieved.

The RMA also provides data on the time required to draw down the tank, at various draw rates, to the required level as determined by the mixing time calculations.

Note, the data provided on the required drawdown, % turnover and volume exchange are to ensure complete mixing of the tank volume to prevent water quality problems associated with short-circuiting, incomplete mixing, and increased water age. A water age evaluation of the entire distribution system may dictate greater tank turnover than provided with the RMA. As long as the actual tank turnover/fluctuation is equal to or greater than that provided with the RMA, the tank will be completely mixed.

RESERVOIR MIXING ANALYSIS (TMS)

Tideflex Technologies — A Division of Red Valve Company, Inc.

13-Jun-2017

RESERVOIR / TANK NAME: 1.0MG Elevated Tank

CONSULTANT: Olsson Associates
Contact: Craig Reinsch, P.E.
Address:
phone
fax
email

UTILITY / OWNER: City of Fairbury, NE
Contact:
Address:
phone
fax
email

RED VALVE REP.: Willco Inc.
Contact: Jim Paprocki

ANALYSIS BY: Michael Duer, P.E.

** If "Effective" Bowl Diameter is shown, the tank diameter is calculated to make the volume compute correctly. Mixing times are based on volume.

RESERVOIR / TANK DATA

Effective Bowl Diameter	62.20	ft
Head Range / Depth to HWL	44.00	ft
Depth to LWL	40.00	ft
Tank Volume	1,000,000	Gallons
Tank Volume	133,681	ft^3
Gallons Per Foot =	22.727	

INLET / OUTLET PIPES / FILL / DRAW RATES

Outlet Dia. = 12.00 in

* Effective Diameter of TMS (See Note 1)

		Fill Rates (gpm)	Draw Rates (gpm)
Effec. Dia (in) =	AT	100.0	100
Effec. Dia (in) =	AT	200.0	500
Effec. Dia (in) =	AT	500.0	1000
Effec. Dia (in) =	AT	1000.0	2000

PROPRIETARY NOTICE

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FILL

INLET FLOW RATES (gpm)	Time to Fill Tank from Empty to H.W.L (Hours)	(Days)	Time to Fill to 1' Depth (Minutes)	(Hours)	Input Fill Time (Hours)	Resulting Increase in Water level (ft)	Volume Change (gallons)
100.0	166.67	6.94	227.27	3.79	7.7 →	2.0 →	45,961.91
200.0	83.33	3.47	113.64	1.89	4.6 →	2.4 →	54,611.00
500.0	33.33	1.39	45.45	0.76	2.3 →	3.0 →	68,493.62
1000.0	16.67	0.69	22.73	0.38	1.4 →	3.6 →	81,108.12

FILL / GUIDE TO TANK FLUCTUATION AND TURNOVER

INLET FLOW RATES (gpm)	Jet Velocity (fps)	JV^2 / 2g (feet)	Reynold's Number	Inlet Momentum (ft^4 / min^2)	Velocity Gradient, G (1/sec)	Theoretical Mixing Time (Fill Time Req'd for Complete Mixing) MT = K * V^(2/3) / M^(1/2) (Minutes)	(Hours) (SEE NOTE 2)	Req'd Drawdown on Previous Draw to Mix on Next Fill (feet) (SEE NOTE 2)	% Turnover Required (%) (SEE NOTE 2)	Volume Exchange Required (gallons) (SEE NOTE 2)
100.0	2.71	0.11	108,485	2,172	0.71	459.6	7.7	2.0	4.6	46,000.0
200.0	3.84	0.23	182,607	6,155	1.42	273.1	4.6	2.4	5.5	55,000.0
500.0	6.10	0.58	363,989	24,453	3.57	137.0	2.3	3.0	6.8	68,000.0
1000.0	8.70	1.18	614,758	69,755	7.20	81.1	1.4	3.6	8.1	81,000.0

MINIMUM TANK FLUCTUATION TARGET

DRAW

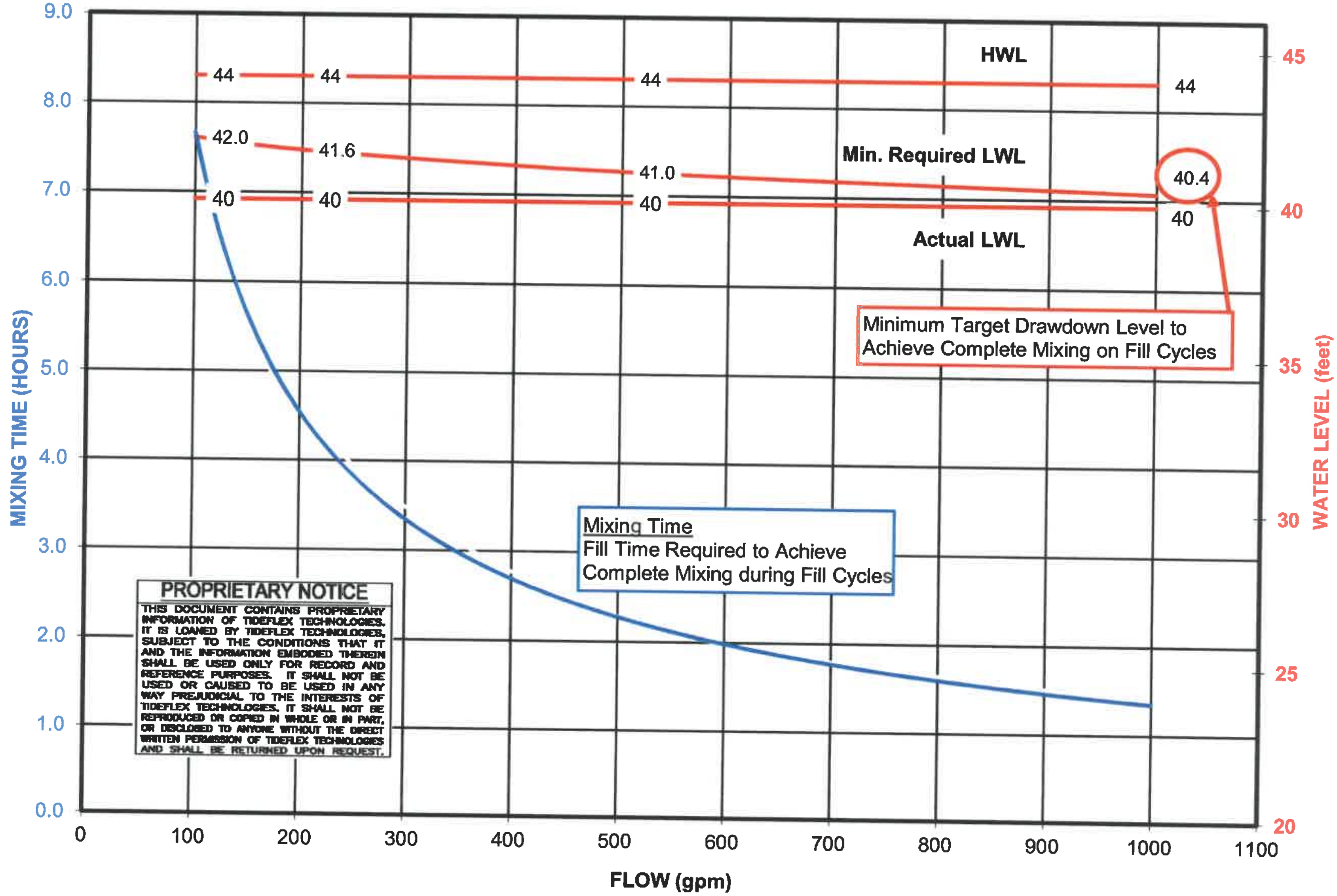
OUTLET FLOW RATES (gpm)	TIME TO DRAW TANK FROM FULL TO EMPTY (Hours)	(Days)	Time to Draw Down 1' Depth (Minutes)	(Hours)	Pipe Velocity (fps)
100	166.67	6.94	227.27	3.79	0.28
500	33.33	1.39	45.45	0.76	1.42
1000	16.67	0.69	22.73	0.38	2.83
2000	8.33	0.35	11.36	0.19	5.67

Volume Exchange Required (gallons)	Draw Time Required (Hours)	
81,000 →	13.5	@ 100 gpm Draw Rate
81,000 →	2.7	@ 500 gpm Draw Rate
81,000 →	1.4	@ 1000 gpm Draw Rate
81,000 →	0.7	@ 2000 gpm Draw Rate

* NOTE: 1. TIDEFLEX VALVES ARE INHERENTLY A VARIABLE ORIFICE SO THE TMS EFFECTIVE DIAMETER VARIES WITH FLOW RATE
2. MIXING TIME EQUATIONS DO NOT ACCOUNT FOR DIFFERENCES IN TEMPERATURE BETWEEN INLET WATER AND TANK (BUOYANT JETS) THESE CALCULATIONS MAY UNDERESTIMATE THE FILL TIME REQUIRED FOR MIXING.

TMS - Mixing Time and Minimum Required Drawdown

1.0MG Elevated Tank



Tideflex Technologies
A Division of Red Valve Company, Inc.

WATER AGE ANALYSIS

TIDEFLEX MIXING SYSTEM (TMS)

Actual/Predicted Daily Turnover and Water Age

High Water Level (HWL) = 44.00 ft
Low Water Level (LWL) = 40.00 ft

Turnover = 4.0 feet | 9.1 % | 90,906 gal

Ave. Water Age = 11.0 days

(Assumes tank is mixed. CAUTION: A single inlet pipe often does not mix. Water age could be much higher

Turnover Required for TMS to Achieve Complete Mixing

(GOAL: For Required Turnover for Complete Mixing to be Less Than Actual/Predicted Turnover)

The TMS will mix the tank with **Turnover =** 3.6 feet | 8.1 % | 81,106 gal
(see Mixing Analysis)

Ave. Water Age = 12.3 days

(Water age if tank turnover was the minimum required to achieve complete mixing)

RESULT

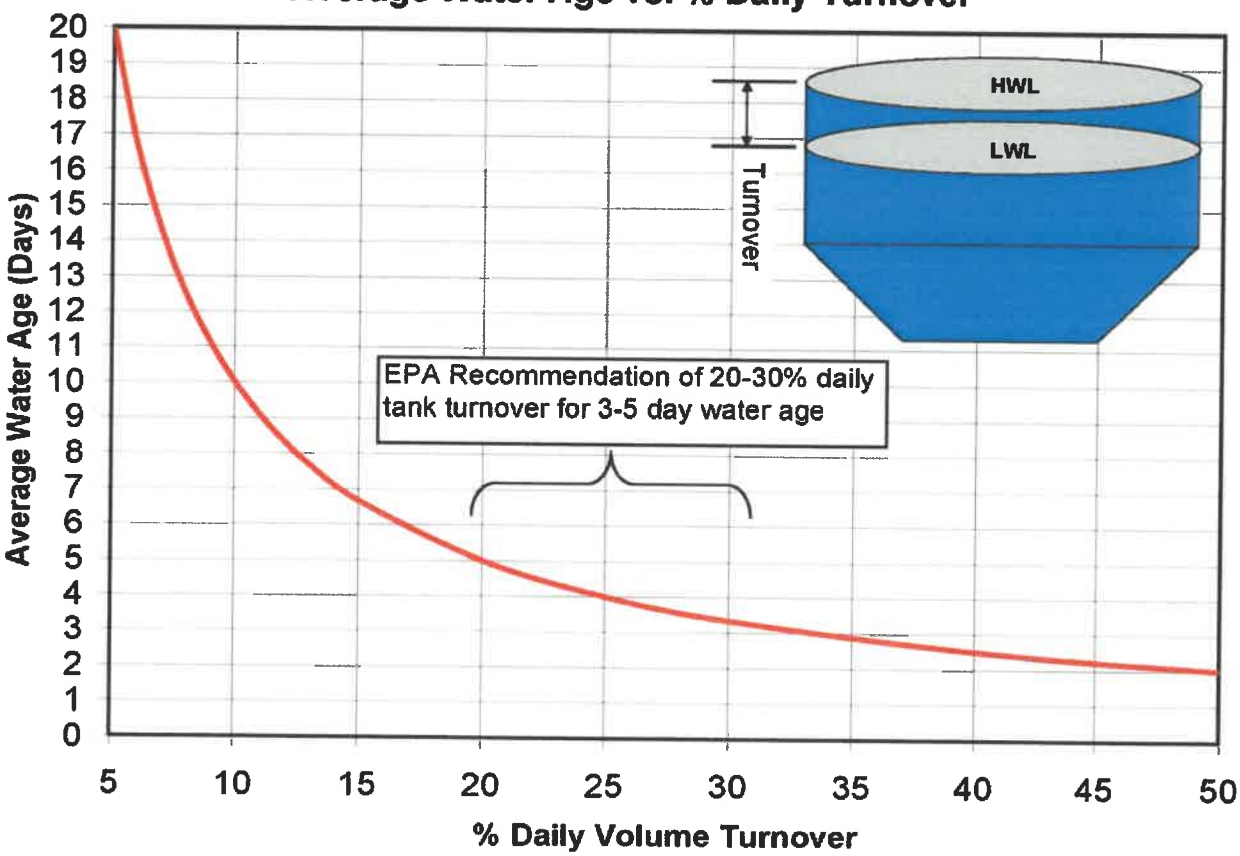
Is Actual Turnover Greater than Required Turnover to Mix with TMS? **YES**

If Yes, the TMS will Completely Mix the Tank. Applicable Water Age is from Actual/Predicted Turnover
If No, Tank May not be Completely Mixed but Will Not Short-Circuit. The TMS Separates the "Inlet" and "Outlet" and will Draw the Oldest Water from the Tank First

WATER QUALITY:

* Maintaining storage tank water quality is a function of:
  1) Maximizing volume turnover to minimize water age. See Water Age vs. Turnover Guideline below.
  2) Achieving complete mixing to avoid a localized increase in water age due to incomplete mixing and short-circuiting
* The TMS design addresses #2. Consultant and/or Owner to address #1 by looking at the "operation" of the distribution system and tank in order to maximize turnover. See Water Age vs. Turnover Guideline below.

Average Water Age vs. % Daily Turnover



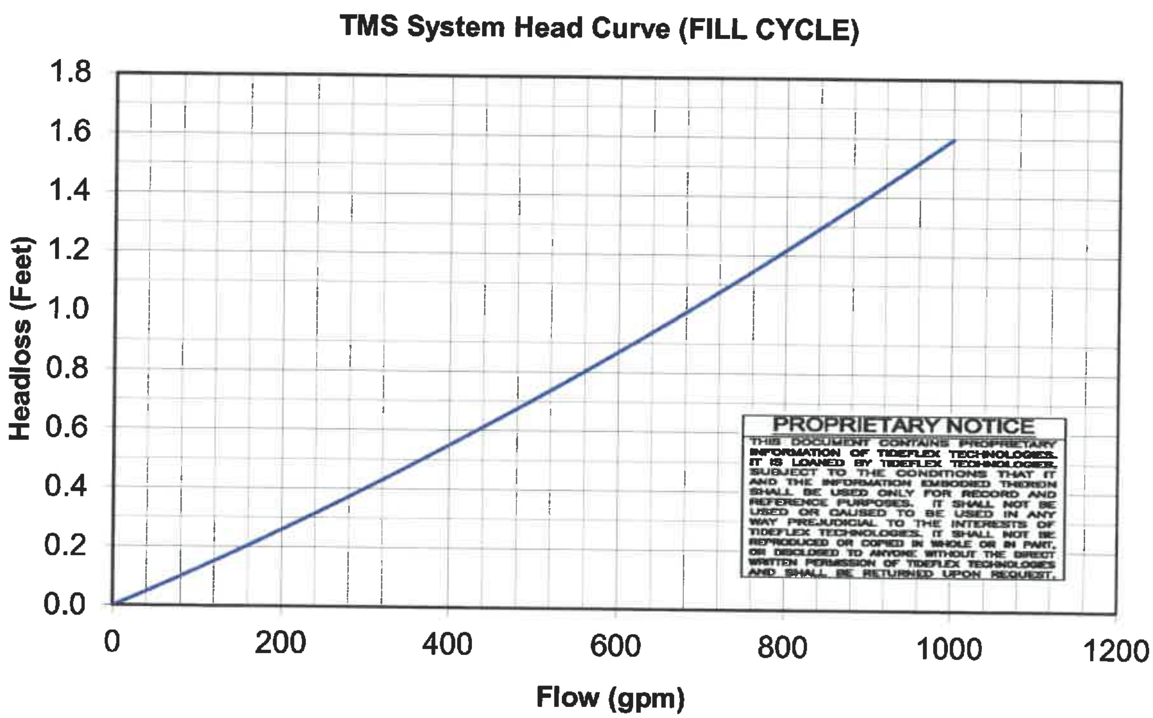
Tideflex Technologies
A Division of Red Valve Company, Inc.

TMS Manifold Hydraulics (FILL CYCLE)

Reservoir Name: **1.0MG Elevated Tank**
Reservoir Size: **64.5' Dia. x 44' HR**
Reservoir Capacity: **1.0 MG**
End User: **City of Fairbury, NE**
Consultant: **Olsson Associates**

Ambient Density = **62.4** lbm/ft^3
Effluent Density = **62.4** lbm/ft^3
dS/S = **0**
C = **100** Hazen Williams Coeff.
Cd = **0.95** Cd

Flow Rate (gpm)	Jet Velocity (fps)	Friction Headloss (ft)	Total Headloss (ft)
100.0	2.7	0.01	0.1
200.0	3.8	0.02	0.3
500.0	6.1	0.10	0.7
1000.0	8.7	0.36	1.6



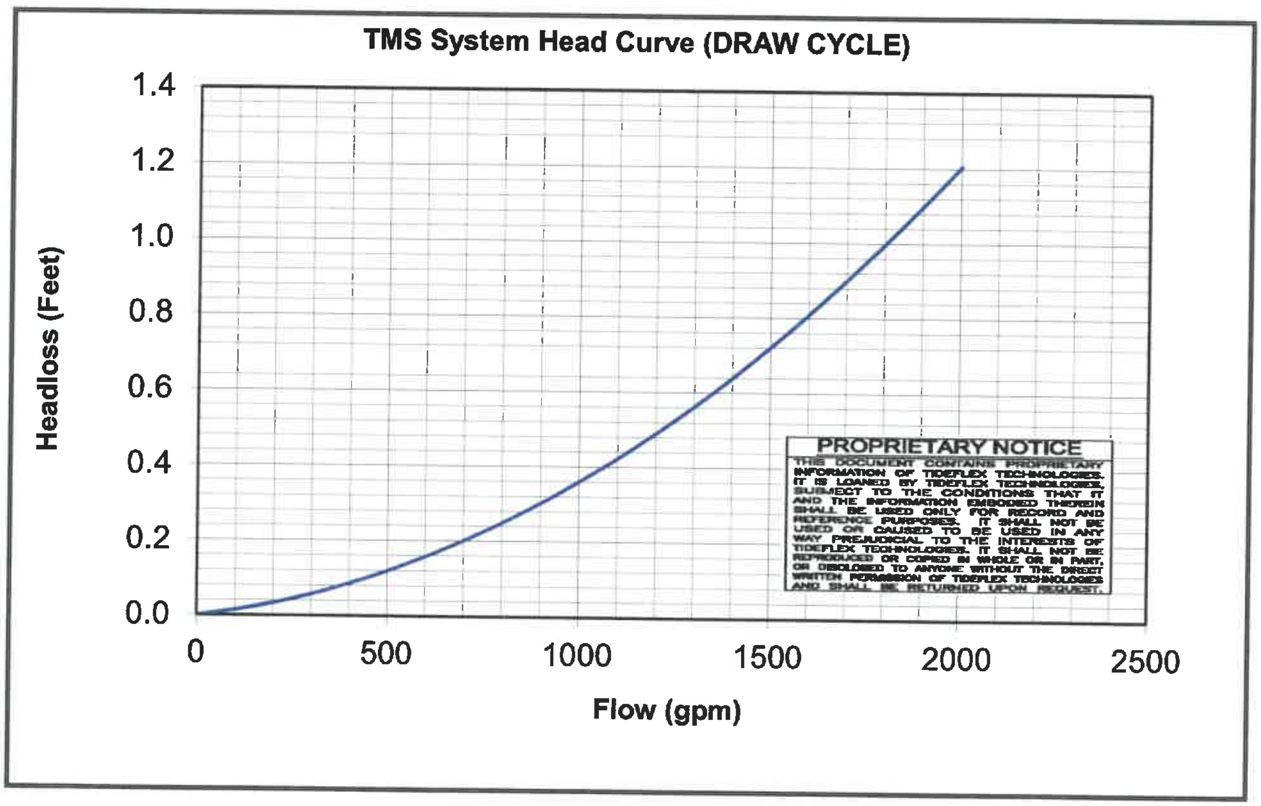
Tideflex Technologies
A Division of Red Valve Company, Inc.

TMS Manifold Hydraulics (DRAW CYCLE)

Reservoir Name: **1.0MG Elevated Tank**
Reservoir Size: **64.5' Dia. x 44' HR**
Reservoir Capacity: **1.0 MG**
End User: **City of Fairbury, NE**
Consultant: **Olsson Associates**

Ambient Density = **62.4** lbm/ft^3
Effluent Density = **62.4** lbm/ft^3
dS/S = **0**
C = **100** Hazen Williams Coeff.
Cd = **0.95** Cd

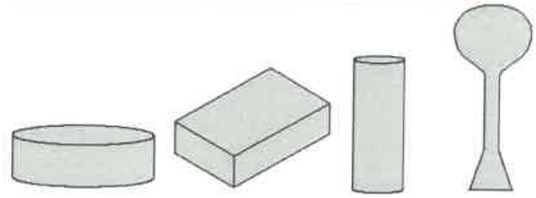
Flow Rate (gpm)	WF-3 Headloss (ft)	Friction Headloss (ft)	Total Headloss (ft)
100.0	0.0	0.00	0.0
500.0	0.1	0.00	0.1
1000.0	0.4	0.00	0.4
2000.0	1.2	0.00	1.2



Tideflex® Mixing System

FOR FINISHED WATER STORAGE FACILITIES

DESIGN DATA SHEET



I. GENERAL INFORMATION

Reservoir/Tank Name:	Fairbury	☐ Advertises on ☐ Bids on (mm-dd-yyyy)
Project Location:	Fairbury, NE	

Water Utility/Owner Name:	Fairbury Board of Public Works		
Owner Contact:			
Email:			
Address:			
City:		State:	
Zip:		Country:	
Phone:		Fax:	

Consulting Engineering Firm:	Olsson Associates		
Engineer Contact:	Craig Reinsch, PE		
Email:	creinsch@olssonassociates.com		
Address:	601 P Street, Suite 200		
City:	Lincoln	State:	NE
Zip:	68508	Country:	USA
Phone:	402.458.5671	Fax:	

II. SYSTEM INFORMATION

INSTALLATION:
☐ New Tank
☒ Existing Tank

SCADA:
Tank on SCADA?
☒ yes ☐ no

WATER SOURCE:
☒ Surface Water ☐ Reclaimed Water
☒ Ground Water ☐ Both GWUDI and GW

OPERATION:
☒ Distribution System Reservoir
☐ Clearwell
☐ Combination

MODE:
☒ Fill-then-draw
☐ Simultaneous fill and draw

PRIMARY DISINFECTION:
☒ Chlorine ☐ UV ☐ Chlorine Dioxide
☐ Chloramine ☐ Ozone ☐ None
☐ ____

HIGH WATER LEVEL SHUTOFF:
☐ by Altitude Valve ☐ None, floats on system
☒ by Pressure Switch ☐ ____

SECONDARY DISINFECTION:
☐ Chlorine ☐ Chloramine ☒ None
☐ Chlorine Dioxide ☐ ____

III. RESERVOIR / TANK DATA *(Provide tank drawings if available. See nomenclature on page 4.)*

TYPE OF RESERVOIR / TANK:		Tank Manufacturer or Basis of Design: ____
☐ Circular Reservoir ☐ Irregular Shape ☐ Rectangular Reservoir		☐ At Grade ☐ Semi-Buried ☐ Buried
☐ Standpipe		
☒ Elevated Tank	☐ Dry Riser	☐ Sphere/Spheroid ☐ Composite ☐ Hydropillar ☒ Legged
	☒ Wet Riser	Wet Riser Diameter Unknown ☐ ft ☐ in ☐ m

TANK DETAILS: *(Provide tank drawings if available. **See nomenclature on page 4.**)*		
VOLUME:	1.0	☒ MG ☐ gallons ☐ m³ ☐ Megaliters

Circular Reservoir / Standpipe	☐ ft ☐ m	Elevated Tank	☒ ft ☐ m	Rectangular Reservoir	☐ ft ☐ m
Tank Diameter:		Bowl Diameter:	64.5	Length x Width	x
Depth to Maximum Operating Level		Head Range:	44	Depth to Maximum Operating Level	
Depth to Overflow		Height From Foundation to Overflow		Depth to Overflow	
		Height from Foundation to Max. Operating Level		Number of Cells	1
Bottom Elevation:		Foundation Elevation:		Bottom Elevation:	

TANK MATERIAL: *(select multiple if alternates for new tank)*

☒ Welded Steel ☐ Bolted Steel (conc. floor) ☐ Bolted Steel (steel floor) ☐ Riveted Steel

☐ Prestressed Concrete ☐ Post-tensioned Concrete ☐ Cast-in-place Concrete

☐ Composite (Elevated) ☐ Earthen Lined ☐ _____

TYPE OF ROOF / COVER:

☒ Fixed Roof → Internal Roof Supports? ☐ yes ☐ no ☐ Floating Cover ☐ None, Open Reservoir

IV. INLET / OUTLET PIPING

(For new tanks that operate in fill-then-draw and for existing tanks that have a common inlet/outlet pipe, complete the "Inlet" pipe data. The TMS separates inlet/outlet inside the tank)

☒ Common Inlet/Outlet Pipe ☐ Separate Inlet and Outlet Pipes

Inlet Diameter	12	☒ in ☐ mm	Material:	Penetration: ☒ bottom ☐ sidewall ☐ top
Outlet Diameter		☐ in ☐ mm	Material:	Penetration: ☐ bottom ☐ sidewall

Outlet have Silt Stop? ☒ yes ☐ no → ☒ fixed pipe extension ☐ removable

Does tank have a dedicated drain pipe? ☒ yes ☐ no

V. HYDRAULIC DATA

Minimum **Fill** Rate:		☐ gpm ☐ lps ☐ _____	☒ Pumped ☐ Gravity
Maximum **Fill** Rate:			
Maximum **Draw** Rate: peak demand + fire flow (if applicable)		☐ gpm ☐ lps ☐ _____	☐ Pumped ☐ Gravity

VI. TANK FLUCTUATION / TURNOVER DATA

*(With one of the methods below, provide data on the typical, or expected, daily fluctuation of tank levels in summer and winter, if different. ***See nomenclature, page 4)***

	Method 1				Method 2	Method 3	
	Max. Operating Level*		Min. Operating Level*		% (percent)	Volume Exchange	
Summer	44	☒ ft	40	☒ ft			☐ gallons/day
Winter	44	☒ m	40	☒ m			☐ liters/day

VII. REFROFIT INFORMATION

Year Tank Constructed:	1963
Date of Last Inspection:	2013
Date of Last Rehab/Repaint:	
Next Scheduled Rehab:	
Internal Baffles?	☐ yes ☒ no
Ice Formation?	☐ yes ☒ no
Water Temperature Range	min
☐ ºF ☐ ºC	max
Size of Largest Roof Hatch	☐ dia ☐ sq.
Size of Largest Shell Hatch	☐ dia ☐ sq.
Rechlorination/Recirculation Sytems Installed?	☐ yes ☒ no
Are Sampling taps installed?	☒ yes ☐ no
Samples been taken at different locations/depths inside the tank?	☐ yes ☒ no
Has a tracer study, CFD, or scale model been done?	☐ yes ☒ no

VIII. WATER QUALITY ISSUES

Identify Water Quality Issues
☐ Loss of Residual
☐ DBPs > ☐ TTHM ☐ HAA5
☐ Coliform Bacteria
☐ Nitrification
☐ Elevated HPC
☐ Biofilms
☐ Taste & Odor
☐ Increased pH
☐ Color
☐ Turbidity
☐
Identify known/suspected causes:
☐ Poor Mixing
☐ Short-Circuiting
☐ Poor Turnover / Tank Fluctuation
☐ Long Detention Time
☐ Thermal Stratification
☐ High Levels of Organics
☐

IX. OVERFLOW PIPE PROTECTION

Check method used to prevent birds, rodents, cold drafts, etc. from entering tank thru overflow pipes

Overflow Pipe Size:	**Unknown**	☐ in ☐ mm

☐ **Tideflex Valve**

☐ **Overflow Security Valve (OSV)**

☐ **Screen**

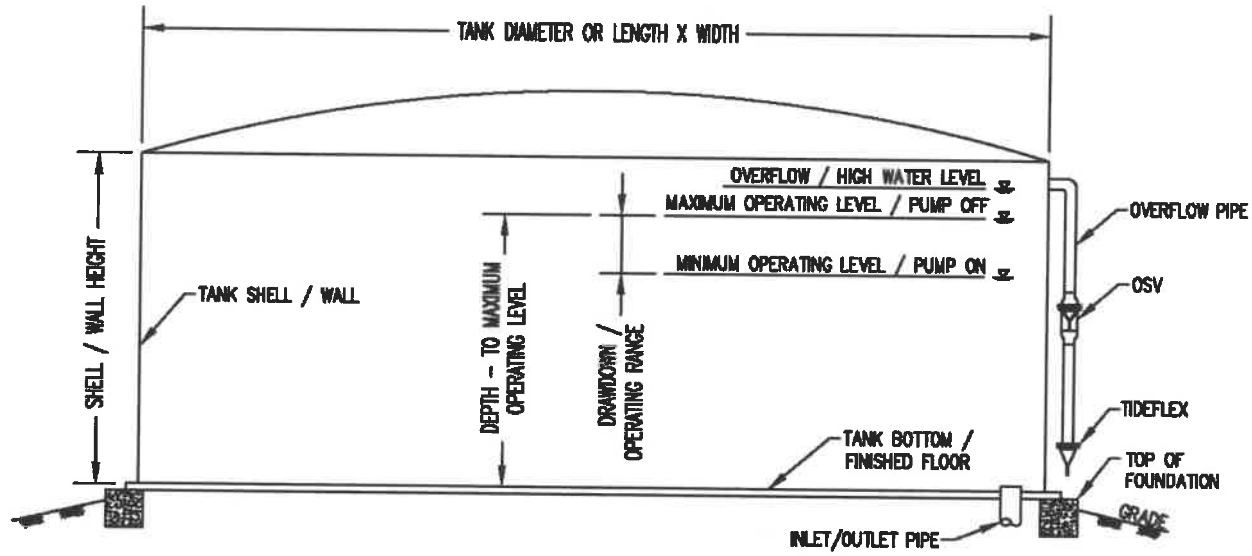
☐ **Flap Valve**

X. COMMENT

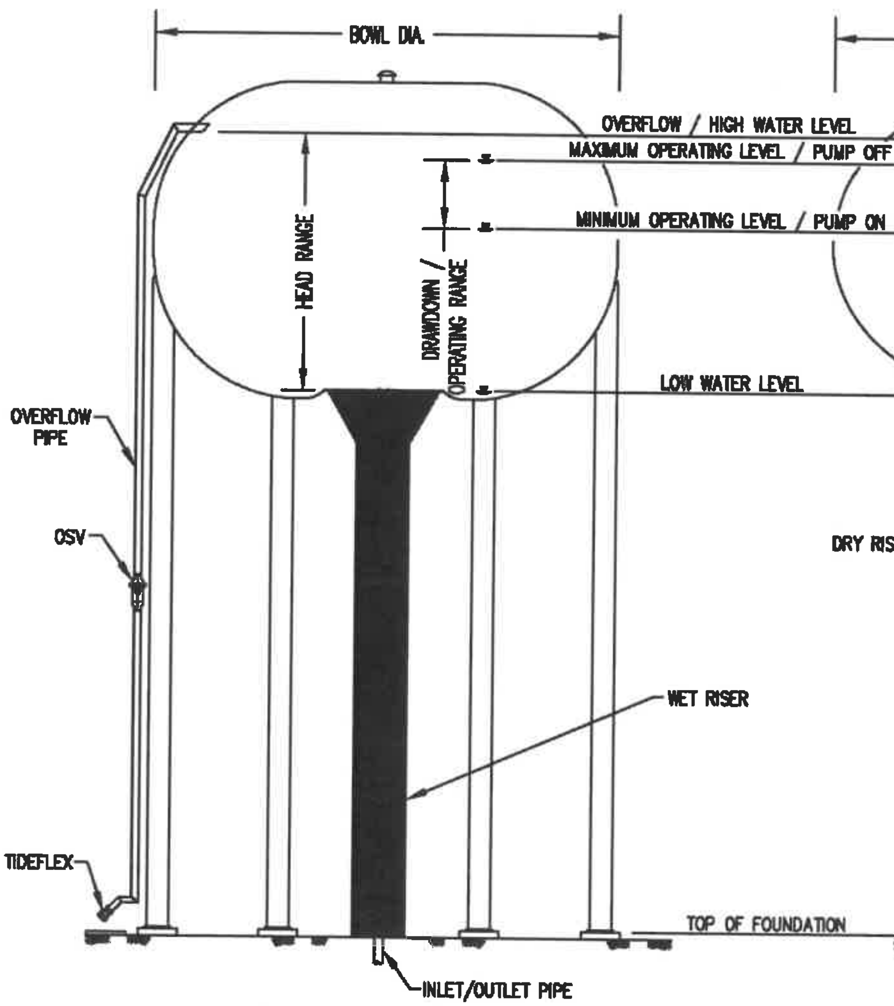
PLEASE MAIL, FAX OR E-MAIL COPIES OF TANK DRAWINGS, INSPECTION REPORTS/PHOTOS TO:

Tideflex Technologies
600 North Bell Ave. Carnegie, PA 15106 USA
PHONE: 412-279-0044 **FAX:** 412-279-5410
E-MAIL: mduer@tideflex.com (Mike Duer) or info@tideflex.com

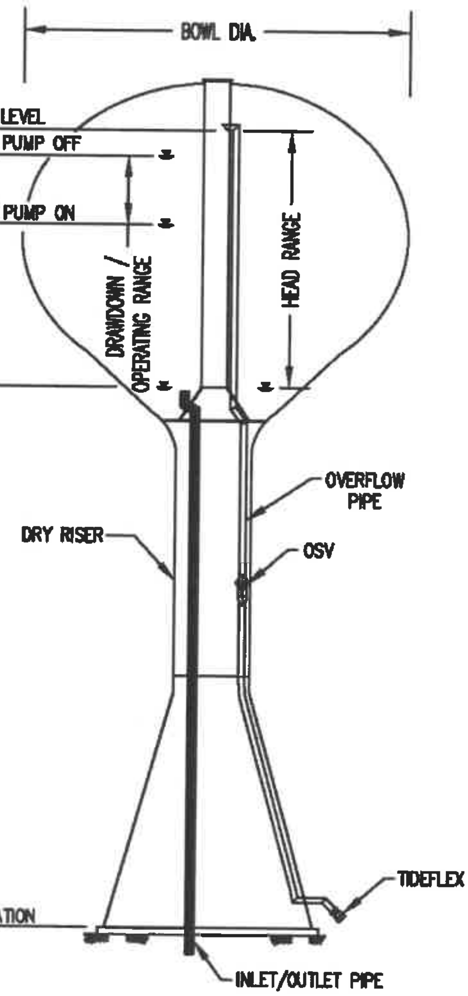
XI. TANK NOMENCLATURE



CIRCULAR AND RECTANGULAR RESERVOIRS AND STANDPIPES



WET RISER ELEVATED TANK



DRY RISER ELEVATED TANK

APPENDIX “J”

Inspection Reports for Elevated and Underground Water Reservoirs

Liquid Engineering Corporation

Potable Water Reservoir Sanitary, Safety, Security (ROV)

Job Number: 45511
Inspector: A. Burson M. Stilwell
Utility: City of Fairbury
Tank Name: Ground Reseviour
Date: 08/05/2013
ROV Team: 10

Sanitary Condition Findings

Vent Properly Screened?	☒ Yes	☐ No	Comments:
Hatch Sealed?	☒ Yes	☐ No	Comments:
Hatch Properly Secured?	☒ Yes	☐ No	Comments:
Overflow Properly Screened?	☒ Yes	☐ No	Comments:
Holes in the Roof?	☐ Yes	☒ No	Comments:
Holes in the Walls?	☐ Yes	☒ No	Comments:
Manway Leaking?	☐ Yes	☐ No	Comments: N/A

Safety Condition Findings

Hatch Safety	☒ Good	☐ Fair	☐ Poor	Comments:
Ladder Safety	☒ Good	☐ Fair	☐ Poor	Comments:
Manway Safety	☐ Good	☐ Fair	☐ Poor	Comments: N/A
Balcony Safety	☐ Good	☐ Fair	☐ Poor	Comments: N/A
Handrail Safety	☐ Good	☐ Fair	☐ Poor	Comments: N/A

Security Condition Findings

Vent Security	☒ Good	☐ Fair	☐ Poor	Comments:
Hatch Security	☒ Good	☐ Fair	☐ Poor	Comments:
Ladder Security	☒ Good	☐ Fair	☐ Poor	Comments:
Fence Present?	☐ Yes	☒ No		Comments:
Adequate Lighting?	☒ Yes	☐ No		Comments:

Summary Recommendations

The tank is in excellent condition. Recommend and clean and inspect every three years. Their is no health and safety concerns at this time.

Disclaimer

Liquid Engineering does not provide consulting engineering services. Unless otherwise noted, the finding contained in this report were neither prepared nor reviewed by a licensed Professional Engineer, but are based on experience, training and visual examination of the Dive Maintenance Technician.

Liquid Engineering Corporation

Concrete Potable Water Reservoir Inspection Report (ROV)

Job Number: 45511
Inspector: A. Burson M. Stiwlell

Utility: City of Fairbury
Tank Name: Ground Reseviour

Date: 08/05/2013
ROV Team: 10

Interior Condition Findings

Roof Condition	☒ Good	☐ Fair	☐ Poor	Comments:
Roof Coating Condition	☒ Good	☐ Fair	☐ Poor	Comments:
Wall Condition	☒ Good	☐ Fair	☐ Poor	Comments:
Wall Coating Condition	☒ Good	☐ Fair	☐ Poor	Comments:
Floor Condition	☒ Good	☐ Fair	☐ Poor	Comments:
Floor Coating Condition	☒ Good	☐ Fair	☐ Poor	Comments:
Support Column Condition	☒ Good	☐ Fair	☐ Poor	Comments:
Column Coating Condition	☒ Good	☐ Fair	☐ Poor	Comments:
Expansion Joints	☒ Good	☐ Fair	☐ Poor	Comments:
Plumbing Condition	☒ Good	☐ Fair	☐ Poor	Comments:
Ladder Conditiion	☒ Good	☐ Fair	☐ Poor	Comments:
Visible Leaking	☒ Yes	☐ No		Comments:

Exterior Condition Findings

Vent Condition	☒ Good	☐ Fair	☐ Poor	Comments:
Roof Condition	☒ Good	☐ Fair	☐ Poor	Comments:
Roof Coating Condition	☒ Good	☐ Fair	☐ Poor	Comments:
Hatch Condition	☒ Good	☐ Fair	☐ Poor	Comments:
Wall Condition	☒ Good	☐ Fair	☐ Poor	Comments:
Wall Coating Condition	☒ Good	☐ Fair	☐ Poor	Comments:
Foundation Condition	☒ Good	☐ Fair	☐ Poor	Comments:
Ladder Condition	☒ Good	☐ Fair	☐ Poor	Comments:
Plumbing Condition	☒ Good	☐ Fair	☐ Poor	Comments:
Visible Leaking	☒ Yes	☐ No		Comments:

Additional Comments

The tank is in excellent condition. Recommend and clean and inspect every three years.

Liquid Engineering Corporation

Steel Potable Water Reservoir Inspection Report (ROV)

Job Number: 45511 | Utility: City of Fairbury | Date: 08/05/2013

Inspector: A. Burson M. Stilwell | Tank Name: Tower | ROV Team: 10

Interior Condition Findings

Item	Good	Fair	Poor	Comments
Roof Condition	☐	☑	☐	Lot of feedback due to antennas and dishes
Roof Coating Condition	☐	☑	☐	Lot of feedback due to antennas and dishes
Roof Weld Condition	☐	☑	☐	Lot of feedback due to antennas and dishes
Wall Condition	☐	☑	☐	Few random spots of coating failure and concentration cells.
Wall Coating Condition	☐	☑	☐	Few random spots of coating failure and concentration cells.
Wall Weld Condition	☐	☑	☐	Few random spots of coating failure and concentration cells.
Floor Condition	☑	☐	☐	
Floor Coating Condition	☑	☐	☐	
Floor Weld Condition	☑	☐	☐	
Support Column Condition	☐	☐	☐	N/A
Column Coating Condition	☐	☐	☐	N/A
Plumbing Condition	☑	☐	☐	
Ladder Condition	☐	☐	☐	N/A

Item	Yes	No	Comments
Cathodic Protection Installed	☐	☑	
Visible Leaking	☐	☑	

Exterior Condition Findings

Item	Good	Fair	Poor	Comments
Vent Condition	☑	☐	☐	
Roof Condition	☑	☐	☐	
Roof Coating Condition	☑	☐	☐	
Roof Weld Condition	☑	☐	☐	
Hatch Condition	☐	☑	☐	Underside of lid all coating has corroded.
Wall Condition	☑	☐	☐	
Wall Coating Condition	☑	☐	☐	
Wall Weld Condition	☑	☐	☐	
Foundation Condition	☑	☐	☐	
Ladder Condition	☑	☐	☐	
Plumbing Condition	☑	☐	☐	

Item	Yes	No	Comments
Visible Leaking	☐	☑	

Additional Comments

Recommend at least four hours of epoxy repairs. Most of the repaid area is on the upper walls. Recommend a clean and inspect every three years. Their was a poor quality of video feed due to the large amount of interference from the dishes that have been placed on the tower.

Liquid Engineering Corporation

Potable Water Reservoir Sanitary, Safety, Security (ROV)

Job Number: 45511 Utility: City of Fairbury Date: 08/05/2013

Inspector: A. Burson M. Stilwell Tank Name: Tower ROV Team: 10

Sanitary Condition Findings

Vent Properly Screened?	☒ Yes	☐ No	Comments:
Hatch Sealed?	☒ Yes	☐ No	Comments:
Hatch Properly Secured?	☒ Yes	☐ No	Comments:
Overflow Properly Screened?	☒ Yes	☐ No	Comments:
Holes in the Roof?	☐ Yes	☒ No	Comments:
Holes in the Walls?	☐ Yes	☒ No	Comments:
Manway Leaking?	☐ Yes	☒ No	Comments:

Safety Condition Findings

Hatch Safety	☒ Good	☐ Fair	☐ Poor	Comments:
Ladder Safety	☒ Good	☐ Fair	☐ Poor	Comments:
Manway Safety	☒ Good	☐ Fair	☐ Poor	Comments:
Balcony Safety	☒ Good	☐ Fair	☐ Poor	Comments:
Handrail Safety	☒ Good	☐ Fair	☐ Poor	Comments:

Security Condition Findings

Vent Security	☒ Good	☐ Fair	☐ Poor	Comments:
Hatch Security	☒ Good	☐ Fair	☐ Poor	Comments:
Ladder Security	☒ Good	☐ Fair	☐ Poor	Comments:
Fence Present?	☒ Yes	☐ No		Comments:
Adequate Lighting?	☐ Yes	☒ No		Comments:

Summary Recommendations

Their was no health and safety recommendations at this time. Recommended at least four hours of epoxy work at this time. Clean and inspect tank every three years.

Disclaimer

Liquid Engineering does not provide consulting engineering services. Unless otherwise noted, the finding contained in this report were neither prepared nor reviewed by a licensed Professional Engineer, but are based on experience, training and visual examination of the Dive Maintenance Technician.

Additional Work Authorization

Liquid Engineering Corporation
P.O. Box 80230
Billings, MT 59108
(800) 438-2187

Client FAIRBURY		Date 08142014	
Address P.O. BOX 554		LEC Job Number 45973	
City FAIRBURY	State NE	Reservoir Name TOWER	
Phone 402-729-3648		Date of Contract	

You are authorized to perform the following specifically described additional work:

For the coating repair we are contracted to a 4 hour minimum at $2,100.00. After the minimum an additional charge of $425.00 an hour. We covered all the problem areas above the painters ring in all the 4 quadrants. We did not notice any areas of corrosion on the floor and lower walls of the tank.

Contract amount-$2,100.00
Rate after minimum- $425.00 an hour
Total repair time- 1hr
Total repair cost-$2,525.00

ADDITIONAL CHARGE FOR ABOVE WORK IS: $2,525.00

Payment will be made as follows: Net 30

Above additional work to be performed under same conditions as specified in original contract unless otherwise stipulated.

Date: 8/14/2014 Authorizing Signature: ____________________ Print Name: ____________________
(Client signs here)

We hereby agree to furnish labor and materials – complete in accordance with the above specifications, at above stated price.

Authorized Signature: ____________________ Date: 08142014
(Contractor signs here)

THIS IS CHANGE ORDER NO. 01

Note: This revision becomes part of, and in conformance with, the existing contract.

Liquid Engineering Corporation

Potable Water Reservoir Supplemental Report

Job Number: 45973 | Utility: CITY OF FAIRBURY | Tank: TOWER

Inspector: D.RYALS | Dive Controller: K.PRIEST | Date: 8-14-2014

Once the diver entered the water he did a swim around the tank to see the problem areas. We noticed a couple areas in quadrant one, two and three on the upper walls above the painters ring. We went down to the bottom of the tank to see if any areas needed attention on the floor and lower walls. We ended up finding the floor in excellent shape so we focused our attention on the upper walls of the tank. The Diver used a wire brush to clean all the corrosion off the walls to prep for epoxy. We worked our way around the tank covering all the problem areas on the walls. The biggest area of corrosion we found in the tank is at the 6 o'clock position above the painters ring. About 40% of the panel was covered in corrosion. After we finished the epoxy we did an overview off all the areas we covered. Tank is looking in good working condition.

APPENDIX “K”

Water Quality Sampling Results

Fairbury Water Study/PER
OA Project 016-3570

	Nitrate Level (mg/L)						
	POE	Well #1	Well #2	Well #3			
Sample Date	Crystal Springs	(G-032647)	(G-068253)	(G-096478)	MCL	Avg	Max
1/12/2004	8.30	8.40	8.60	7.80	10	8.4	8.6
4/5/2004	8.80	8.40	8.20	7.60	10	8.5	8.8
7/6/2004	8.70	8.60	8.30	7.50	10	8.5	8.7
10/5/2004	8.70	8.70	8.50	7.80	10	8.6	8.7
1/10/2005	8.00	8.40	8.50	7.40	10	8.3	8.5
4/11/2005	8.80	8.70	8.20	7.90	10	8.6	8.8
8/24/2005	8.40	8.20	7.80	7.60	10	8.1	8.4
10/12/2005	7.80	8.30	8.30	7.60	10	8.1	8.3
1/17/2006	7.80	8.00	7.80	7.20	10	7.9	8
4/10/2006	8.40	8.50	8.20	7.60	10	8.4	8.5
7/5/2006	8.20	8.80	8.30	8.00	10	8.4	8.8
10/16/2006	8.00	9.20	8.70	7.80	10	8.6	9.2
1/10/2007	8.00	8.50	8.20	7.40	10	8.2	8.5
4/9/2007	8.20	8.50	8.40	7.20	10	8.4	8.5
7/16/2007	8.30	9.10	8.50	8.40	10	8.6	9.1
10/29/2007	7.90	9.40	8.50	7.80	10	8.6	9.4
1/16/2008	8.00	9.00	8.20	7.20	10	8.4	9
4/15/2008	8.30	8.30	8.10	7.20	10	8.2	8.3
7/16/2008	7.80	8.60	8.30	8.10	10	8.2	8.6
11/18/2008	7.20	8.60	8.50	7.40	10	8.1	8.6
1/21/2009	7.80	8.10	8.20	7.40	10	8.0	8.2
4/20/2009	7.70	7.50	8.00	7.00	10	7.7	8
8/4/2009	7.73	8.35	8.62	8.13	10	8.2	8.62
10/26/2009	7.40	7.64	8.27	7.44	10	7.8	8.27
1/13/2010	8.87	7.91	8.69	8.09	10	8.5	8.87
4/12/2010	9.41	7.80	8.59	7.47	10	8.6	9.41
6/6/2010	9.18	7.73	8.59	7.48	10	8.5	9.18
10/20/2010	9.20	8.23	8.29	8.15	10	8.6	9.2
1/18/2011	9.91	7.74	8.47	7.71	10	8.7	9.91
4/11/2011	**10.20**	7.67	8.58	7.29	10	8.8	10.2
4/19/2011	9.87				10	9.9	9.87
6/26/2011	9.55	8.32	8.10	8.59	10	8.7	9.55
10/11/2011	9.32	7.85	8.29	8.01	10	8.5	9.32
1/9/2012	9.74	7.33	8.89	7.98	10	8.7	9.74
4/9/2012	9.15	6.75	8.14	7.82	10	8.0	9.15
7/17/2012	9.65	8.30	7.96	8.63	10	8.6	9.65
10/22/2012	9.39	7.54	8.11	8.56	10	8.3	9.39
1/14/2013	9.18	7.56	8.14	8.64	10	8.3	9.18
4/16/2013	**10.20**	9.06	9.07	9.45	10	9.4	10.2
7/16/2013	8.93	7.88	7.90	8.41	10	8.2	8.93
10/8/2013	9.48	7.96	8.26	8.90	10	8.6	9.48
1/13/2014	9.82	7.89	8.40	9.46	10	8.7	9.82
4/7/2014	9.31	7.50	7.96	9.03	10	8.3	9.31
7/21/2014	8.02	7.30	7.66	8.39	10	7.7	8.02

Fairbury Water Study/PER
OA Project 016-3570

	Nitrate Level (mg/L)						
	POE	Well #1	Well #2	Well #3			
Sample Date	Crystal Springs	(G-032647)	(G-068253)	(G-096478)	MCL	Avg	Max
10/21/2014	8.16	8.08	8.16	9.02	10	8.1	8.16
1/13/2015	8.48	7.43	8.01	9.15	10	8.0	8.48
4/13/2015	8.75	7.51	8.01	8.91	10	8.1	8.75
8/10/2015	8.25	7.79	8.48	9.28	10	8.2	8.48
10/6/2015	8.09	8.35	8.14	8.74	10	8.2	8.35
1/5/2016	8.25	7.07	7.44	8.89	10	7.6	8.25
4/12/2016	8.72	7.69	7.90	9.22	10	8.1	8.72
7/19/2016	8.26	8.38	8.39	9.08	10	8.3	8.39
10/31/2016	8.28	8.31	8.51	9.29	10	8.4	8.51
1/10/2017	7.85	8.19	7.90	8.96	10	8.0	8.19
4/10/2017	9.30	8.99	8.56	9.68	10	9.0	9.3
5/31/2017	8.70	8.60	8.40	**10.00**	10	8.6	8.7
Average	9.00	7.89	8.26	8.62		8.25	
Maximum	10.20	9.06	9.07	10.00			

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17-158-4166

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13542

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DATE SAMPLED
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CITY OF FAIRBURY
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BOX 554
FAIRBURY NE 68352-

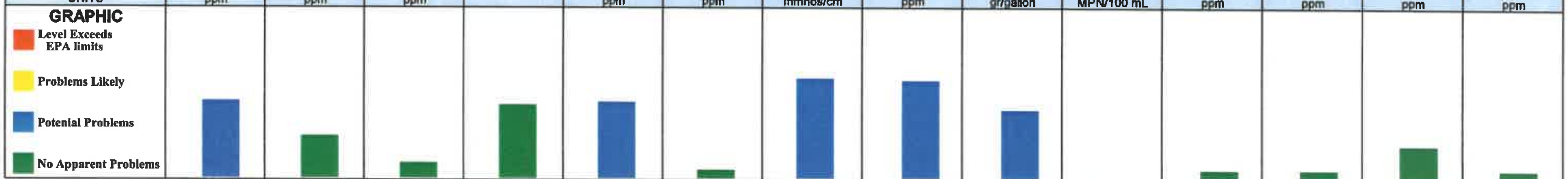
Domestic Suitability

For: (13542) CITY OF FAIRBURY
Water Quality As, TOC

Analytical Results for RESERVOIR

PARAMETER	SODIUM	CALCIUM	MAGNESIUM	pH	NITRATE	SULFATE	CONDUC-TIVITY	TOTAL DISSOLVED SOLIDS	HARDNESS	TOTAL COLIFORM	IRON	MANGANESE	CHLORIDE	FLUORIDE
METHOD	EPA 200.7 Na	EPA 200.7 Ca	EPA 200.7 Mg	SM 4500 H+B	EPA 300.0 NO_3-N	EPA 300.0 SO_4	SM 2510 B	CALC	SM 2310B	SM 9223B	EPA 200.7 Fe	EPA 200.7 Mn	EPA 300.0 Cl	EPA 300.0 F
UNITS	ppm	ppm	ppm		ppm	ppm	mmhos/cm	ppm	gr/gallon	MPN/100 mL	ppm	ppm	ppm	ppm
LEVEL FOUND	68.2	66.7	9.04	7.21	8.7	26	0.688	447	11.9		n.d.	n.d.	66	0.2
CAUTION LEVEL	100	80	30	6.5/9	10	400	0.75	500	20		0.3	0.05	200	4

PARAMETER	SODIUM	CALCIUM	MAGNESIUM	pH	NITRATE	SULFATE	CONDUC-TIVITY	TOTAL DISSOLVED SOLIDS	HARDNESS	TOTAL COLIFORM	IRON	MANGANESE	CHLORIDE	FLUORIDE
METHOD	EPA 200.7 Na	EPA 200.7 Ca	EPA 200.7 Mg	SM 4500 H+B	EPA 300.0 NO_3-N	EPA 300.0 SO_4	SM 2510 B	CALC	SM 2310B	SM 9223B	EPA 200.7 Fe	EPA 200.7 Mn	EPA 300.0 Cl	EPA 300.0 F
UNITS	ppm	ppm	ppm		ppm	ppm	mmhos/cm	ppm	gr/gallon	MPN/100 mL	ppm	ppm	ppm	ppm



All results are reported on an AS RECEIVED basis., n.d. = not detected , ppm = parts per million, ppm = mg/kg, ppm = mg/L

For questions please contact:
Heather Ramig
Account Manager
hramig@midwestlabs.com (402)829-9891

SUGGESTED WATER QUALITY GUIDELINES FOR HUMAN CONSUMPTION

Sodium (Na)	Less than 20 ppm: No adverse effects.	20-80 ppm: Persons on restricted sodium diets should consult a physician concerning use.	More than 80 ppm: Should be used sparingly by persons on low-sodium diets.
Calcium (Ca)	Less than 80 ppm: No adverse effects.	80-150 ppm: Hard water problems such as scale formation can be expected.	More than 150 ppm: May be associated with high levels of sulfate (see sulfate below). Extreme hardness is undesirable for household use.
Magnesium (Mg)	Less than 30 ppm: No adverse effects.	30-80 ppm: Contributes to hardness when associated with high calcium levels.	More than 80 ppm: When associated with high sulfate, is likely to have a laxative effect (magnesium sulfate is Epsom Salts).
pH	Less than 6.5: Corrosive to metal.	6.5-8.5: No adverse effects.	Higher than 8.5: Possible bitter taste, and germicidal activity of chlorine is reduced, corrosive to pipes.
Nitrate Nitrogen (NO3-N)	Less than 2 ppm: No adverse effects.	2-10 ppm: No acute toxicity. Could have some negative health effects in young children.	More than 10 ppm: Increasing probability of health effect in children under 6 months of age due of reduced oxygen carrying capacity of the blood. EPA MCL standard of < 10 ppm.
Sulfate (SO4)	Less than 250 ppm: No adverse effects.	250-500 ppm: Likely to have a laxative effect, especially when first introduced. Diarrhea may or may not persist.	More than 500 ppm: Strongly laxative.
Conductivity	Less than 0.30: Extremely pure water can be corrosive metal.	0.30-1.50: No adverse effects.	Greater than 1.50: High levels of dissolved solids (see below).
Total Dissolved Solids (TDS)	Less than 200 ppm: No adverse health or nutritional effects. May be corrosive if extremely pure.	200-1000 ppm: No adverse effects.	More than 1000 ppm: Increasingly adverse effects, especially diarrhea. Water loses esthetic effect.
Hardness	Less than 6 gr/gal: No adverse effects (17.1 mg/L CaCO3 = (1 gr/gal).	6-12 gr/gal: Some scale may form in pipes and water heaters. Softening may be desirable.	More than 12 gr/gal: Scale will form rapidly and laundry will not come clean. Softening for household use is desirable.
Total Coliform*	Negative: No coliform bacteria present in 100 mL of water.		Positive: Coliforms are a bacteria that are naturally present in the environment and can be used to indicate the presence of other potentially harmful bacteria such as Fecal Coliform or *E.coli*. The presence of Fecal and *E. coli* may indicate a contamination from human or animal waste. The EPA acceptable level is less than one (<1) MPN (most probable number) per 100 mL of water.
Iron (Fe)	Less than 0.3 ppm: No adverse effects.	0.3-1.0 ppm: Some staining will occur.	More than 1.0 ppm: Iron oxide (rust) will cause extensive staining and will precipitate out, forming a red sludge. Taste will be bitter.
Manganese (Mn)	Less than 0.05 ppm: No adverse effects.	0.05-0.50 ppm: May cause black or brown staining of pipes, sinks and laundry.	More than 0.50 ppm: Besides the staining effect, will cause a metallic taste.
Chloride (Cl)	Less than 200 ppm: No adverse effects.	200-500 ppm: Increasingly salty taste.	More than 500 ppm: Very salty taste.

*Holding/Transit time between sampling and analysis cannot exceed 30 hours. If this time has been exceeded, the results might be invalid.
N.D. = Not Detected
EPA Guidelines suggest less than 0.015 ppm (mg/L) for Lead (Pb) and 1.30 ppm (mg/L) for Copper (Cu).

REPORT NUMBER
17-158-4166

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CITY OF FAIRBURY
CITY OFFICES/DENNIS MCATEE
BOX 554
FAIRBURY NE 68352-

REPORT OF ANALYSIS

For: (13542) CITY OF FAIRBURY
Water Quality As, TOC

Analysis	Level Found As Received	Units	Reporting Limit	Method	Analyst-Date	Verified-Date
Sample ID: **RESERVOIR** Lab Number: **2677420**	Date Sampled: **2017-05-31 1319**					
Alkalinity (total)	195	mg CaCO3/L	20	SM 2320 B-(1997)	mgn8-2017/06/05	cmw2-2017/06/06
Langelier saturation index	-0.326		0.000	Calculation	cmw2-2017/06/07	cmw2-2017/06/07
Total organic carbon (TOC)	n.d.	mg/L	1.0	SM 5310 B-(2011)	lkm2-2017/06/05	cmw2-2017/06/06
Arsenic (total)	0.0023	mg/L	0.0005	EPA 200.8	cjm4-2017/06/06	kkh9-2017/06/07
Ammonia - N (total)	n.d.	mg/L	0.10	SM 4500-NH3 G-(1997) *	mjw0-2017/06/01	cmw2-2017/06/06

All results are reported on an AS RECEIVED basis., n.d. = not detected

For questions please contact:
Heather Ramig
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hramig@midwestlabs.com (402)829-9891

REPORT NUMBER
17-158-4168

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CITY OF FAIRBURY
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FAIRBURY NE 68352-

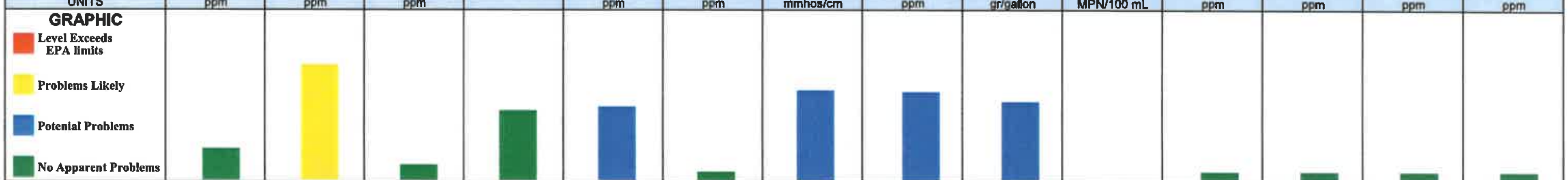
Domestic Suitability

For: (13542) CITY OF FAIRBURY
Water Quality As, TOC

Analytical Results for EAST WELL #1

PARAMETER	SODIUM	CALCIUM	MAGNESIUM	pH	NITRATE	SULFATE	CONDUC-TIVITY	TOTAL DISSOLVED SOLIDS	HARDNESS	TOTAL COLIFORM	IRON	MANGANESE	CHLORIDE	FLUORIDE
METHOD	EPA 200.7 Na	EPA 200.7 Ca	EPA 200.7 Mg	SM 4500 H+B	EPA 300.0 NO_3-N	EPA 300.0 SO_4	SM 2510 B	CALC	SM 2310B	SM 9223B	EPA 200.7 Fe	EPA 200.7 Mn	EPA 300.0 Cl	EPA 300.0 F
UNITS	ppm	ppm	ppm		ppm	ppm	mmhos/cm	ppm	gr/gallon	MPN/100 mL	ppm	ppm	ppm	ppm
LEVEL FOUND	31.3	81.6	9.05	7.03	8.6	31	0.592	385	14.1		n.d.	n.d.	14	0.4
CAUTION LEVEL	100	80	30	6.5/9	10	400	0.75	500	20		0.3	0.05	200	4

PARAMETER	SODIUM	CALCIUM	MAGNESIUM	pH	NITRATE	SULFATE	CONDUC-TIVITY	TOTAL DISSOLVED SOLIDS	HARDNESS	TOTAL COLIFORM	IRON	MANGANESE	CHLORIDE	FLUORIDE
METHOD	EPA 200.7 Na	EPA 200.7 Ca	EPA 200.7 Mg	SM 4500 H+B	EPA 300.0 NO_3-N	EPA 300.0 SO_4	SM 2510 B	CALC	SM 2310B	SM 9223B	EPA 200.7 Fe	EPA 200.7 Mn	EPA 300.0 Cl	EPA 300.0 F
UNITS	ppm	ppm	ppm		ppm	ppm	mmhos/cm	ppm	gr/gallon	MPN/100 mL	ppm	ppm	ppm	ppm



All results are reported on an AS RECEIVED basis., n.d. = not detected , ppm = parts per million, ppm = mg/kg, ppm = mg/L

For questions please contact:

Heather Ramig
Account Manager
hramig@midwestlabs.com (402)829-9891

The result(s) issued on this report only reflect the analysis of the sample(s) submitted.

SUGGESTED WATER QUALITY GUIDELINES FOR HUMAN CONSUMPTION

Sodium (Na)	Less than 20 ppm: No adverse effects.	20-80 ppm: Persons on restricted sodium diets should consult a physician concerning use.	More than 80 ppm: Should be used sparingly by persons on low-sodium diets.
Calcium (Ca)	Less than 80 ppm: No adverse effects.	80-150 ppm: Hard water problems such as scale formation can be expected.	More than 150 ppm: May be associated with high levels of sulfate (see sulfate below). Extreme hardness is undesirable for household use.
Magnesium (Mg)	Less than 30 ppm: No adverse effects.	30-80 ppm: Contributes to hardness when associated with high calcium levels.	More than 80 ppm: When associated with high sulfate, is likely to have a laxative effect (magnesium sulfate is Epsom Salts).
pH	Less than 6.5: Corrosive to metal.	6.5-8.5: No adverse effects.	Higher than 8.5: Possible bitter taste, and germicidal activity of chlorine is reduced, corrosive to pipes.
Nitrate Nitrogen (NO3-N)	Less than 2 ppm: No adverse effects.	2-10 ppm: No acute toxicity. Could have some negative health effects in young children.	More than 10 ppm: Increasing probability of health effect in children under 6 months of age due of reduced oxygen carrying capacity of the blood. EPA MCL standard of < 10 ppm.
Sulfate (SO4)	Less than 250 ppm: No adverse effects.	250-500 ppm: Likely to have a laxative effect, especially when first introduced. Diarrhea may or may not persist.	More than 500 ppm: Strongly laxative.
Conductivity	Less than 0.30: Extremely pure water can be corrosive metal.	0.30-1.50: No adverse effects.	Greater than 1.50: High levels of dissolved solids (see below).
Total Dissolved Solids (TDS)	Less than 200 ppm: No adverse health or nutritional effects. May be corrosive if extremely pure.	200-1000 ppm: No adverse effects.	More than 1000 ppm: Increasingly adverse effects, especially diarrhea. Water loses esthetic effect.
Hardness	Less than 6 gr/gal: No adverse effects (17.1 mg/L CaCO3 = (1 gr/gal).	6-12 gr/gal: Some scale may form in pipes and water heaters. Softening may be desirable.	More than 12 gr/gal: Scale will form rapidly and laundry will not come clean. Softening for household use is desirable.
Total Coliform*	Negative: No coliform bacteria present in 100 mL of water.		Positive: Coliforms are a bacteria that are naturally present in the environment and can be used to indicate the presence of other potentially harmful bacteria such as Fecal Coliform or *E.coli*. The presence of Fecal and *E. coli* may indicate a contamination from human or animal waste. The EPA acceptable level is less than one (<1) MPN (most probable number) per 100 mL of water.
Iron (Fe)	Less than 0.3 ppm: No adverse effects.	0.3-1.0 ppm: Some staining will occur.	More than 1.0 ppm: Iron oxide (rust) will cause extensive staining and will precipitate out, forming a red sludge. Taste will be bitter.
Manganese (Mn)	Less than 0.05 ppm: No adverse effects.	0.05-0.50 ppm: May cause black or brown staining of pipes, sinks and laundry.	More than 0.50 ppm: Besides the staining effect, will cause a metallic taste.
Chloride (Cl)	Less than 200 ppm: No adverse effects.	200-500 ppm: Increasingly salty taste.	More than 500 ppm: Very salty taste.

*Holding/Transit time between sampling and analysis cannot exceed 30 hours. If this time has been exceeded, the results might be invalid.

N.D. = Not Detected

EPA Guidelines suggest less than 0.015 ppm (mg/L) for Lead (Pb) and 1.30 ppm (mg/L) for Copper (Cu).

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CITY OF FAIRBURY
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BOX 554
FAIRBURY NE 68352-

REPORT OF ANALYSIS

For: (13542) CITY OF FAIRBURY
Water Quality As, TOC

Analysis	Level Found As Received	Units	Reporting Limit	Method	Analyst-Date	Verified-Date
Sample ID: **EAST WELL #1** Lab Number: **2677421**	Date Sampled: **2017-05-31 1420**					
Alkalinity (total)	217	mg CaCO3/L	20	SM 2320 B-(1997)	mgn8-2017/06/05	cmw2-2017/06/06
Langelier saturation index	-0.357		0.000	Calculation	cmw2-2017/06/07	cmw2-2017/06/07
Total organic carbon (TOC)	n.d.	mg/L	1.0	SM 5310 B-(2011)	lkm2-2017/06/05	cmw2-2017/06/06
Arsenic (total)	0.0010	mg/L	0.0005	EPA 200.8	cjm4-2017/06/06	kkh9-2017/06/07
Ammonia - N (total)	n.d.	mg/L	0.10	SM 4500-NH3 G-(1997) *	mjw0-2017/06/01	cmw2-2017/06/06

All results are reported on an AS RECEIVED basis., n.d. = not detected

For questions please contact:
Heather Ramig
Heather Ramig
Account Manager
hramig@midwestlabs.com (402)829-9891

REPORT NUMBER
17-158-4171

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Jun 07, 2017
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DATE SAMPLED
May 31, 2017
TIME SAMPLED
12:00

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BOX 554
FAIRBURY NE 68352-

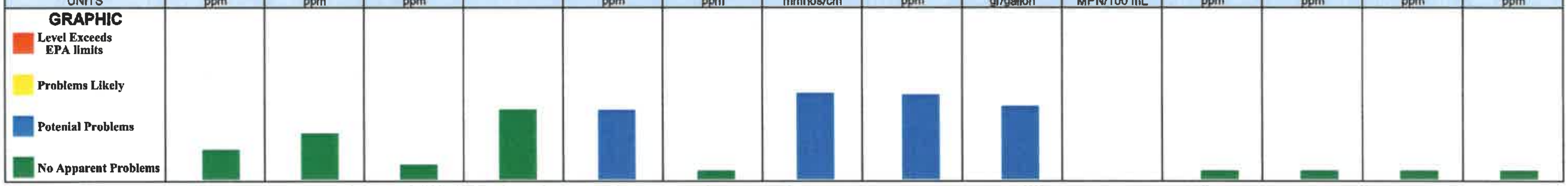
Domestic Suitability

For: (13542) CITY OF FAIRBURY
Water Quality As, TOC

Analytical Results for EAST WELL #2

PARAMETER	SODIUM	CALCIUM	MAGNESIUM	pH	NITRATE	SULFATE	CONDUC-TIVITY	TOTAL DISSOLVED SOLIDS	HARDNESS	TOTAL COLIFORM	IRON	MANGANESE	CHLORIDE	FLUORIDE
METHOD	EPA 200.7 Na	EPA 200.7 Ca	EPA 200.7 Mg	SM 4500 H+B	EPA 300.0 NO_3-N	EPA 300.0 SO_4	SM 2510 B	CALC	SM 2310B	SM 9223B	EPA 200.7 Fe	EPA 200.7 Mn	EPA 300.0 Cl	EPA 300.0 F
UNITS	ppm	ppm	ppm		ppm	ppm	mmhos/cm	ppm	gr/gallon	MPN/100 mL	ppm	ppm	ppm	ppm
LEVEL FOUND	29.5	73.3	8.79	7.01	8.4	31	0.553	359	12.8		n.d.	n.d.	14	0.2
CAUTION LEVEL	100	80	30	6.5/9	10	400	0.75	500	20		0.3	0.05	200	4

PARAMETER	SODIUM	CALCIUM	MAGNESIUM	pH	NITRATE	SULFATE	CONDUC-TIVITY	TOTAL DISSOLVED SOLIDS	HARDNESS	TOTAL COLIFORM	IRON	MANGANESE	CHLORIDE	FLUORIDE
METHOD	EPA 200.7 Na	EPA 200.7 Ca	EPA 200.7 Mg	SM 4500 H+B	EPA 300.0 NO_3-N	EPA 300.0 SO_4	SM 2510 B	CALC	SM 2310B	SM 9223B	EPA 200.7 Fe	EPA 200.7 Mn	EPA 300.0 Cl	EPA 300.0 F
UNITS	ppm	ppm	ppm		ppm	ppm	mmhos/cm	ppm	gr/gallon	MPN/100 mL	ppm	ppm	ppm	ppm



All results are reported on an AS RECEIVED basis., n.d. = not detected , ppm = parts per million, ppm = mg/kg, ppm = mg/L

For questions please contact:
Heather Ramig
Heather Ramig
Account Manager
hramig@midwestlabs.com (402)829-9891

SUGGESTED WATER QUALITY GUIDELINES FOR HUMAN CONSUMPTION

Sodium (Na)	Less than 20 ppm: No adverse effects.	20-80 ppm: Persons on restricted sodium diets should consult a physician concerning use.	More than 80 ppm: Should be used sparingly by persons on low-sodium diets.
Calcium (Ca)	Less than 80 ppm: No adverse effects.	80-150 ppm: Hard water problems such as scale formation can be expected.	More than 150 ppm: May be associated with high levels of sulfate (see sulfate below). Extreme hardness is undesirable for household use.
Magnesium (Mg)	Less than 30 ppm: No adverse effects.	30-80 ppm: Contributes to hardness when associated with high calcium levels.	More than 80 ppm: When associated with high sulfate, is likely to have a laxative effect (magnesium sulfate is Epsom Salts).
pH	Less than 6.5: Corrosive to metal.	6.5-8.5: No adverse effects.	Higher than 8.5: Possible bitter taste, and germicidal activity of chlorine is reduced, corrosive to pipes.
Nitrate Nitrogen (NO3-N)	Less than 2 ppm: No adverse effects.	2-10 ppm: No acute toxicity. Could have some negative health effects in young children.	More than 10 ppm: Increasing probability of health effect in children under 6 months of age due of reduced oxygen carrying capacity of the blood. EPA MCL standard of < 10 ppm.
Sulfate (SO4)	Less than 250 ppm: No adverse effects.	250-500 ppm: Likely to have a laxative effect, especially when first introduced. Diarrhea may or may not persist.	More than 500 ppm: Strongly laxative.
Conductivity	Less than 0.30: Extremely pure water can be corrosive metal.	0.30-1.50: No adverse effects.	Greater than 1.50: High levels of dissolved solids (see below).
Total Dissolved Solids (TDS)	Less than 200 ppm: No adverse health or nutritional effects. May be corrosive if extremely pure.	200-1000 ppm: No adverse effects.	More than 1000 ppm: Increasingly adverse effects, especially diarrhea. Water loses esthetic effect.
Hardness	Less than 6 gr/gal: No adverse effects (17.1 mg/L CaCO3 = (1 gr/gal).	6-12 gr/gal: Some scale may form in pipes and water heaters. Softening may be desirable.	More than 12 gr/gal: Scale will form rapidly and laundry will not come clean. Softening for household use is desirable.
Total Coliform*	Negative: No coliform bacteria present in 100 mL of water.		Positive: Coliforms are a bacteria that are naturally present in the environment and can be used to indicate the presence of other potentially harmful bacteria such as Fecal Coliform or *E.coli* . The presence of Fecal and *E. coli* may indicate a contamination from human or animal waste. The EPA acceptable level is less than one (<1) MPN (most probable number) per 100 mL of water.
Iron (Fe)	Less than 0.3 ppm: No adverse effects.	0.3-1.0 ppm: Some staining will occur.	More than 1.0 ppm: Iron oxide (rust) will cause extensive staining and will precipitate out, forming a red sludge. Taste will be bitter.
Manganese (Mn)	Less than 0.05 ppm: No adverse effects.	0.05-0.50 ppm: May cause black or brown staining of pipes, sinks and laundry.	More than 0.50 ppm: Besides the staining effect, will cause a metallic taste.
Chloride (Cl)	Less than 200 ppm: No adverse effects.	200-500 ppm: Increasingly salty taste.	More than 500 ppm: Very salty taste.

*Holding/Transit time between sampling and analysis cannot exceed 30 hours. If this time has been exceeded, the results might be invalid.
N.D. = Not Detected
EPA Guidelines suggest less than 0.015 ppm (mg/L) for Lead (Pb) and 1.30 ppm (mg/L) for Copper (Cu).

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CITY OF FAIRBURY
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BOX 554
FAIRBURY NE 68352-

REPORT OF ANALYSIS

For: (13542) CITY OF FAIRBURY
Water Quality As, TOC

Analysis	Level Found As Received	Units	Reporting Limit	Method	Analyst-Date	Verified-Date
Sample ID: **EAST WELL #2**	Lab Number: **2677422**	Date Sampled: **2017-05-31 1440**				
Alkalinity (total)	201	mg CaCO3/L	20	SM 2320 B-(1997)	mgn8-2017/06/05	cmw2-2017/06/06
Langelier saturation index	-0.450		0.000	Calculation	cmw2-2017/06/07	cmw2-2017/06/07
Total organic carbon (TOC)	n.d.	mg/L	1.0	SM 5310 B-(2011)	lkm2-2017/06/05	cmw2-2017/06/06
Arsenic (total)	0.0009	mg/L	0.0005	EPA 200.8	cjm4-2017/06/06	kkh9-2017/06/07
Ammonia - N (total)	n.d.	mg/L	0.10	SM 4500-NH3 G-(1997) *	mjw0-2017/06/01	cmw2-2017/06/06

All results are reported on an AS RECEIVED basis., n.d. = not detected

For questions please contact:

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Heather Ramig
Account Manager
hramig@midwestlabs.com (402)829-9891

The result(s) issued on this report only reflect the analysis of the sample(s) submitted.

REPORT NUMBER
17-158-4172

REPORT DATE
Jun 07, 2017

SEND TO
13542

RECEIVED DATE
Jun 01, 2017

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ISSUE DATE
Jun 07, 2017
LAB NUMBER
2677423
DATE SAMPLED
May 31, 2017
TIME SAMPLED
12:00

CITY OF FAIRBURY
CITY OFFICES/DENNIS MCATEE
BOX 554
FAIRBURY NE 68352-

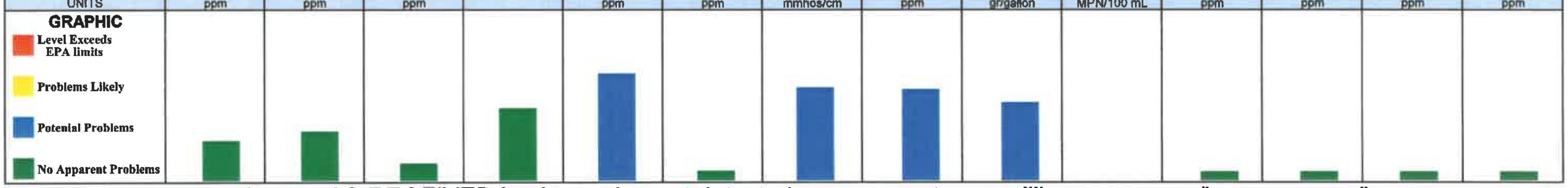
Domestic Suitability

For: (13542) CITY OF FAIRBURY
Water Quality As, TOC

Analytical Results for EAST WELL #3

PARAMETER	SODIUM	CALCIUM	MAGNESIUM	pH	NITRATE	SULFATE	CONDUC-TIVITY	TOTAL DISSOLVED SOLIDS	HARDNESS	TOTAL COLIFORM	IRON	MANGANESE	CHLORIDE	FLUORIDE
METHOD	EPA 200.7 Na	EPA 200.7 Ca	EPA 200.7 Mg	SM 4500 H+B	EPA 300.0 NO_3-N	EPA 300.0 SO_4	SM 2510 B	CALC	SM 2310B	SM 9223B	EPA 200.7 Fe	EPA 200.7 Mn	EPA 300.0 Cl	EPA 300.0 F
UNITS	ppm	ppm	ppm		ppm	ppm	mmhos/cm	ppm	gr/gallon	MPN/100 mL	ppm	ppm	ppm	ppm
LEVEL FOUND	39.4	77.8	10.1	7.14	10.0	36	0.614	399	13.8		n.d.	n.d.	15	0.2
CAUTION LEVEL	100	80	30	6.5/9	10	400	0.75	500	20		0.3	0.05	200	4

PARAMETER	SODIUM	CALCIUM	MAGNESIUM	pH	NITRATE	SULFATE	CONDUC-TIVITY	TOTAL DISSOLVED SOLIDS	HARDNESS	TOTAL COLIFORM	IRON	MANGANESE	CHLORIDE	FLUORIDE
METHOD	EPA 200.7 Na	EPA 200.7 Ca	EPA 200.7 Mg	SM 4500 H+B	EPA 300.0 NO_3-N	EPA 300.0 SO_4	SM 2510 B	CALC	SM 2310B	SM 9223B	EPA 200.7 Fe	EPA 200.7 Mn	EPA 300.0 Cl	EPA 300.0 F
UNITS	ppm	ppm	ppm		ppm	ppm	mmhos/cm	ppm	gr/gallon	MPN/100 mL	ppm	ppm	ppm	ppm



All results are reported on an AS RECEIVED basis., n.d. = not detected , ppm = parts per million, ppm = mg/kg, ppm = mg/L

For questions please contact:
Heather Ramig
Account Manager
hramig@midwestlabs.com (402)829-9891

The result(s) issued on this report only reflect the analysis of the sample(s) submitted.

SUGGESTED WATER QUALITY GUIDELINES FOR HUMAN CONSUMPTION

Sodium (Na)	Less than 20 ppm: No adverse effects.	20-80 ppm: Persons on restricted sodium diets should consult a physician concerning use.	More than 80 ppm: Should be used sparingly by persons on low-sodium diets.
Calcium (Ca)	Less than 80 ppm: No adverse effects.	80-150 ppm: Hard water problems such as scale formation can be expected.	More than 150 ppm: May be associated with high levels of sulfate (see sulfate below). Extreme hardness is undesirable for household use.
Magnesium (Mg)	Less than 30 ppm: No adverse effects.	30-80 ppm: Contributes to hardness when associated with high calcium levels.	More than 80 ppm: When associated with high sulfate, is likely to have a laxative effect (magnesium sulfate is Epsom Salts).
pH	Less than 6.5: Corrosive to metal.	6.5-8.5: No adverse effects.	Higher than 8.5: Possible bitter taste, and germicidal activity of chlorine is reduced, corrosive to pipes.
Nitrate Nitrogen (NO3-N)	Less than 2 ppm: No adverse effects.	2-10 ppm: No acute toxicity. Could have some negative health effects in young children.	More than 10 ppm: Increasing probability of health effect in children under 6 months of age due of reduced oxygen carrying capacity of the blood. EPA MCL standard of < 10 ppm.
Sulfate (SO4)	Less than 250 ppm: No adverse effects.	250-500 ppm: Likely to have a laxative effect, especially when first introduced. Diarrhea may or may not persist.	More than 500 ppm: Strongly laxative.
Conductivity	Less than 0.30: Extremely pure water can be corrosive metal.	0.30-1.50: No adverse effects.	Greater than 1.50: High levels of dissolved solids (see below).
Total Dissolved Solids (TDS)	Less than 200 ppm: No adverse health or nutritional effects. May be corrosive if extremely pure.	200-1000 ppm: No adverse effects.	More than 1000 ppm: Increasingly adverse effects, especially diarrhea. Water loses esthetic effect.
Hardness	Less than 6 gr/gal: No adverse effects (17.1 mg/L CaCO3 = (1 gr/gal).	6-12 gr/gal: Some scale may form in pipes and water heaters. Softening may be desirable.	More than 12 gr/gal: Scale will form rapidly and laundry will not come clean. Softening for household use is desirable.
Total Coliform*	Negative: No coliform bacteria present in 100 mL of water.		Positive: Coliforms are a bacteria that are naturally present in the environment and can be used to indicate the presence of other potentially harmful bacteria such as Fecal Coliform or *E.coli*. The presence of Fecal and *E. coli* may indicate a contamination from human or animal waste. The EPA acceptable level is less than one (<1) MPN (most probable number) per 100 mL of water.
Iron (Fe)	Less than 0.3 ppm: No adverse effects.	0.3-1.0 ppm: Some staining will occur.	More than 1.0 ppm: Iron oxide (rust) will cause extensive staining and will precipitate out, forming a red sludge. Taste will be bitter.
Manganese (Mn)	Less than 0.05 ppm: No adverse effects.	0.05-0.50 ppm: May cause black or brown staining of pipes, sinks and laundry.	More than 0.50 ppm: Besides the staining effect, will cause a metallic taste.
Chloride (Cl)	Less than 200 ppm: No adverse effects.	200-500 ppm: Increasingly salty taste.	More than 500 ppm: Very salty taste.

*Holding/Transit time between sampling and analysis cannot exceed 30 hours. If this time has been exceeded, the results might be invalid.

N.D. = Not Detected

EPA Guidelines suggest less than 0.015 ppm (mg/L) for Lead (Pb) and 1.30 ppm (mg/L) for Copper (Cu).

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17-158-4172

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CITY OF FAIRBURY
CITY OFFICES/DENNIS MCATEE
BOX 554
FAIRBURY NE 68352-

REPORT OF ANALYSIS

For: (13542) CITY OF FAIRBURY
Water Quality As, TOC

Analysis	Level Found As Received	Units	Reporting Limit	Method	Analyst-Date	Verified-Date
Sample ID: **EAST WELL #3**	Lab Number: **2677423**	Date Sampled: **2017-05-31 1405**				
Alkalinity (total)	216	mg CaCO3/L	20	SM 2320 B-(1997)	mgn8-2017/06/05	cmw2-2017/06/06
Langelier saturation index	-0.273		0.000	Calculation	cmw2-2017/06/07	cmw2-2017/06/07
Total organic carbon (TOC)	1.0	mg/L	1.0	SM 5310 B-(2011)	lkm2-2017/06/05	cmw2-2017/06/06
Arsenic (total)	0.0011	mg/L	0.0005	EPA 200.8	cjm4-2017/06/06	kkh9-2017/06/07
Ammonia - N (total)	n.d.	mg/L	0.10	SM 4500-NH3 G-(1997) *	mjw0-2017/06/01	cmw2-2017/06/06

All results are reported on an AS RECEIVED basis., n.d. = not detected

For questions please contact:
Heather Ramig
Heather Ramig
Account Manager
hramig@midwestlabs.com (402)829-9891

The result(s) issued on this report only reflect the analysis of the sample(s) submitted.

Water Quality Testing Results (2011 Report – 011-1474)

Chemical Constituent (mg/L)	Crystal Springs	Well #1 (701)	Well #2 (801)	Well #3 (971)	MCL	SMCL	Rec. Limits
Year of Analysis	2011	2011	2011	2011	-	-	-
Total Alkalinity (as $CaCO_3$)	214	210	198	234	-	-	>75
Total Hardness (as $CaCO_3$)	236	232	224	250	-	-	300
pH (S.U.)	6.8	6.87	6.84	6.87	-	6.5 - 8.5	-
Total Dissolved Solids	474	349	335	381	-	500	-
Sodium	65.5	26.4	25.1	32.0	-	-	20
Calcium	76.5	76.4	71.6	80.0	-	-	-
Iron	<RL	<RL	<RL	<RL	-	0.3	-
Manganese	<RL	<RL	<RL	<RL	-	0.05	-
Fluoride	<RL	0.62	0.30	0.23	4.0	2.0	-
Chloride	80.3	12.2	11.4	13.6	-	250	-
Sulfate	28.7	24.5	24.9	30.5	-	250	-
Nitrate + Nitrite (as N)	9.68	8.37	8.45	8.05	10	-	-
Arsenic, Total[1]	-	<RL	<RL	<RL	0.01	-	-
Gross Alpha (pCi/L) [1]	<RL	<RL	<RL	2.6	15	-	-
Combined Radium 226 & 228 (pCi/L) [1]	0.5	-	-	0	5	-	-

All bold numbers exceed existing or proposed limits by USEPA.
<RL = Below reporting level, SU = Standard Units
1) Arsenic, Gross Alpha, and Combined Radium levels were obtained from Nebraska DHHS Drinking Water Branch on-line reporting (2017) for the City of Fairbury.

Nebraska Public Health Environmental Laboratory
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(402) 471-2080 (fax)

NE3109507 - FAIRBURY, CITY OF
MICHAEL BEACHLER
612 D ST
PO BOX 554
FAIRBURY, NE 68352

ANALYTICAL RESULTS QUALIFIERS

Workorder: Profile: Special, Special

Lab ID:	**139966**	Date Received:	**10/20/2011** Matrix: **Water**
Sample ID:	**139966**	Date Collected:	**10/19/2011 13:35**
Sampled By:	**SWEETSER, JEFF**	Date Reported:	**11/8/2011**
Location:	**POE 011**		

Parameters	Results	Units	Qual	Report Limit	MCL	Analyzed	By
Analytical Method: EPA 353.2-Nitrate/Nitrite							
Nitrate + Nitrite (As N)	9.68	mg/L		0.05	10	10/20/2011	SKH
Analytical Method: SM 3111B - Minerals by AA							
Sodium, Total	65.5	mg/L		0.15	500	11/3/2011	AMJ
Calcium, Total	76.5	mg/L		0.15		11/3/2011	AMJ
Iron, Total	<RL	ug/L		50	300	10/21/2011	AMJ
Analytical Method: SM 4500 SO4-E - Sulfate							
Sulfate	28.7	mg/L		10		10/25/2011	TSW
Analytical Method: SM 9223B - Colilert Quantitray							
Total Coliform	0	cfu/100 ml		0		10/21/2011	KMM
E.coli	0	cfu/100 ml		0		10/21/2011	KMM
Analytical Method: ALK SM2320B							
Alkalinity (Total) As CaCO3	214	mg/L		20		10/21/2011	SKH
Analytical Method: TDS SM 2540C							
Total Dissolved Solids	474	mg/L		10.0		10/25/2011	SKH
Analytical Method: EPA 200.8 - ICP-MS Metals							
Manganese, Total	<RL	ug/L		1		10/28/2011	CFC
Analytical Method: SM 4500F-C, Fluoride							
Fluoride	<RL	mg/L		0.2	4	10/21/2011	MAP
Analytical Method: EPA 150.1, pH							
Ph, Laboratory	6.80	pH unit				10/20/2011	SKH
Analytical Method: EPA 325.2 - Chloride							
Chloride	80.3	mg/L		1		10/25/2011	MAP
Analytical Method: SM 2340C - Total Hardness							
Total Hardness	236	mg/L		4		10/21/2011	SKH

REMARKS See reverse side of report for description of acronyms and data qualifiers. For inquiries on result interpretation call: (402) 471-6435.

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PO BOX 554
FAIRBURY, NE 68352

ANALYTICAL RESULTS QUALIFIERS

Workorder: Profile: Special, Special

Lab ID:	**139968**	Date Received:	**10/20/2011** Matrix: **Water**
Sample ID:	**139968**	Date Collected:	**10/19/2011 14:19**
Sampled By:	**SWEETSER, JEFF**	Date Reported:	**11/8/2011**
Location:	**WELL 701**		

Parameters	Results	Units	Qual	Report Limit	MCL	Analyzed	By
Analytical Method: EPA 353.2-Nitrate/Nitrite							
Nitrate + Nitrite (As N)	8.37	mg/L		0.05	10	10/20/2011	SKH
Analytical Method: SM 3111B - Minerals by AA							
Sodium, Total	26.4	mg/L		0.15	500	11/3/2011	AMJ
Calcium, Total	76.4	mg/L		0.15		11/3/2011	AMJ
Iron, Total	<RL	ug/L		50	300	10/21/2011	AMJ
Analytical Method: SM 4500 SO4-E - Sulfate							
Sulfate	24.5	mg/L		10		10/25/2011	TSW
Analytical Method: SM 9223B - Colilert Quantitray							
Total Coliform	0	cfu/100 ml		0		10/21/2011	KMM
E.coli	0	cfu/100 ml		0		10/21/2011	KMM
Analytical Method: ALK-SM2320B							
Alkalinity (Total) As CaCO3	210	mg/L		20		10/21/2011	SKH
Analytical Method: TDS, SM 2540C							
Total Dissolved Solids	349	mg/L	1	10.0		10/25/2011	SKH
Analytical Method: EPA 200.8 - ICP-MS Metals							
Manganese, Total	<RL	ug/L		1		10/28/2011	CFC
Analytical Method: SM 4500F-C, Fluoride							
Fluoride	0.620	mg/L		0.2	4	10/21/2011	MAP
Analytical Method: EPA 150.1, pH							
Ph, Laboratory	6.87	pH unit				10/20/2011	SKH
Analytical Method: EPA 325.2 - Chloride							
Chloride	12.2	mg/L		1		10/25/2011	MAP
Analytical Method: SM 2340C - Total Hardness							
Total Hardness	232	mg/L		4		10/21/2011	SKH

REMARKS See reverse side of report for description of acronyms and data qualifiers. For inquiries on result interpretation call: (402) 471-6435.

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612 D ST
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FAIRBURY, NE 68352

ANALYTICAL RESULTS QUALIFIERS

Workorder: Profile: Special, Special

Lab ID:	**139965**	Date Received:	**10/20/2011** Matrix: **Water**
Sample ID:	**139965**	Date Collected:	**10/19/2011 13:59**
Sampled By:	**SWEETSER, JEFF**	Date Reported:	**11/8/2011**
Location:	**WELL 801**		

Parameters	Results	Units	Qual	Report Limit	MCL	Analyzed	By
Analytical Method: EPA 353.2 Nitrate/Nitrite							
Nitrate + Nitrite (As N)	8.45	mg/L		0.05	10	10/20/2011	SKH
Analytical Method: SM 3111B - Minerals by AA							
Sodium, Total	25.1	mg/L		0.15	500	11/3/2011	AMJ
Calcium, Total	71.6	mg/L		0.15		11/3/2011	AMJ
Iron, Total	<RL	ug/L		50	300	10/21/2011	AMJ
Analytical Method: SM 4500 SO4-E - Sulfate							
Sulfate	24.9	mg/L		10		10/25/2011	TSW
Analytical Method: SM 9223B - Colilert Quantitray							
Total Coliform	0	cfu/100 ml		0		10/21/2011	KMM
E.coli	0	cfu/100 ml		0		10/21/2011	KMM
Analytical Method: ALK SM2320B							
Alkalinity (Total) As CaCO3	198	mg/L		20		10/21/2011	SKH
Analytical Method: TDS, SM 2540C							
Total Dissolved Solids	335	mg/L		10.0		10/25/2011	SKH
Analytical Method: EPA 200.8 - ICP-MS Metals							
Manganese, Total	<RL	ug/L		1		10/28/2011	CFC
Analytical Method: SM 4500F-C, Fluoride							
Fluoride	0.301	mg/L		0.2	4	10/21/2011	MAP
Analytical Method: EPA 150.1, pH							
Ph, Laboratory	6.84	pH unit				10/20/2011	SKH
Analytical Method: EPA 325.2 - Chloride							
Chloride	11.4	mg/L		1		10/25/2011	MAP
Analytical Method: SM 2340C - Total Hardness							
Total Hardness	224	mg/L		4		10/21/2011	SKH

REMARKS See reverse side of report for description of acronyms and data qualifiers. For inquiries on result interpretation call: (402) 471-6435.

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PO BOX 554
FAIRBURY, NE 68352

ANALYTICAL RESULTS QUALIFIERS

Workorder: Profile: Special, Special

Lab ID:	**139967**	Date Received:	**10/20/2011**	Matrix:	**Water**
Sample ID:	**139967**	Date Collected:	**10/19/2011 14:10**		
Sampled By:	**SWEETSER, JEFF**	Date Reported:	**11/8/2011**		
Location:	**WELL 971**				

Parameters	Results	Units	Qual	Report Limit	MCL	Analyzed	By
Analytical Method: EPA 353.2 Nitrate/Nitrite							
Nitrate + Nitrite (As N)	8.05	mg/L		0.05	10	10/20/2011	SKH
Analytical Method: SM 3111B - Minerals by AA							
Sodium, Total	32.0	mg/L		0.15	500	11/3/2011	AMJ
Calcium, Total	80.0	mg/L		0.15		11/3/2011	AMJ
Iron, Total	<RL	ug/L		50	300	10/21/2011	AMJ
Analytical Method: SM 4500 SO4-E - Sulfate							
Sulfate	30.5	mg/L		10		10/25/2011	TSW
Analytical Method: SM 9223B - Colilert Quantitray							
Total Coliform	0	cfu/100 ml		0		10/21/2011	KMM
E.coli	0	cfu/100 ml		0		10/21/2011	KMM
Analytical Method: ALK SM2320B							
Alkalinity (Total) As CaCO3	234	mg/L		20		10/21/2011	SKH
Analytical Method: TDS SM 2540C							
Total Dissolved Solids	381	mg/L		10.0		10/25/2011	SKH
Analytical Method: EPA 200.8 - ICP-MS Metals							
Manganese, Total	<RL	ug/L		1		10/28/2011	CFC
Analytical Method: SM 4500F-C, Fluoride							
Fluoride	0.234	mg/L		0.2	4	10/21/2011	MAP
Analytical Method: EPA 150.1, pH							
Ph, Laboratory	6.87	pH unit				10/20/2011	SKH
Analytical Method: EPA 325.2 - Chloride							
Chloride	13.6	mg/L		1		10/25/2011	MAP
Analytical Method: SM 2340C - Total Hardness							
Total Hardness	250	mg/L		4		10/21/2011	SKH

REMARKS See reverse side of report for description of acronyms and data qualifiers. For inquiries on result interpretation call: (402) 471-6435.

APPENDIX "L"

City Financial Information: Water Fund

Exhibit D

CITY OF FAIRBURY, NEBRASKA - ENTERPRISE FUNDS

Statement of Revenues, Expenditures, and Changes in Fund Net Assets

Fiscal Year Ended April 30, 2012
(With Comparative Totals for Fiscal Year Ended April 30, 2011)

	Light Fund	Water Fund	Sewage Disposal Fund	Totals 2012	Totals 2011
Operating revenues:					
City services	$ 3,853,199	608,896	0	4,462,095	4,562,771
Rural service	2,293,014	135,373	0	2,428,387	2,479,066
Power pool	10,464	0	0	10,464	10,878
Public services	185,982	0	0	185,982	195,804
Intergovernmental service	119,492	96	0	119,588	137,947
Sewer services	0	0	490,003	490,003	507,573
Miscellaneous	64,319	10,830	0	75,149	82,632
Total operating revenues	6,526,470	755,195	490,003	7,771,668	7,976,671
Operating expenses:					
Production and purchased power	4,504,664	226,776	209,704	4,941,144	4,797,597
Distribution	746,753	225,251	0	972,004	835,320
General	385,615	62,853	59,559	508,027	467,650
Administrative	1,044,113	224,759	89,448	1,358,320	1,393,991
Total operating expenses	6,681,145	739,639	358,711	7,779,495	7,494,558
Operating income (loss)	(154,675)	15,556	131,292	(7,827)	482,113
Non-operating revenues (expenses):					
Gain on sale of assets	875	0	0	875	0
Interest and other income	88,013	536	4,639	93,188	92,288
Interest on long-term debt	0	(18,758)	(37,653)	(56,411)	(61,779)
Farm income/expenses	194	3,688	28,182	32,064	41,779
Total non-operating revenues (expenses)	89,082	(14,534)	(4,832)	69,716	72,288
Income (loss) before contributions and transfers	(65,593)	1,022	126,460	61,889	554,401
Transfers out	0	0	0	0	(39,761)
Changes in net assets	(65,593)	1,022	126,460	61,889	514,640
Total net assets - beginning	8,640,184	1,751,060	1,353,079	11,744,323	11,229,683
Total net assets - ending	$ 8,574,591	1,752,082	1,479,539	11,806,212	11,744,323

The notes to financial statements are an integral part of this statement.

Exhibit D

CITY OF FAIRBURY, NEBRASKA - ENTERPRISE FUNDS

Statement of Revenues, Expenditures, and Changes in Fund Net Assets

Fiscal Year Ended April 30, 2013
(With Comparative Totals for Fiscal Year Ended April 30, 2012)

	Light Fund	Water Fund	Sewage Disposal Fund	Totals 2013	Totals 2012
Operating revenues:					
City services	$ 4,090,429	660,876	0	4,751,305	4,462,095
Rural service	2,521,068	142,743	0	2,663,811	2,428,387
Power pool	7,866	0	0	7,866	10,464
Public services	191,221	0	0	191,221	185,982
Intergovernmental service	131,043	96	0	131,139	119,588
Sewer services	0	0	498,702	498,702	490,003
Miscellaneous	76,827	31,756	0	108,583	75,149
Total operating revenues	7,018,454	835,471	498,702	8,352,627	7,771,668
Operating expenses:					
Production and purchased power	5,287,532	274,592	209,975	5,772,099	4,941,144
Distribution	789,579	235,961	0	1,025,540	972,004
General	378,206	58,927	70,593	507,726	508,027
Administrative	1,077,388	219,048	90,109	1,386,545	1,358,320
Total operating expenses	7,532,705	788,528	370,677	8,691,910	7,779,495
Operating income (loss)	(514,251)	46,943	128,025	(339,283)	(7,827)
Non-operating revenues (expenses):					
Gain on sale of assets	0	0	0	0	875
Interest and other income	77,859	4,072	11,792	93,723	93,188
Interest on long-term debt	0	(17,684)	(33,778)	(51,462)	(56,411)
Farm income/expenses	0	29,783	28,965	58,748	32,064
Total non-operating revenues (expenses)	77,859	16,171	6,979	101,009	69,716
Income (loss) before contributions and transfers	(436,392)	63,114	135,004	(238,274)	61,889
Transfers out	0	0	(34,806)	(34,806)	0
Changes in net assets	(436,392)	63,114	100,198	(273,080)	61,889
Total net assets - beginning	8,574,591	1,752,082	1,479,539	11,806,212	11,744,323
Total net assets - ending	$ 8,138,199	1,815,196	1,579,737	11,533,132	11,806,212

The notes to financial statements are an integral part of this statement.

CITY OF FAIRBURY, NEBRASKA - ENTERPRISE FUNDS

Statement of Revenues, Expenditures, and Changes in Fund Net Assets

Fiscal Year Ended April 30, 2014
(With Comparative Totals for Fiscal Year Ended April 30, 2013)

	Light Fund	Water Fund	Sewage Disposal Fund	Totals 2014	Totals 2013
Operating revenues:					
City services	$ 4,468,751	697,117	0	5,165,868	4,751,305
Rural service	2,275,997	124,676	0	2,400,673	2,663,811
Power pool	8,679	0	0	8,679	7,866
Public services	190,376	0	0	190,376	191,221
Intergovernmental service	127,434	16	0	127,450	131,139
Sewer services	0	0	491,412	491,412	498,702
Miscellaneous	70,932	7,012	0	77,944	108,583
Total operating revenues	7,142,169	828,821	491,412	8,462,402	8,352,627
Operating expenses:					
Production and purchased power	5,810,978	254,032	217,545	6,282,555	5,772,099
Distribution	846,712	217,630	0	1,064,342	1,025,540
General	424,361	65,316	96,397	586,074	507,726
Administrative	1,014,798	217,287	97,278	1,329,363	1,386,545
Total operating expenses	8,096,849	754,265	411,220	9,262,334	8,691,910
Operating income (loss)	(954,680)	74,556	80,192	(799,932)	(339,283)
Non-operating revenues (expenses):					
RITA settlement	(246,961)	0	0	(246,961)	0
Interest and other income	67,973	2,971	2,797	73,741	93,723
Interest on long-term debt	0	(16,513)	(28,941)	(45,454)	(51,462)
Farm income/expenses	0	16,133	28,288	44,421	58,748
Total non-operating revenues (expenses)	(178,988)	2,591	2,144	(174,253)	101,009
Income (loss) before contributions and transfers	(1,133,668)	77,147	82,336	(974,185)	(238,274)
Transfers out	0	0	(38,969)	(38,969)	(34,806)
Changes in net assets	(1,133,668)	77,147	43,367	(1,013,154)	(273,080)
Total net assets - beginning	8,138,199	1,815,196	1,579,737	11,533,132	11,806,212
Total net assets - ending	$ 7,004,531	1,892,343	1,623,104	10,519,978	11,533,132

The notes to financial statements are an integral part of this statement.

Exhibit D

CITY OF FAIRBURY, NEBRASKA - ENTERPRISE FUNDS

Statement of Revenues, Expenditures, and Changes in Net Position

Fiscal Year Ended April 30, 2015
(With Comparative Totals for Fiscal Year Ended April 30, 2014)

	Light Fund	Water Fund	Sewage Disposal Fund	Totals 2015	Totals 2014
Operating revenues:					
City services	$ 4,708,542	731,395	0	5,439,937	5,165,868
Rural service	2,490,455	147,844	0	2,638,299	2,400,673
Power pool	9,808	0	0	9,808	8,679
Public services	196,026	0	0	196,026	190,376
Intergovernmental service	110,109	107	0	110,216	127,450
Sewer services	0	0	486,794	486,794	491,412
Miscellaneous	72,945	15,570	0	88,515	77,944
Total operating revenues	7,587,885	894,916	486,794	8,969,595	8,462,402
Operating expenses:					
Production and purchased power	6,382,270	191,154	226,649	6,800,073	6,282,555
Distribution	866,500	245,245	0	1,111,745	1,064,342
General	356,510	56,581	85,103	498,194	586,074
Administrative	1,052,192	198,663	94,093	1,344,948	1,329,363
Total operating expenses	8,657,472	691,643	405,845	9,754,960	9,262,334
Operating income (loss)	(1,069,587)	203,273	80,949	(785,365)	(799,932)
Non-operating revenues (expenses):					
PEA charges/RITA settlement	(69,178)	0	0	(69,178)	(246,961)
Interest and other income	63,974	3,000	2,699	69,673	73,741
Interest on long-term debt	0	(15,174)	(25,302)	(40,476)	(45,454)
Farm income/expenses	0	22,024	44,709	66,733	44,421
Total non-operating revenues (expenses)	(5,204)	9,850	22,106	26,752	(174,253)
Income (loss) before contributions and transfers	(1,074,791)	213,123	103,055	(758,613)	(974,185)
Transfers out	0	0	0	0	(38,969)
Changes in net position	(1,074,791)	213,123	103,055	(758,613)	(1,013,154)
Total net position - beginning	7,004,531	1,892,343	1,623,104	10,519,978	11,533,132
Total net position - ending	$ 5,929,740	2,105,466	1,726,159	9,761,365	10,519,978

The notes to financial statements are an integral part of this statement.

Exhibit D

CITY OF FAIRBURY, NEBRASKA - ENTERPRISE FUNDS

Statement of Revenues, Expenditures, and Changes in Net Position

Fiscal Year Ended April 30, 2016
(With Comparative Totals for Fiscal Year Ended April 30, 2015)

	Light Fund	Water Fund	Sewage Disposal Fund	Totals 2016	Totals 2015
Operating revenues:					
City services	$ 5,101,223	699,083	0	5,800,306	5,439,937
Rural service	2,772,289	145,471	0	2,917,760	2,638,299
Power pool	6,809	0	0	6,809	9,808
Public services	182,380	15,834	2,836	201,050	196,026
Intergovernmental service	119,454	97	0	119,551	110,216
Sewer services	0	0	497,709	497,709	486,794
Miscellaneous	100,737	11,587	0	112,324	88,515
Total operating revenues	8,282,892	872,072	500,545	9,655,509	8,969,595
Operating expenses:					
Production and purchased power	6,646,680	244,603	289,955	7,181,238	6,800,073
Distribution	815,065	232,190	0	1,047,255	1,111,745
General	310,664	84,462	77,010	472,136	498,194
Administrative	899,958	192,253	85,706	1,177,917	1,344,948
Total operating expenses	8,672,367	753,508	452,671	9,878,546	9,754,960
Operating income (loss)	(389,475)	118,564	47,874	(223,037)	(785,365)
Non-operating revenues (expenses):					
PEA charges/RITA settlement	0	0	0	0	(69,178)
Interest and other income	33,761	3,039	2,861	39,661	69,673
Interest on long-term debt	0	(14,214)	(20,770)	(34,984)	(40,476)
Farm income/expenses	(207)	23,515	29,387	52,695	66,733
Sale of assets	33,800	0	3,090	36,890	0
Total non-operating revenues (expenses)	67,354	12,340	14,568	94,262	26,752
Changes in net position	(322,121)	130,904	62,442	(128,775)	(758,613)
Total net position - beginning	5,929,740	2,105,466	1,726,159	9,761,365	10,519,978
Total net position - ending	$ 5,607,619	2,236,370	1,788,601	9,632,590	9,761,365

The notes to financial statements are an integral part of this statement.

APPENDIX “M”

Nitrate Best Management Practices and Information from 2011 Report

The recommended plan is as follows (from 2011 Report):

Key Conditions/Milestones	Action Item(s)
Nitrate levels continue to increase in Wellhead Protection Area (WHPA)	• Revise WHPA Rules • Install dedicated wells for nitrate monitoring upgradient of Crystal Springs • Develop a 3D groundwater model to evaluate nitrate reduction strategies in the WHPA
Single quarterly nitrate sample over 10.0 mg/L (MCL)	Re-sample to verify, issue necessary documentation to end users per NDHHS requirements
Four consecutive quarterly nitrate sample over 10.0 mg/L (MCL)	NDHHS will submit Administrative Order requiring action to be completed by City
Administrative Order	Past Administrative Orders have included the following conditions: • Continue monitoring and notify the public when samples are over MCL • Provide written quarterly reports to the Department regarding actions taken to return to compliance. • Retain a professional engineer and complete a Preliminary Engineering Report or final implementation plan schedule for returning to compliance.
Final Implementation Schedule	The City will be required to follow the plan, with continued quarterly updates to the Department.
Failure to comply with Administrative Order conditions	Fines and/or penalties may be assessed
Implement Final Plan	Final plan should include: • Design Memorandum of selected treatment processes • Final Design • Construction of Treatment Facility

Little Blue NRD designates Groundwater Management Areas based on the water quality and water quantity issues affecting the District. Water quantity areas are designated, because of falling water levels due to over pumping. Water quality management areas are designated due to groundwater contamination. For either type of management area, there are three designations; Level I, II, III, and IV based on the severity of the problem.

The Little Blue NRD's water quality concerns are mainly nitrates and other contaminants that are the results of non-point source pollution. Therefore, the groundwater management area designations are designed to reduce nitrate loading in groundwater that are the result of non-point source pollution by encouraging and/or requiring best management practices regarding fertilizer applications. Currently, a 30 square mile area in and around Fairbury has been designated as the Fairbury Water Quality Subarea.

A summary of the designation levels based on nitrate concentrations in groundwater are described below.

- The entire Little Blue NRD is within a Level I Management Area.
- Level II is triggered when over half the wells in an area have nitrate levels greater than 5 mg/L. The Fairbury Subarea currently has a Level II designation.
- Level III is triggered when over half the wells in an area have nitrate concentrations greater than 8.5 mg/L. Based on the NRD's last four years of nitrate monitoring results, the Fairbury subarea should have had a Level III designation for two of the last four years.
- Level IV is triggered when over half the wells in an area have nitrate concentrations greater than 10 mg/L. In 2011, six of the fifteen wells sampled have nitrate concentrations over 10 mg/L.

The required activities for farm operations within the Groundwater Management Areas are based on the level of designation as illustrated in Table VI-1. The types of activities include annual reporting of farm operations, soil and/or groundwater sampling, irrigation scheduling, and fertilizer training, permitting and prohibitions. Further details on the programs are available on the Little Blue NRD website (www.littlebluenrd.org).

Required Activities based on Groundwater Management Area Designation

Description of Required Activity based on Groundwater Management Area Designation	Level I	Level II	Level III	Level IV	Fairbury Subarea
Farm Operations Reports					
Initial Reports		*	*	*	*
Annual Reports (on all cultivated fields)		*1	*	*	*
Sampling					
Soil Sampling		*1	*	*	
Groundwater Sampling			*2	*	
Irrigation					
Irrigation Scheduling on all irrigated fields			*	*	
Fertilizer Applications					
Training (Every four years)	*	*	*	*	*
Fertilizer Application Permit from NRD	*	*	*	*	*
Anhydrous Application prohibited prior to November 1st	*	*	*		*
Anhydrous Application prohibited prior to January 1st				*	
Fertilizer with high nitrogen ratio or if application rate is >20 lbs/acre prohibited prior to March 1st	*	*	*	*	*
Nitrogen inhibitor required if application rate is >20 lbs/acre	*	*	*	*	*

1. Required for Demonstration fields only
2. Encouraged but not required until Level IV
NOTE: All fertilizer permit holders must submit annual reports to the NRD by March 1st.

As stated earlier, the City of Fairbury, the NDEQ and Little Blue NRD have established Wellhead Protection Areas for the Crystal Springs and East well field. Additionally, the City of Fairbury has setback requirements for certain activities and structures that range from 50 to 1,000 feet from any municipal water well. The setback requirements are defined in the City's Wellhead Protection Area.

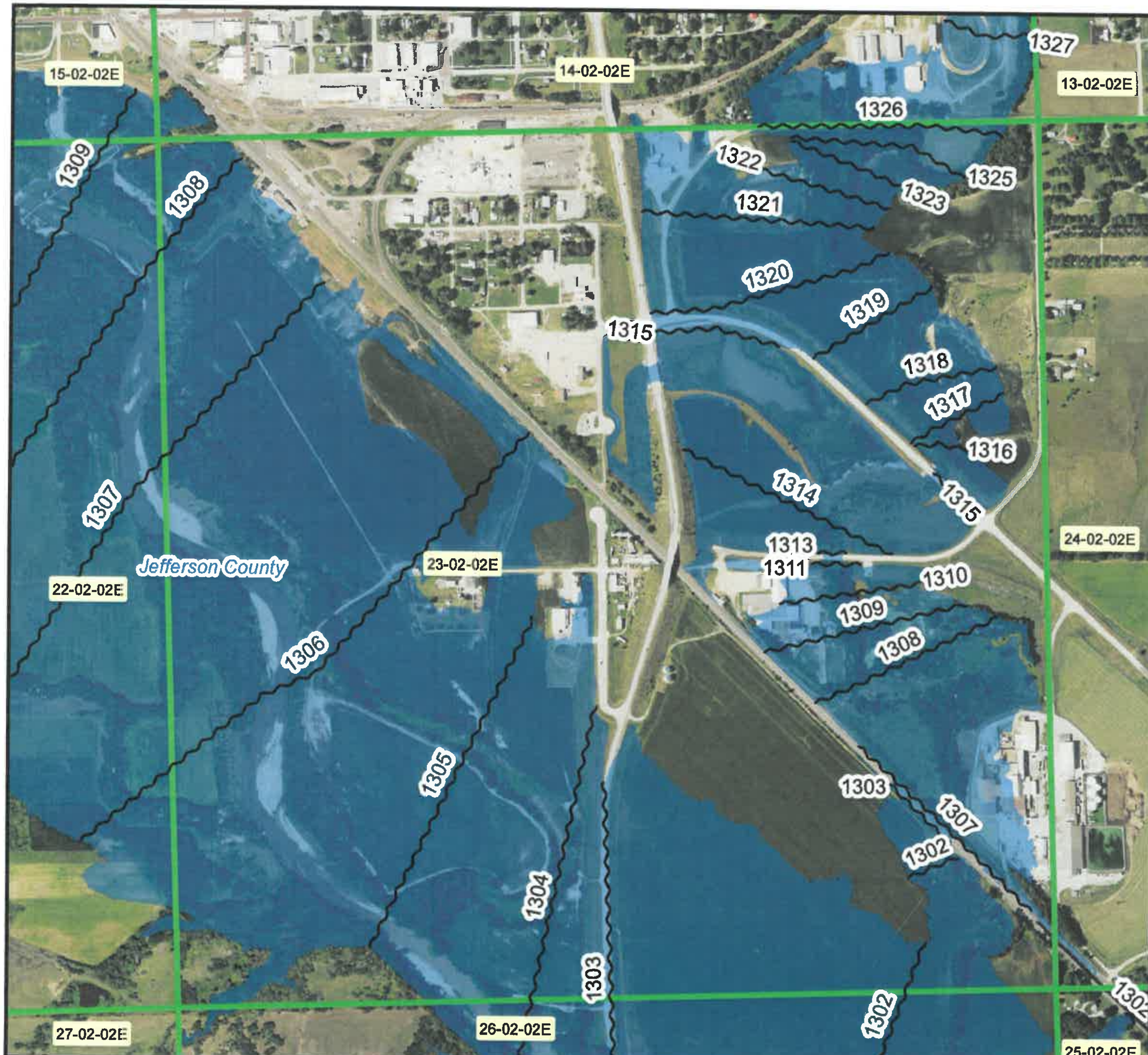
At this time, it is not recommended that the City of Fairbury look to develop a different water supply source. Although the nitrate concentrations in the area will likely continue to increase, the City has already invested substantially in their existing infrastructure. Therefore, Olsson recommends that the City work to decrease nitrates within the wellhead protection area while simultaneously investigating different treatment technologies as part of their future planning process. The following recommendations are presented regarding the WHPA (the treatment analysis and recommendations are presented in the next sections of this report):

- Designate the Fairbury Water Quality Management Area as Level III based on the latest groundwater monitoring results. This action would need to be taken by the Little Blue NRD board.
- Change the Little Blue NRD Groundwater Management Rules and Regulations to require the use of nitrification inhibitors with anhydrous ammonia applications between November 1 and March 1 at the manufacturer's recommended rate. This should be implemented in all Levels II, III and IV Groundwater Management Areas at a minimum. This action would need to be taken by the Little Blue NRD board.
- Review and revise the current Wellhead Protection Area and evaluate potential nitrate reduction strategies using a 3D groundwater model developed for the area in and around Fairbury. As done in Hastings, Nebraska, by better understanding the dynamics of the groundwater system feeding Fairbury's water supply wells and springs, better nitrate management decisions can be made to ensure that the nitrate load is decreasing over time instead of increasing. This work could be initiated by the City of Fairbury in cooperation with the Little Blue NRD. Funding may be available through the NDEQ 319 grant process similar to the grant awarded to the City of Edgar, Nebraska. The estimated cost for this study is $54,500.
- Additional dedicated monitoring wells should be installed upgradient Crystal Springs. The monitoring will provide the City with an early warning system regarding the changes in nitrate concentrations before they reach the City water supply. This will provide the City time to prepare for bottle water supply distribution should the need arise. The wells will also be able to provide information regarding the effects of best management practices implemented within the Wellhead Protection Area. The estimated cost for this study is estimated based on installation of eight new wells at $4,000 each for a total of $32,000. The model includes performing a pump test on one to establish the hydraulic conductivity of the aquifer, cost estimates for alternatives evaluated, a report and presentation of results.

APPENDIX “N”

Floodplain Information near Proposed Project Sites

Base Flood Elevation Determination



Nebraska
Department of Natural Resources

Section 23-02-02E
Jefferson County
Nebraska

Valid: August 12, 2016 to August 12, 2021
(Effective FIRM dated: 08/17/15)

Legend

BFE--NAVD 1988
Sections
Effective Flood Zone AE

N W E S

0 375 750 1,500 Feet

This BFE was determined by:

Jamie L. Reinke

Digitally signed by Jamie L. Reinke
DN: cn=Jamie L. Reinke, o=Nebraska Department of Natural Resources, ou=Floodplain Management, email=jamie.reinke@nebraska.gov, c=US
Date: 2016.08.19 08:11:27 -05'00'

Jamie L. Reinke, PE, CFM (402) 471-3957
Jamie.Reinke@nebraska.gov

BFE Determination Use and Limitations

Nebraska
Department of Natural Resources

Nebraska Statutes:

Nebraska Department of Natural Resources (NeDNR) provides BFE Determinations to local officials for the purpose of administrating floodplain management programs within their jurisdictions. Nebraska State Statute 31-1017 (4) and (6) more specifically say for Floodplain Management Regulations, and defines Floodplain Management Regulations in 31-1012 as "Flood plain management regulations shall mean and include zoning ordinances, subdivision regulations, building codes and other applications of the police power which are authorized by law to secure safety from floods and provide for the reasonable and prudent use of flood plains".

NeDNR BFE Determination Process:

Currently, NeDNR provides BFE Determinations for FEMA Zone A special flood hazard areas and NeDNR flood awareness areas. BFE Determinations for FEMA Zone AE special flood hazard areas must be determined from the Flood Insurance Study (FIS) tables and profiles using the Flood Insurance Rate Map (FIRM) as reference. NeDNR will be providing the FIS tables and trimmed FIRM panels with the requested section identified for FEMA Zone AE requests. NeDNR will also be available for technical assistance in these areas.

NeDNR uses the best available data and basic engineering methods to determine BFEs in FEMA Zone A special flood hazard areas and NeDNR flood awareness areas. This typically involves a regression analysis to compute hydrology and a normal depth calculation to develop water surface elevations for the 1-percent annual chance event. Basic engineering methods are established using bare earth topographic data; meaning structures are not considered and field survey is not conducted for use in the analysis.

Acceptable uses:

- Letter of Map Amendments (LOMAs) on existing structures,
- Elevation Certificates on existing structures, and
- Permitting of new structures, although NeDNR recommends that a professional engineer perform a site-specific analysis for all new development.

Unacceptable uses:

- Design of developments greater than 5 acres or 50 lots (44 CFR 60.3) and
- Hydraulic structure design.

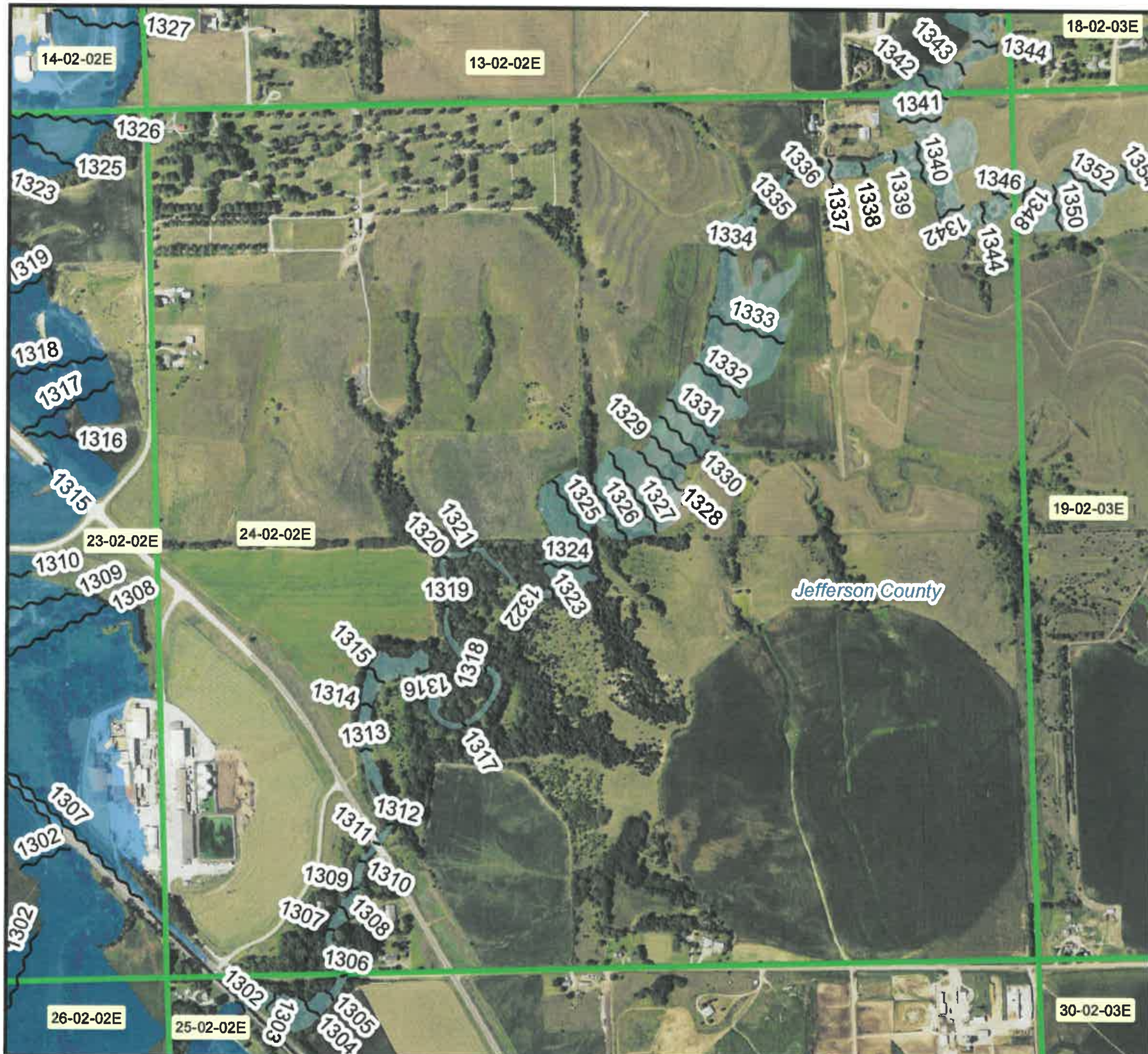
Community Responsibility:

Communities are responsible for maintaining records of the cumulative effect of proposed development (44 CFR 60.3(c)(10)).

BFE Determination Valid Dates:

The valid dates provided on BFE Determinations are the maximum validation period for the determinations and do not mean they are valid for that entire period. BFE Determinations can be superseded at any time. All future determinations will say Valid from XX/XX/XXXX until superseded to remind users to check on the validity of a BFE before its use.

Base Flood Elevation Determination



Nebraska
Department of Natural Resources

Section 24-02-02E
Jefferson County
Nebraska

Valid: August 17, 2016
to August 17, 2021
(Effective FIRM dated: 08/17/15)

Legend

- BFE--NAVD 1988
- Sections
- Effective Flood Zone
- Effective Flood Zone AE

N W E S

0 375 750 1,500 Feet

This BFE was determined by:

Jamie L. Reinke

Digitally signed by Jamie L. Reinke
DN: cn=Jamie L. Reinke, o=Nebraska Department of Natural Resources, ou=Floodplain Management, email=jamie.reinke@nebraska.gov, c=US
Date: 2016.08.19 08:11:27 -05'00'

Jamie L. Reinke, PE, CFM (402) 471-3957
Jamie.Reinke@nebraska.gov

BFE Determination Use and Limitations

Nebraska
Department of Natural Resources

Nebraska Statutes:

Nebraska Department of Natural Resources (NeDNR) provides BFE Determinations to local officials for the purpose of administrating floodplain management programs within their jurisdictions. Nebraska State Statute 31-1017 (4) and (6) more specifically say for Floodplain Management Regulations, and defines Floodplain Management Regulations in 31-1012 as "Flood plain management regulations shall mean and include zoning ordinances, subdivision regulations, building codes and other applications of the police power which are authorized by law to secure safety from floods and provide for the reasonable and prudent use of flood plains".

NeDNR BFE Determination Process:

Currently, NeDNR provides BFE Determinations for FEMA Zone A special flood hazard areas and NeDNR flood awareness areas. BFE Determinations for FEMA Zone AE special flood hazard areas must be determined from the Flood Insurance Study (FIS) tables and profiles using the Flood Insurance Rate Map (FIRM) as reference. NeDNR will be providing the FIS tables and trimmed FIRM panels with the requested section identified for FEMA Zone AE requests. NeDNR will also be available for technical assistance in these areas.

NeDNR uses the best available data and basic engineering methods to determine BFEs in FEMA Zone A special flood hazard areas and NeDNR flood awareness areas. This typically involves a regression analysis to compute hydrology and a normal depth calculation to develop water surface elevations for the 1-percent annual chance event. Basic engineering methods are established using bare earth topographic data; meaning structures are not considered and field survey is not conducted for use in the analysis.

Acceptable uses:

- Letter of Map Amendments (LOMAs) on existing structures,
- Elevation Certificates on existing structures, and
- Permitting of new structures, although NeDNR recommends that a professional engineer perform a site-specific analysis for all new development.

Unacceptable uses:

- Design of developments greater than 5 acres or 50 lots (44 CFR 60.3) and
- Hydraulic structure design.

Community Responsibility:

Communities are responsible for maintaining records of the cumulative effect of proposed development (44 CFR 60.3(c)(10)).

BFE Determination Valid Dates:

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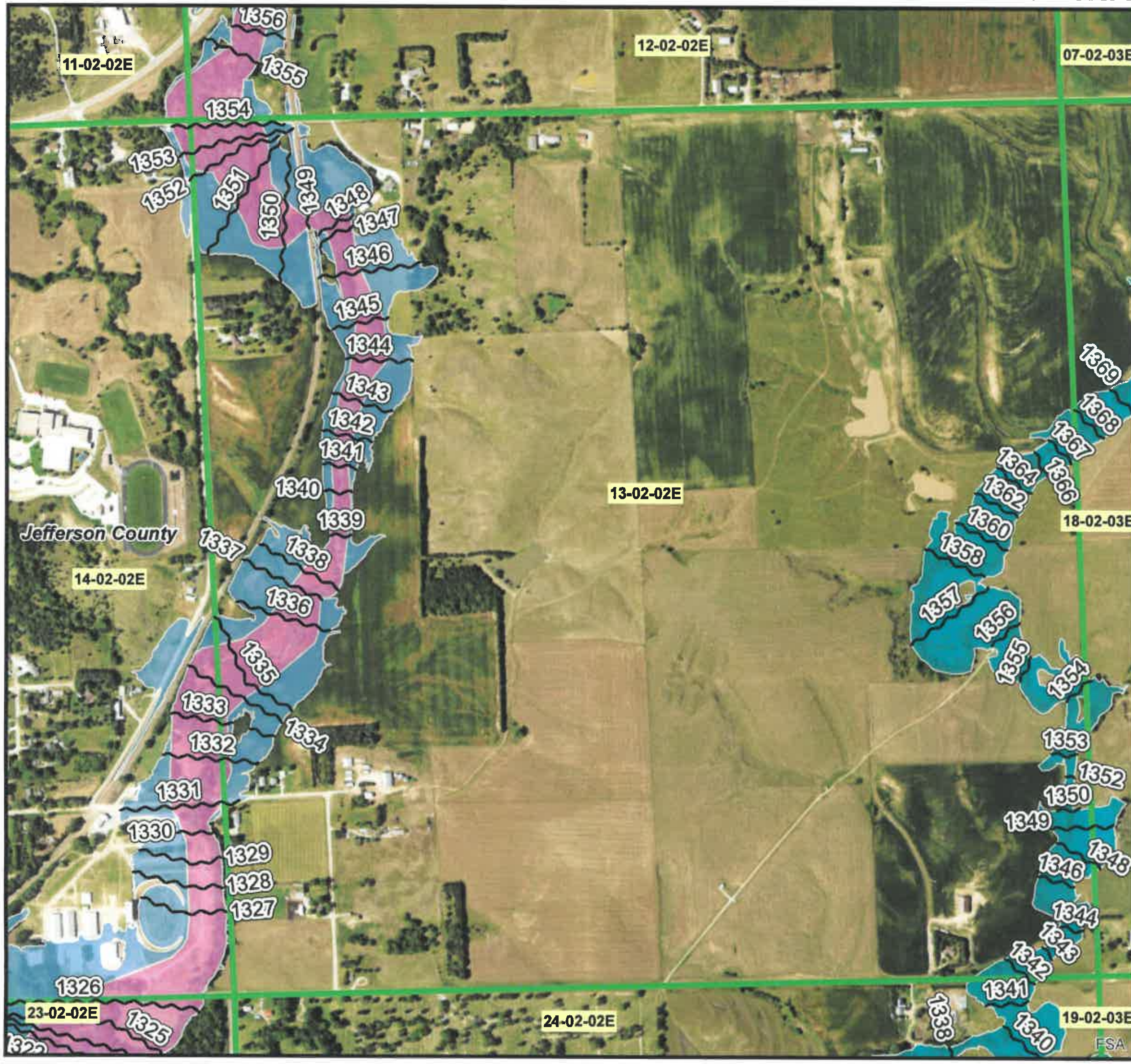
NEBRASKA
DEPT. OF NATURAL RESOURCES

Base Flood Elevation Determination



Section 13-02-02E
City of Fairbury
Jefferson County

Valid: May 31, 2017
until Superseded
(Effective FIRM dated: 8/17/2015)

Legend

BFE--NAVD 1988
Section
Effective Flood Zones
A
AE
AE Floodway

N W E S

0 375 750 1,500 Feet

Please see page 2 for the Use and Limitations of this BFE Determination

This BFE was determined by:

Digitally signed by Jared Ashton
DN: cn=Jared Ashton, o=Nebraska Department of Natural Resources, ou=Floodplain Management, email=jared.ashton@nebraska.gov, c=US
Date: 2017.05.31 11:17:12 -05'00'

Jared Ashton, PE, CFM (402) 471-0500
Jared.Ashton@nebraska.gov

BFE Determination Use and Limitations

NEBRASKA
DEPT. OF NATURAL RESOURCES

Nebraska Statutes:

Nebraska Department of Natural Resources (NeDNR) provides BFE Determinations to local officials for the purpose of administrating floodplain management programs within their jurisdictions. Nebraska State Statute 31-1017 (4) and (6) more specifically say for Floodplain Management Regulations, and defines Floodplain Management Regulations in 31-1012 as "Flood plain management regulations shall mean and include zoning ordinances, subdivision regulations, building codes and other applications of the police power which are authorized by law to secure safety from floods and provide for the reasonable and prudent use of flood plains".

NeDNR BFE Determination Process:

Currently, NeDNR provides BFE Determinations for FEMA Zone A special flood hazard areas and NeDNR flood awareness areas. BFE Determinations for FEMA Zone AE special flood hazard areas must be determined from the Flood Insurance Study (FIS) tables and profiles using the Flood Insurance Rate Map (FIRM) as reference. NeDNR will be available for technical assistance in these areas.

NeDNR uses the best available data and basic engineering methods to determine BFEs in FEMA Zone A special flood hazard areas and NeDNR flood awareness areas. This typically involves a regression analysis to compute hydrology and a normal depth calculation to develop water surface elevations for the 1-percent annual chance event. Basic engineering methods are established using bare earth topographic data; meaning structures are not considered and field survey is not conducted for use in the analysis.

Acceptable uses:

- Letter of Map Amendments (LOMAs) on existing structures,
- Elevation Certificates on existing structures, and
- Permitting of new structures, although NeDNR recommends that a professional engineer perform a site-specific analysis for all new development.

Unacceptable uses:

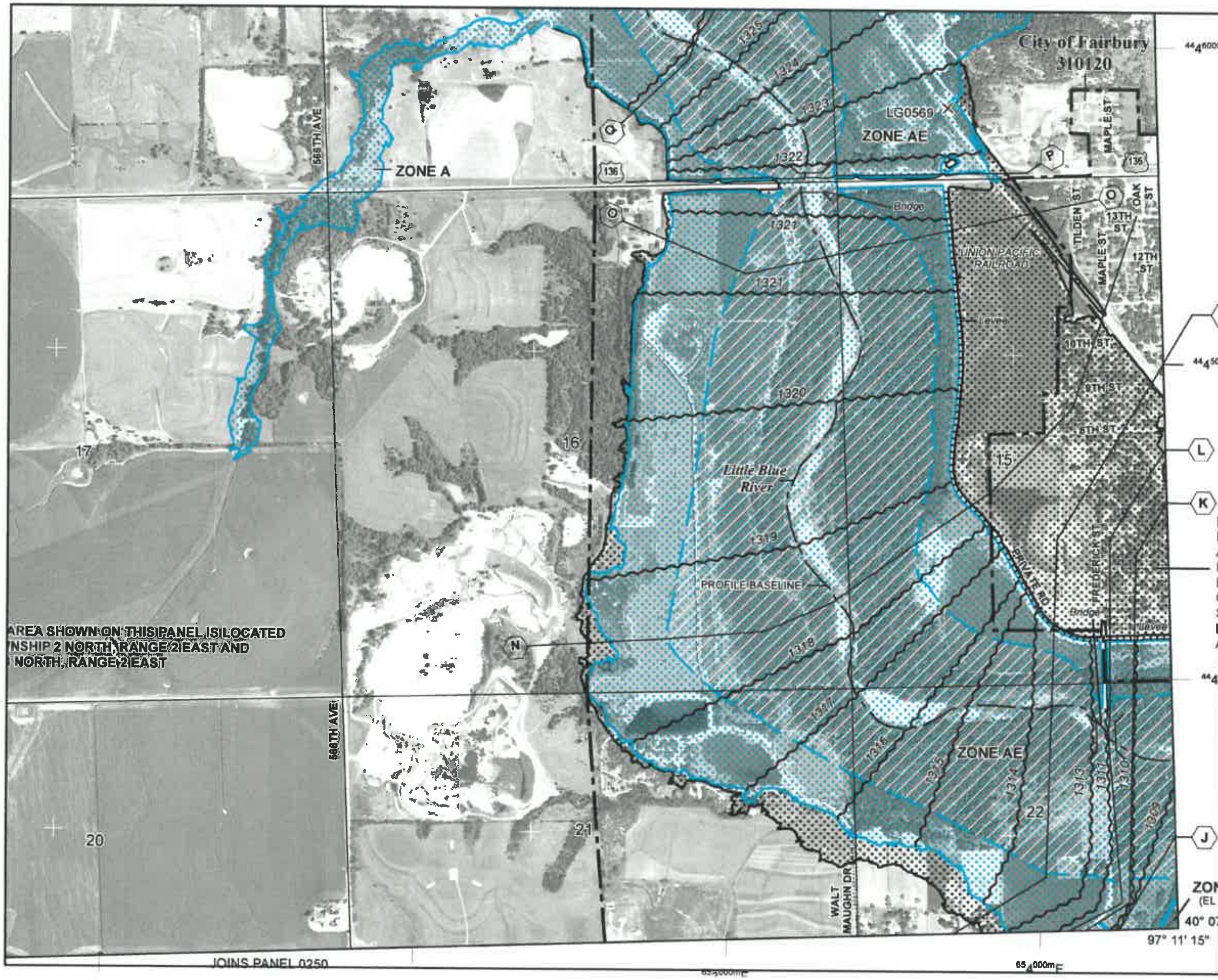
- Design of developments greater than 5 acres or 50 lots (44 CFR 60.3) and
- Hydraulic structure design.

Community Responsibility:

Communities are responsible for maintaining records of the cumulative effect of proposed development (44 CFR 60.3(c)(10)).

BFE Determination Valid Dates:

The valid dates provided on BFE Determinations are the maximum validation period for the determinations and do not mean they are valid for that entire period. BFE Determinations can be superseded at any time. All future determinations will say Valid from XX/XX/XXXX until superseded to remind users to check on the validity of a BFE before its use.



MAP SCALE 1" = 1000'

500 0 1000 2000 FEET

METERS

NFIP NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0140D

FIRM

FLOOD INSURANCE RATE MAP

JEFFERSON COUNTY, NEBRASKA AND INCORPORATED AREAS

PANEL 140 OF 300

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
FAIRBURY, CITY OF	310120	0140	D
JEFFERSON COUNTY	310447	0140	D

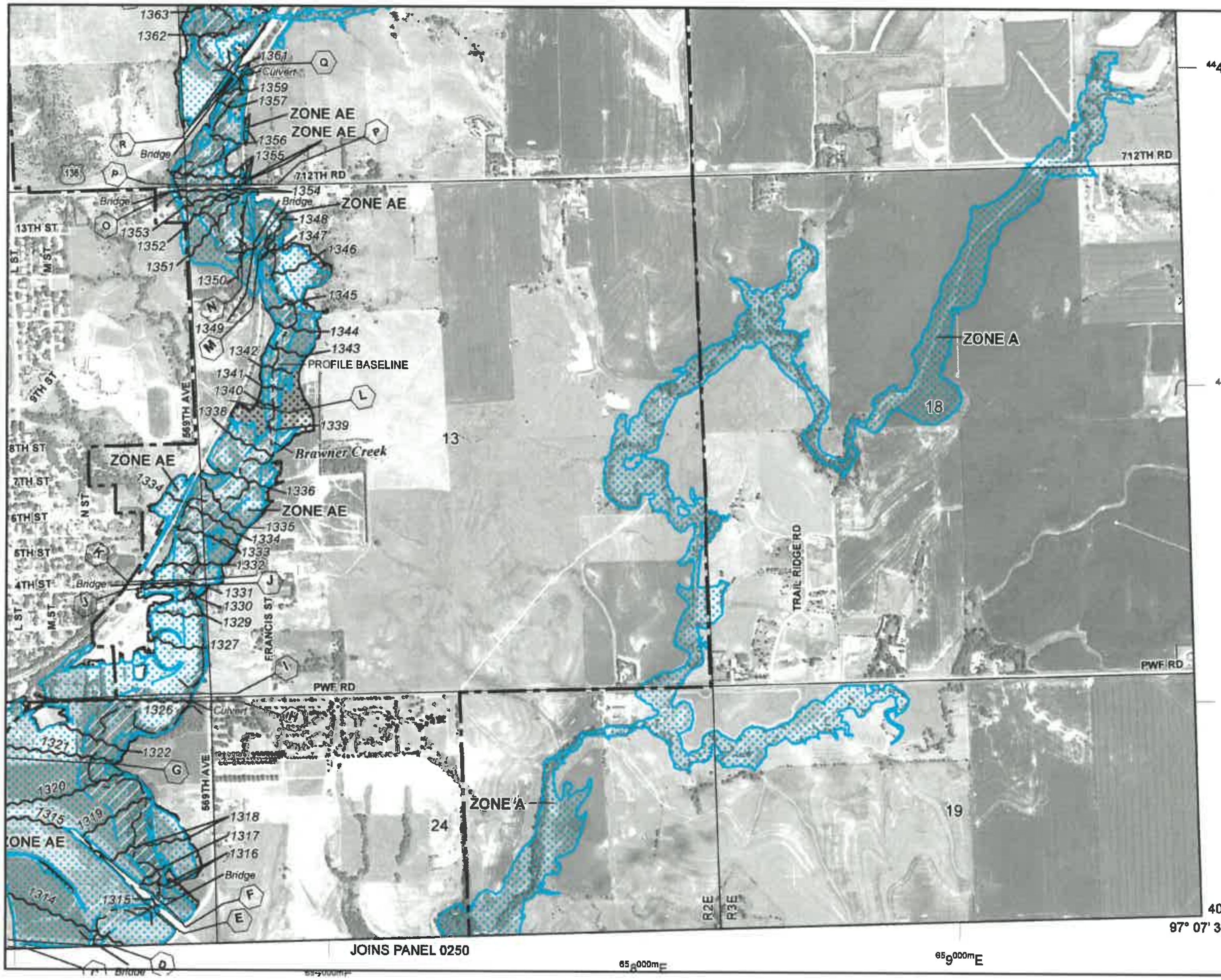
Notice to User: The Map Number shown below should be used when placing map orders; the Community Number shown above should be used on insurance applications for the subject community.

MAP NUMBER
31095C0140D

EFFECTIVE DATE
AUGUST 17, 2015

Federal Emergency Management Agency

This is an official copy of a portion of the above referenced flood map. It was extracted using F-MIT On-Line. This map does not reflect changes or amendments which may have been made subsequent to the date on the title block. For the latest product information about National Flood Insurance Program flood maps check the FEMA Flood Map Store at www.msc.fema.gov



NFIP

NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0145D

FIRM

FLOOD INSURANCE RATE MAP

JEFFERSON COUNTY, NEBRASKA
AND INCORPORATED AREAS

PANEL 145 OF 300

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
FAIRBURY, CITY OF	310126	0145	D
JEFFERSON COUNTY	310447	0145	D

Notice to User: The Map Number shown below should be used when placing map orders; the Community Number shown above should be used on insurance applications for the subject community.

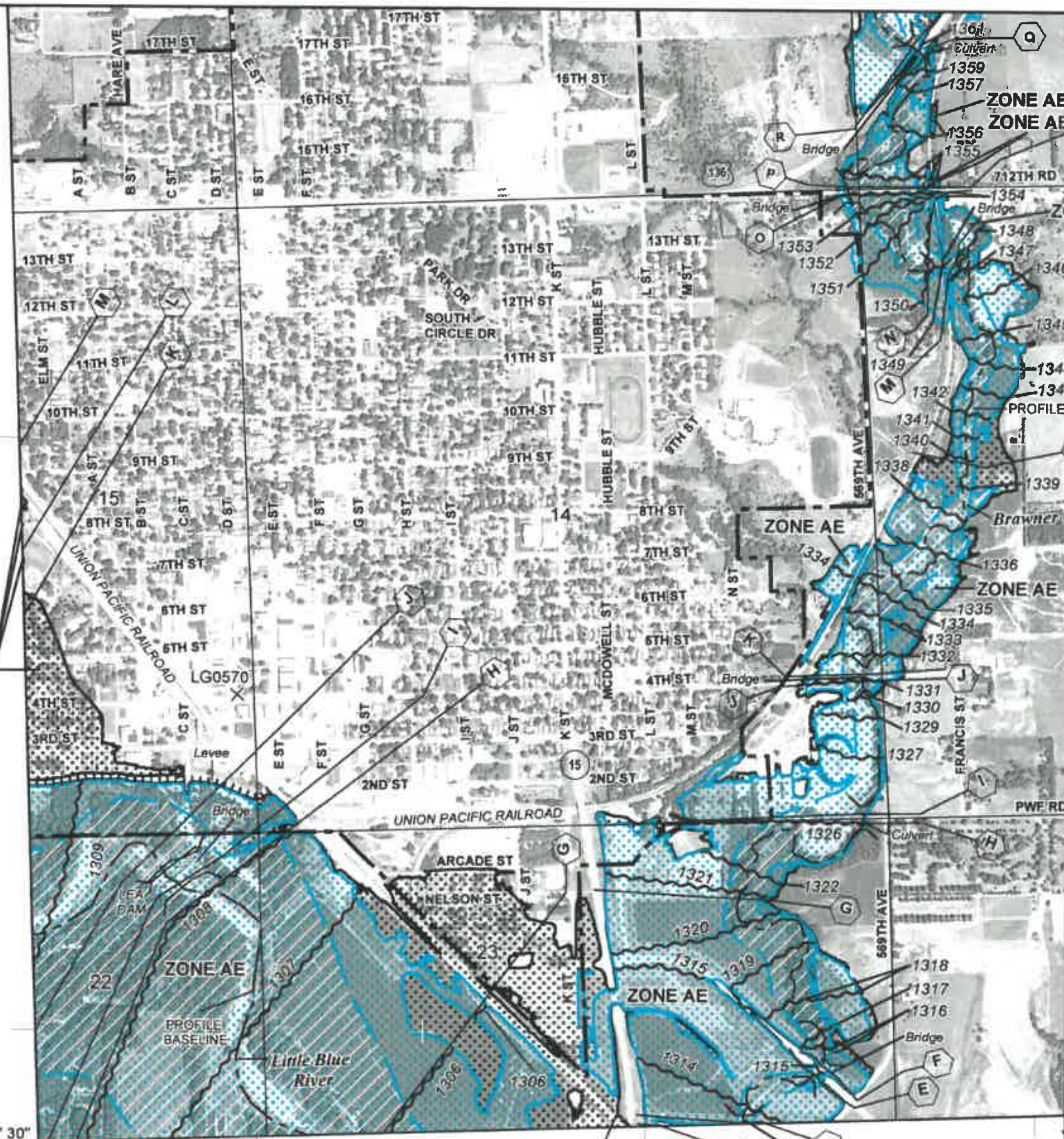
MAP NUMBER
31095C0145D

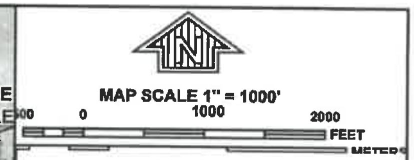
EFFECTIVE DATE
AUGUST 17, 2015

Federal Emergency Management Agency

This is an official copy of a portion of the above referenced flood map. It was extracted using F-MIT On-Line. This map does not reflect changes or amendments which may have been made subsequent to the date on the title block. For the latest product information about National Flood Insurance Program flood maps check the FEMA Flood Map Store at www.msc.fema.gov

NOTE: THIS AREA IS SHOWN AS BEING PROTECTED FROM THE 1-PERCENT-ANNUAL-CHANCE OR GREATER FLOOD HAZARD BY A LEVEE SYSTEM THAT HAS BEEN PROVISIONALLY ACCREDITED. OVERTOPPING OR FAILURE OF ANY LEVEE SYSTEM IS POSSIBLE. FOR ADDITIONAL INFORMATION, SEE THE "PROVISIONALLY ACCREDITED LEVEE NOTE" IN NOTES TO USERS.





NATIONAL FLOOD INSURANCE PROGRAM

NFIP

PANEL 0145D

FIRM

FLOOD INSURANCE RATE MAP

JEFFERSON COUNTY, NEBRASKA AND INCORPORATED AREAS

PANEL 145 OF 300

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
FAIRBURY, CITY OF	310120	0145	D
JEFFERSON COUNTY	310447	0145	D

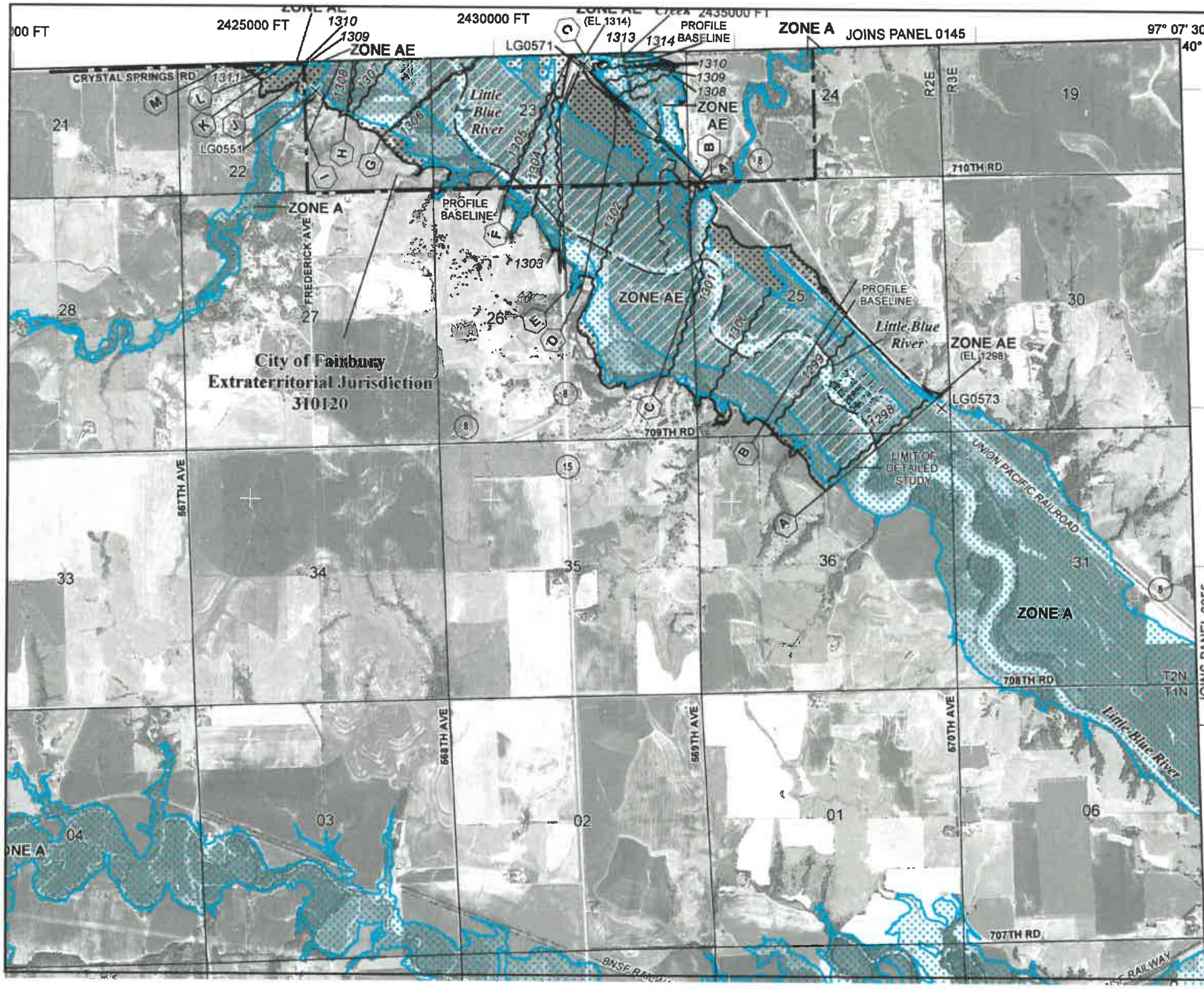
Notice to User: The Map Number shown below should be used when placing map orders; the Community Number shown above should be used on insurance applications for the subject community.

MAP NUMBER
31095C0145D

EFFECTIVE DATE
AUGUST 17, 2015

Federal Emergency Management Agency

This is an official copy of a portion of the above referenced flood map. It was extracted using F-MIT On-Line. This map does not reflect changes or amendments which may have been made subsequent to the date on the title block. For the latest product information about National Flood Insurance Program flood maps check the FEMA Flood Map Store at www.msc.fema.gov



MAP SCALE 1" = 2000'

0 2000 4000 FEET

NATIONAL FLOOD INSURANCE PROGRAM

NFIP

PANEL 0250D

FIRM

FLOOD INSURANCE RATE MAP

JEFFERSON COUNTY, NEBRASKA

AND INCORPORATED AREAS

PANEL 250 OF 300

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
FAIRBURY, CITY OF	310120	0250	D
JEFFERSON COUNTY	310447	0250	D

Notice to User: The Map Number shown below should be used when placing map orders; the Community Number shown above should be used on insurance applications for the subject community.

MAP NUMBER 31095C0250D

EFFECTIVE DATE AUGUST 17, 2015

Federal Emergency Management Agency

This is an official copy of a portion of the above referenced flood map. It was extracted using F-MIT On-Line. This map does not reflect changes or amendments which may have been made subsequent to the date on the title block. For the latest product information about National Flood Insurance Program flood maps check the FEMA Flood Map Store at www.msc.fema.gov

APPENDIX "O"

City WWTP Clean Water Act Effluent Detail
From NDEQ DMR Records
Information: 8/2011 to 1/2017

Wastewater Treatment Facility Historical Flows (8/2011 to 1/2017)

Date	Avg Flow Rate, MGD	Max Flow Rate, MGD
1/30/2017	0.25306	0.32825
10/24/2016	0.29609	0.70403
7/28/2016	0.25831	0.29821
4/25/2016	0.24938	0.31052
1/27/2016	0.25979	0.34720
10/28/2015	0.24866	0.30455
7/27/2015	0.50875	1.52444
4/27/2015	0.25600	0.43000
1/26/2015	0.31871	0.40000
10/27/2014	0.35033	0.42000
7/24/2014	0.34633	0.40000
4/28/2014	0.35710	0.40000
1/27/2014	0.37290	0.81000
10/25/2013	0.37300	0.51000
7/29/2013	0.33767	0.45000
6/23/2013	0.39871	1.21000
5/24/2013	0.21724	0.26000
4/29/2013	0.25429	0.28000
1/28/2013	0.20746	0.25902
2/11/2013	0.20746	0.25902
12/6/2012	0.32113	0.40639
10/17/2012	0.32113	0.40639
7/25/2012	0.24527	0.39949
4/25/2012	0.24527	0.39949
1/26/2012	0.19598	0.22073
10/31/2011	0.31561	0.58309
8/1/2011	0.24809	0.54582
Average	0.29495	0.47654
Minimum	0.19598	0.22073
Maximum	0.50875	1.52444

APPENDIX “P”

Water Treatment Equipment – Vendor Information
Wigen: Reverse Osmosis and Anion Exchange

Water.
Process.
Solutions.

302 Lake Hazeltine Drive
Chaska, MN 55318 USA

Phone 800-240-3330
Phone 952-448-4884
Fax 952-448-4886
Web WIGEN.COM

May 22, 2017

Budgetary Estimate for a RO System for Nitrate Removal for the City of Fairbury WTP

Prepared for: Craig Reinsch, Olsson Associates

Reverse Osmosis Option - Scope of Supply/Design Basis

RO Equipment Budget Price

System sizing is based on a providing 1300 gpm of RO permeate via 2 x 650 gpm skids with a 200 gpm bypass to provide 1500 gpm of treated water. A third 650 gpm skid provides redundancy so that the nitrate level can be achieved with one skid out of service. A Master PLC is located on one RO skid and connected to remote I/O panels on the other two RO skids. The CIP skid is hard wired to the Master PLC panel.

The scope of supply for the RO system consists of:

- Three (3) x 650 gpm (permeate) RO skids (867 gpm feed, 75% recovery).
- Banking per RO skid: 16:8 – 7 long.
- Toray TMG20D-400 membranes.
- One 52 round 40” pre-cartridge filter housing with cartridge filters and one 150 HP feed pump on each RO skid (if feed water has cartridge filter plant, these may be excluded which will reduce the skid price).
- 150 HP high pressure boost pump on each skid with VFD mounted in NEMAA 4X panel.
- Master PLC panel with Allen Bradley CompactLogix PLC controller and PVP600 10” touchscreen in NEMA 4Z enclosure on one RO skid, and remote I/O panels on other RO skids for connection to Master PLC with Ethernet cable.
- CIP Skid with 40 HP pump, 52-Round pre-filter and local NEMA 4X control panel to be hard wired to Master PLC panel.
- 2500 gal flat bottom HDPE CIP tank with heater.
- High pressure piping is Schedule 10 316 Stainless Steel.
- Low pressure feed and permeate piping is Schedule 80 PVC.

- Powder coated carbon steel RO and CIP skids.
- Shipping costs
- Start-up costs

The following would be required **by others**:

- Chemical dosing pumps for antiscalant and pH correction if needed.
- Compressor for instrument air.
- Valving and instrumentation for RO skid bypass blending.
- Installation of equipment and loading of membrane elements.

Budget Price excluding applicable taxes shall be provided by Vessco under separate cover.

Manufacturer Contact:
Michael Bourke
VP Businss Development
Tel: 303-350-3086
Email: Michael.Bourke@wigen.com

Local Representative:
Cory Sonner
Vessco Inc.
Tel: 515-233-8599
Email: csonner@vessco.com

Craig Reinsch

From: Cory Sonner <csonner@vessco.com>
Sent: Monday, May 22, 2017 2:43 PM
To: Craig Reinsch
Cc: Jon Harger
Subject: RE: Fairbury NE water treatment information request
Attachments: City of Fairbury NE RO Budget Estimate 5_2017.pdf

Good afternoon Craig,

Hope all is well sir. Attached is the updated budget pricing for the RO system from Wigen Technologies. Budget price is $1,300,000 plus taxes. Let me know if you have any comments, questions or concerns sir. Cheers-

Best Regards,

Cory A. Sonner | Sales Engineer
Vessco, Inc. | 414 S. 17th Street, Ste 101, Ames, IA 50010
c: (515) 509-0470 | w: (515) 233-8599 | csonner@vessco.com

Celebrating **35** Years of Clean Water

Think before you print!

From: Craig Reinsch [mailto:creinsch@olssonassociates.com]
Sent: Friday, May 5, 2017 11:46 AM
To: Cory Sonner; Jon Harger
Subject: Fairbury NE water treatment information request

Good morning,

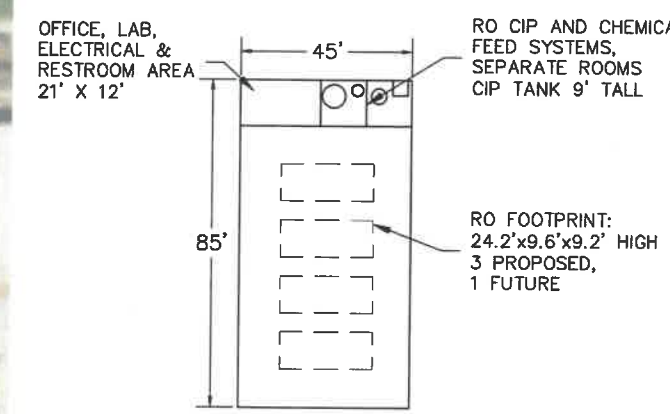
I am working with the City of Fairbury on an updated PER for their water system. In 2011/2012, you helped me to put together budgetary costs for a previous water treatment design report for the City (information attached). Since it has been a few years, I would like to request an update to the cost, layout, etc. Nitrate concentrations are still in the same range that they have been (7.5-9.5 mg/L). Flows haven't changed. I would like to receive updated costs by May 24, 2017 in preparation for meeting(s) with the City. Please let me know what additional information you need from me to provide the requested information. I appreciate your assistance!

Thanks, Craig

Craig Reinsch, PE, ENV SP | Water/Wastewater | Olsson Associates
601 P Street, Suite 200 | Lincoln, NE 68508 | creinsch@olssonassociates.com
TEL 402.474.6311 | DIR 402.458.5671 | FAX 402.474.5059

N

RO FOR NITRATE REMOVAL
PUMP THROUGH UNITS



GENERAL NOTES:

1. DUAL 12 INCH TRANSMISSION MAINS ARE LOCATED UNDERNEATH 3RD STREET, NORTH OF CENTERLINE.
2. NEW VALVES, FITTINGS, AND PIPING WILL PROVIDE THE OPTION OF FULL SYSTEM BYPASS OF THE TREATMENT FACILITY.

DWG: F:\2016\3501-4000\016-3570\40-Design\Exhibits\17-05-31_WTWW_Aerial.dwg USER: hdeboer
DATE: May 31, 2017 1:44pm XREFS:

PROJECT NO: 016-3570
DRAWN BY: HGD
DATE: 05/31/2017

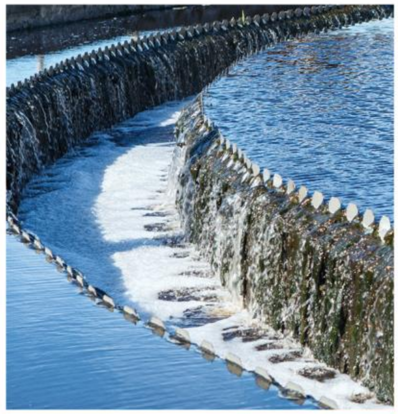
PROPOSED WATER TREATMENT PLANT LOCATION: REVERSE OSMOSIS
FAIRBURY, NEBRASKA

OLSSON® ASSOCIATES
601 P Street, Suite 200
P.O. Box 84608
Lincoln, NE 68508
TEL 402.474.6311
FAX 402.474.5160

FIGURE
P-1

APPENDIX “Q”

Water Treatment Equipment – Vendor Information
Tonka: Reverse Osmosis and Ion Exchange


Pur-IX™ and Conventional Ion Exchange

To:	Mr. Craig Reinsch, PE Olsson Associates 1111 Lincoln Mall, Suite 111 Lincoln, NE 68508
Proposal number	20615
Proposal date:	5/23/2017

Tonka Water Contact:

Alan Schneider
13305 Watertower Circle
Plymouth, MN 55441

We are represented on this project by:

Chris Johnson
Bert Gurney & Associates, Inc.
4428 South 108th Street,
Omaha, NE 68137
(402) 551-7995
chrisj@bgagurney.com

Tonka Water
ISO 9001:2008 Certified

TONKAWATER™
Trusted systems. Resourceful thinking.

Tonka Water

Tonka Water has provided customized water treatment systems and solutions since 1956 through a broad range of products and services. Tonka Water systems provide cost-effective solutions for the most challenging surface and ground water applications having successfully furnished over 2,200 treatment systems in the U.S. Tonka Water is known for innovative, quality systems, and superior customer service.

Tonka Water is a proven leader in ion exchange technology, and has a long, successful track record in the industry, including nitrate, organics, uranium, softening, and other anion and cation exchange processes.

Through an exclusive licensing agreement, Tonka Water offers the Pur-IX™ advanced Ion Exchange System for potable and process waters throughout North America.

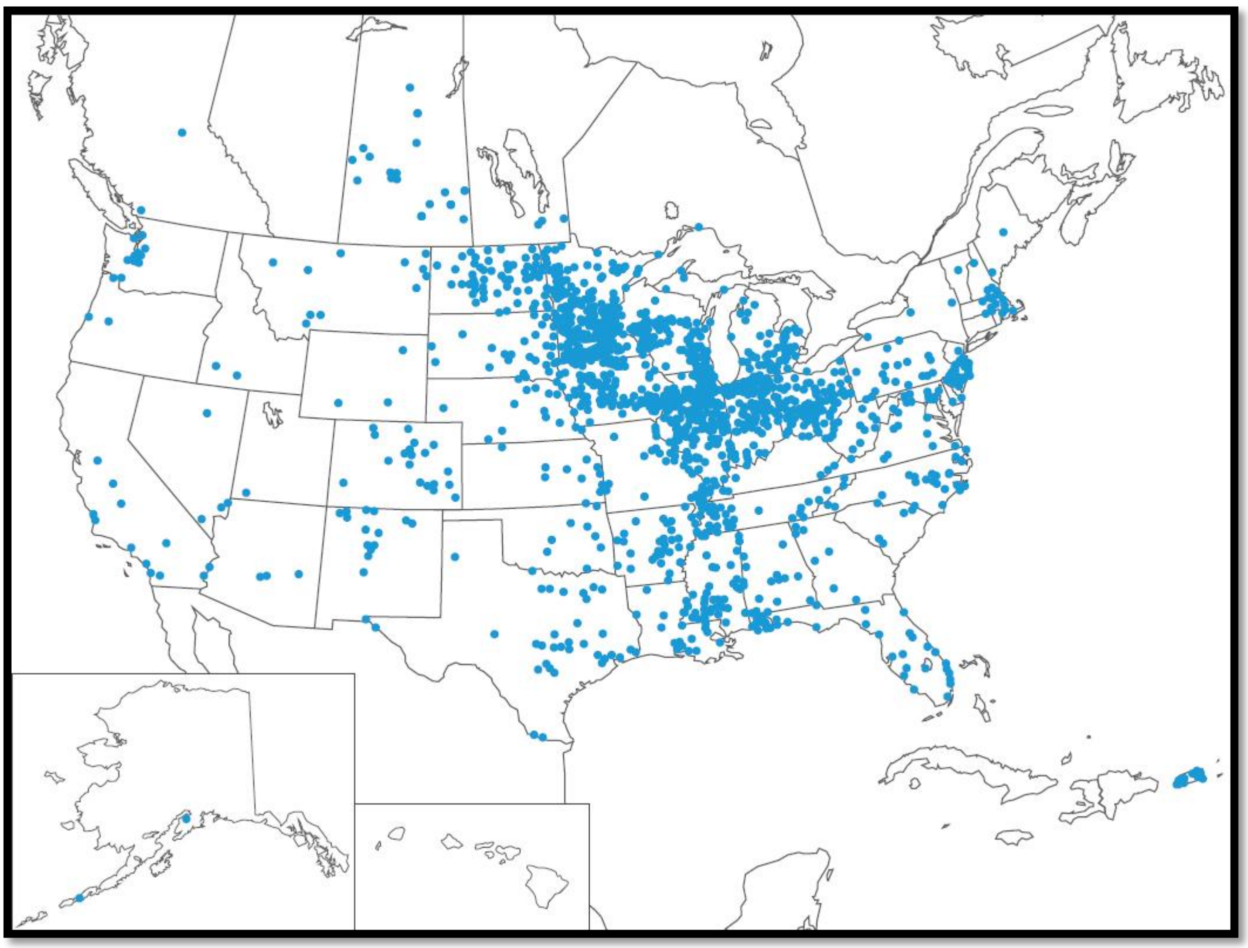


Figure 1: Tonka Water Treatment Installations

Section 1 Introduction

1.1 General System Description

Tonka Water is providing options for conventional ion exchange and Pur-IX™ to remove hardness and radium from municipal drinking water by the use of cation resin.

The Tonka Water Pur-IX™ system is the industry's most advanced ion exchange technology, resulting in unsurpassed efficiency and cost-effective removal of ionized contaminants from potable and process waters.

Pur-IX™ employs conventional ion exchange in a new, innovative way, allowing designers to minimize footprint while ensuring the lowest waste volume – all the while maintaining continuous and consistent flow of high quality treated water.

At the heart of the Pur-IX™ system is the centrally located Pur-IX™ multi-port valve, making Pur-IX™ the most simple and cost-effective continuous ion exchange technology available.

Figure 2: Pur-IX Valve

The Pur-IX™ Advantage

- **Lowest Cost of Operation**: The system's in-series cascade regeneration consumes minimal salt, much less than conventional or other types of ion exchange. Since salt consumption is the highest cost of operation, with Pur-IX™ your plant will be less expensive to operate, saving operating dollars for years and years to come.
- **Lowest Waste Volume**: The Pur-IX™ process generates a single continuous, low flow, waste stream, eliminating the need for enhancements such as waste equalization, gradual "bleeding" to final discharge, or large evaporative pond waste handling systems.
- **Consistent Product Water**: Pur-IX™ ensures a continuous and uniform treated water quality. There are no flow surges requiring adjustment in operation and product water quality stays consistent.

- **Simplicity of Operation**: The automatic controls and multi-port valve do all the work, directing process flow and regeneration as the inner disc intermittently indexes. This unique arrangement provides the highest level of process sophistication without the complexity of larger valve nests or brine recycle systems.

- **Compact Footprint**: Because flow is distributed among twenty individual vessels, the Pur-IX™ footprint is minimal – saving building space and clear height when compared to other ion exchange or treatment systems.

- **Minimal Energy Consumption**: The Pur-IX™ process has only one moving part – the interior disc of the multi-port valve. This disc momentarily indexes once every 30-60 minutes, in aggregate, operating less than 12 minutes per day. The only other moving parts are brine feed pumps, driven by fractional horsepower motors.

How Pur-IX™ Works

The Pur-IX™ valve performs several key ***treatment*** functions:

- Distributes untreated water to multiple in-service continuous ion exchange vessels.
- Collects treated water from multiple in-service continuous ion exchange vessels.

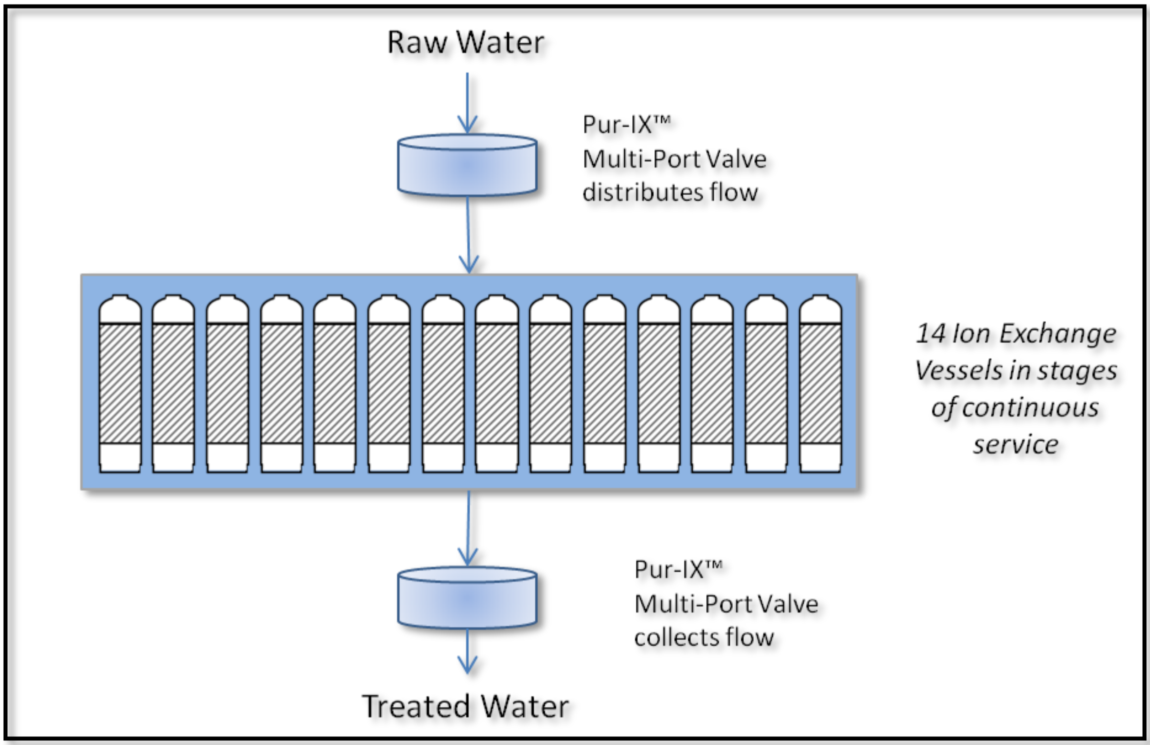


Figure 3: Continuous Ion Exchange

The Pur-IX™ valve performs several key ***regeneration*** functions:

- Automatically removes exhausted vessels from service.
- Continuously cycles out-of-service vessels through a multi-step regeneration process.
- Automatically returns regenerated vessels back into service.

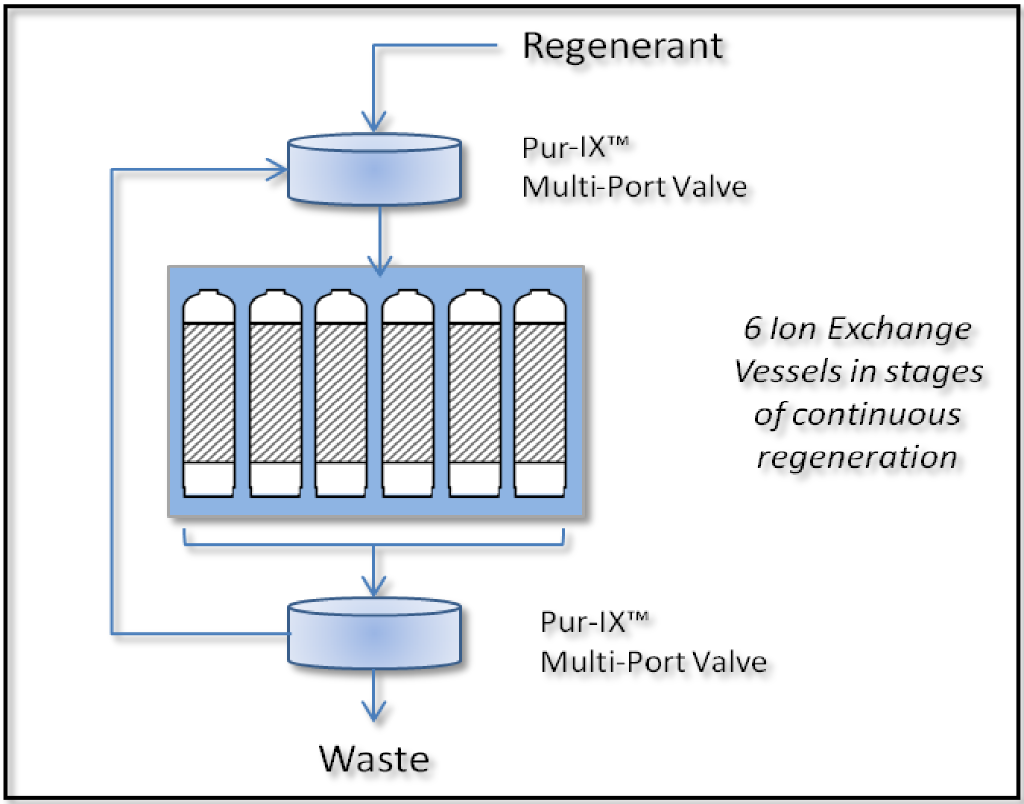


Figure 4: The Pur-IX™ valve performs automatic and continuous regeneration

1.2 Pur-IX™ Process: Description of Operation

Continuous, Parallel Ion Exchange

The Pur-IX™ process incorporates twenty ion exchange vessels, fourteen of which are treating water in parallel, while the remaining six are being regenerated. In many applications, a portion of raw water is designed to bypass treatment and blend with finished water to yield a targeted blended concentration:

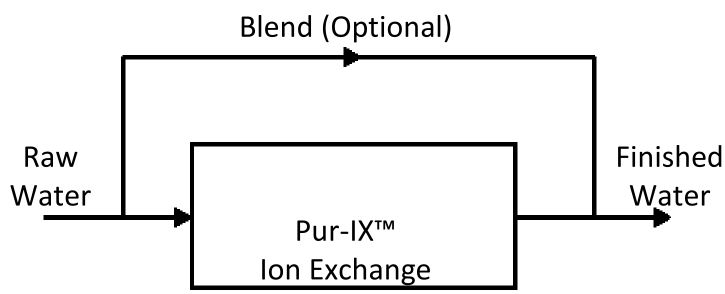


Figure 5: Typical System Configuration

Of the fourteen vessels treating water, each is at a different point in its run length, which is the amount of time a vessel can treat water before it must be regenerated. At any one time, as shown in Figure 6, one vessel has just been regenerated (vessel position 14), while another is nearly depleted in capacity and will soon need to be regenerated (vessel position 1). The other twelve are at varying stages of treatment capacity (vessel positions 2-13).

This unique arrangement allows the resin to be loaded completely to capacity before regeneration is required. Operating in this way ensures that the resin is used to its fullest and maximum capacity, making the Pur-IX™ process the most efficient possible.

At the point of complete resin bed exhaustion, the Pur-IX™ valve indexes, causing the exhausted vessel in position 1 to shift to position 20 and enter the regeneration phase, while returning the newly regenerated vessel (position 15) back to the first service position (position 14).

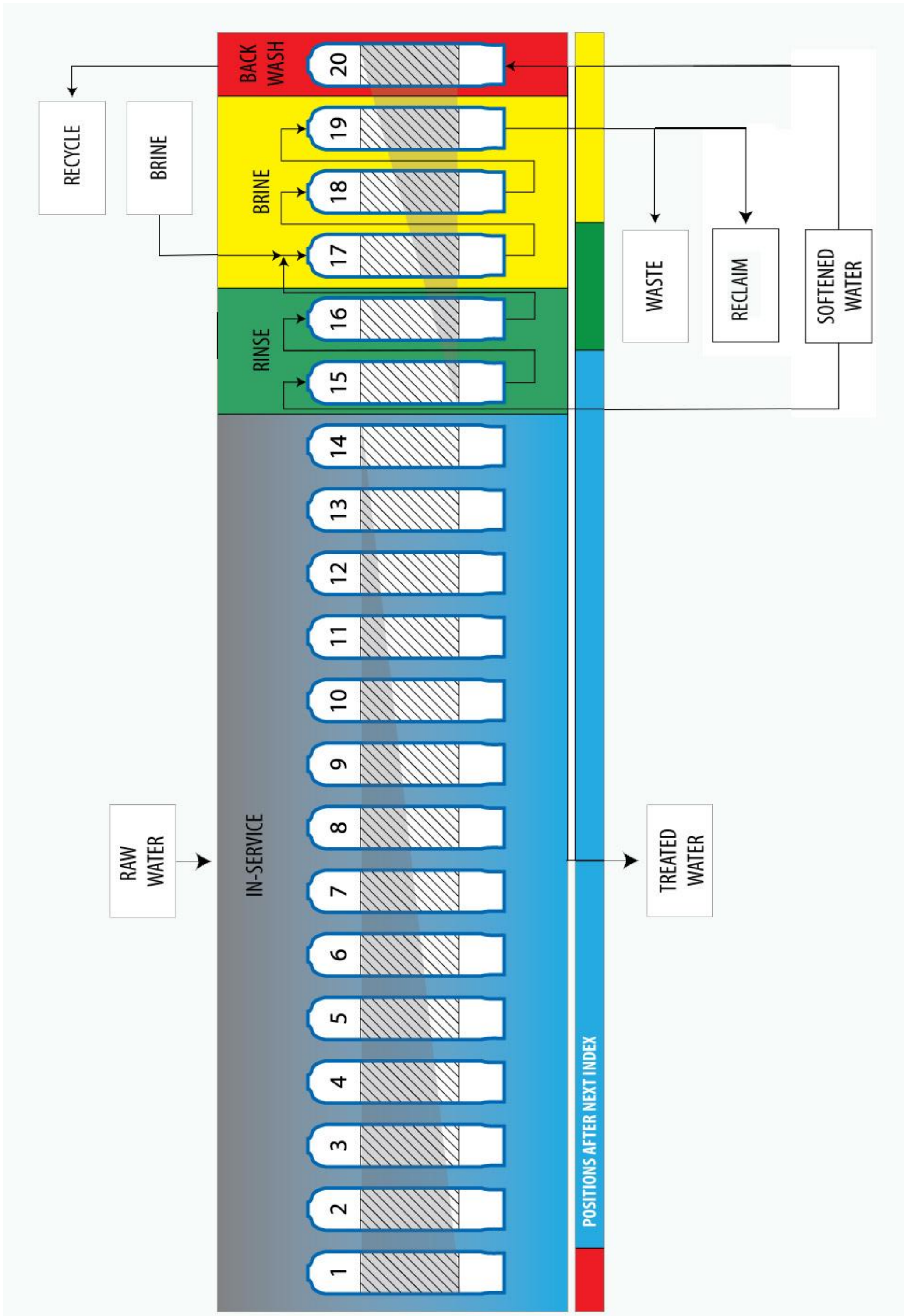


Figure 3: Pur-IX™ Process Schematic and Vessel Positions

Continuous Regeneration

General: As fourteen of the vessels are treating water in parallel, the remaining six are simultaneously being regenerated. Of the six vessels in regeneration, one is in Displacement/Backwash (vessel position 20), three are in Brine Regeneration (vessel positions 17-19), and two are in Rinse (vessel positions 15 and 16).

Displacement/Backwash: The Displacement/Backwash step displaces raw water with treated water, done in an up-flow manner to fluidize and backwash the media. The displaced water is recycled back to the front of the treatment process for recovery.

Brine Regeneration: A cascade-type, in-series regeneration utilizes a sodium chloride brine solution to its fullest, minimizing salt consumption. Three vessels (positions 17-19) are regenerated in series as shown in Figure 6, with a diluted sodium chloride brine solution. Fresh brine first enters at vessel position 17, then passes through the second vessel (position 18), and finally through the third vessel (position 19). By directing the brine through several vessels, it ensures that every last bit of regeneration capacity is extracted from the sodium chloride regenerant. This means less salt is needed for regeneration. This efficient salt usage is the key advantage Pur-IX™ offers over conventional ion exchange, which regenerates one vessel at a time and disposes of the waste immediately, in a “slug flow”.

Rinse: After exposure to the cascading brine steps, the remaining two vessels at positions 15 and 16 are rinsed with soft water before being returned to service. The rinse water is used to displace any brine in the vessels remaining from the previous regeneration steps. Softened water enters the first vessel (position 15), and the effluent is then sent through the next vessel (position 16). The effluent from the second vessel combines with the incoming brine solution, which is done for two reasons: (1) any remaining brine being rinsed out of the vessels is re-used to regenerate other vessels – so no brine is being wasted; and (2) the rinse water mixes with saturated brine to effectively dilute the brine and prevent resin osmotic shock from occurring during regeneration. Osmotic shock is a phenomenon that sometimes occurs when ion exchange resin is exposed to an extreme concentration of brine, resulting in surface cracking and ultimate resin attrition. Diluting the saturated brine prevents this situation.

Final Waste/Disposal: Because displacement water is recycled, and rinse effluent combines with the incoming brine solution, there is only one low-flow waste stream from the Pur-IX™ system. This stream comes out of the third vessel in the brine regeneration series (vessel position 19). This waste stream is continuous and extremely low in volume.

Valve Indexing and Flow Distribution

The Pur-IX™ process steps, for both treatment and regeneration, occur simultaneously. This is accomplished through the multi-port valve, which has an inner disc with channels that appropriately direct the different flow streams to each vessel simultaneously.

When the vessel in position 1 is ready for regeneration, the inner disc "indexes," or rotates, to line up with the next set of ports, effectively changing the process positions of all vessels. It should be noted that the vessels remain stationary; the only moving part is the inner disc of the multi-port valve as it indexes.

Along with the inner disc, the valve has an outer shell with twenty send ports. Both the inner disc and outer shell are machined from solid blocks of high density polypropylene, making them very strong and durable. The valve is furnished with internal o-rings to provide double-wall protection between ports and allow for early leak detection in the event of an unlikely o-ring failure. All wetted parts are certified to ANSI/NSF standards.

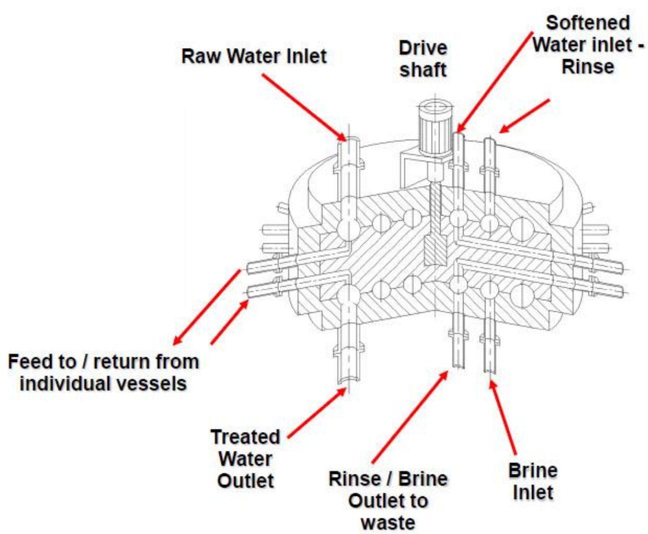
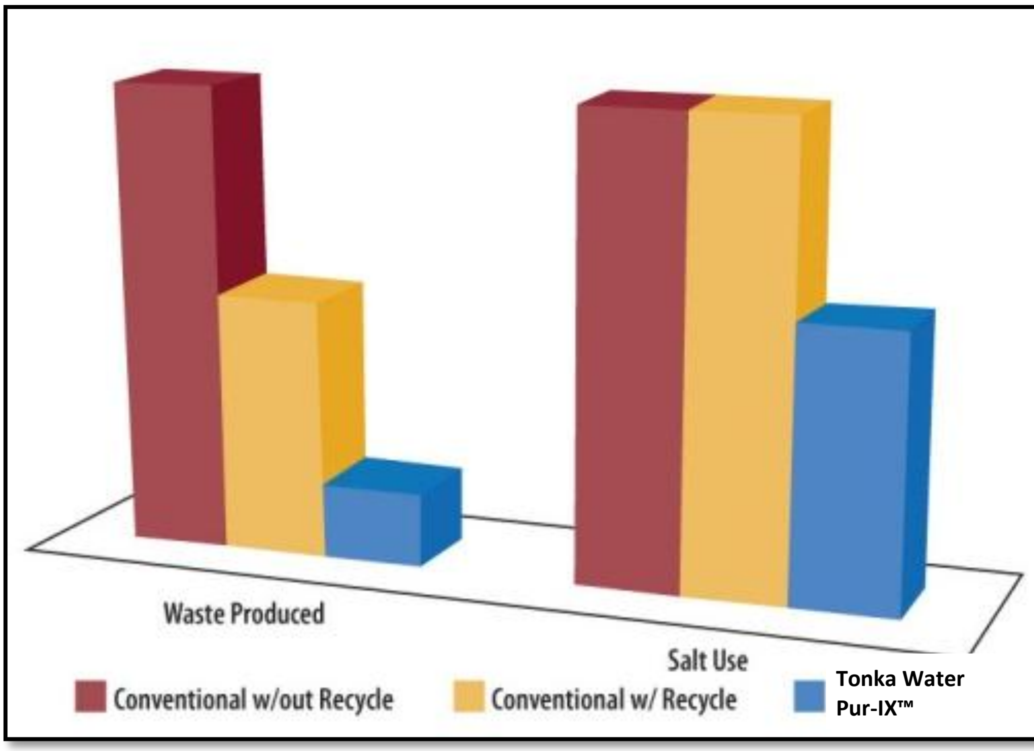


Figure 7: Cut-away of Pur-IX™ valve

Summary of Operation

All of the above functions (14 vessels in parallel operation; six vessels in regeneration) happen simultaneously through the Pur-IX™ valve. The multi-port valve facilitates the flow splitting to each vessel, directs cascade regeneration, and combines the rinse waste with the inlet brine, all kept within the valve's internal channeling. Vessel process positions are changed only when the valve changes internal channel positions, that is, when it indexes – typically occurring once or twice per hour of operation. The indexing interval is selected considering factors such as: inlet containment concentration; system flow; and facility treatment goals. The Pur-IX™ process, through superior valve innovation, minimizes salt usage and waste production, making it a much more efficient ion exchange technology.



1.3 Conventional Process: Description of Operation

Intermittent Ion Exchange

The conventional process incorporates a smaller number of ion exchange vessels, all of which are treating water in parallel, and one vessel is taken off and regenerated in a batch process. In many applications, a portion of raw water is designed to bypass treatment and blend with finished water to yield a targeted blended concentration:

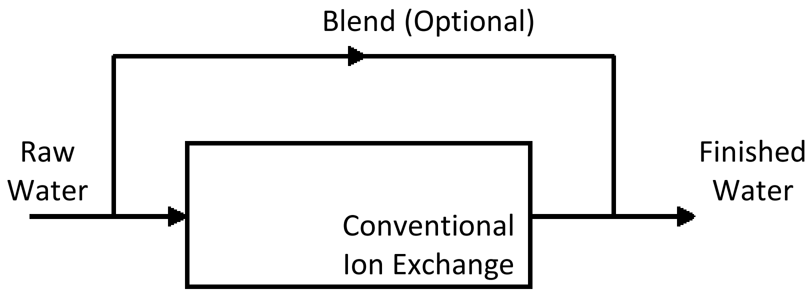


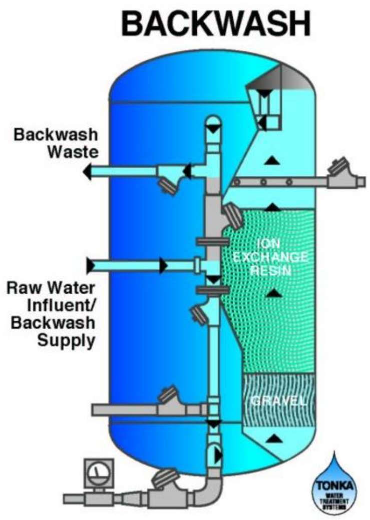
Figure 4: Typical System Configuration

With a small number of vessels in service, as a vessel reaches its design capacity and begins to produce water with higher contaminants, the vessel is taken off line. This point of "break-through" is experienced before a large amount of resin in the lower portion of the resin bed had used its capacity for ion exchange. This early breakthrough causes in increase in the amount of salt needed for regeneration in comparison to the amount of water treated.

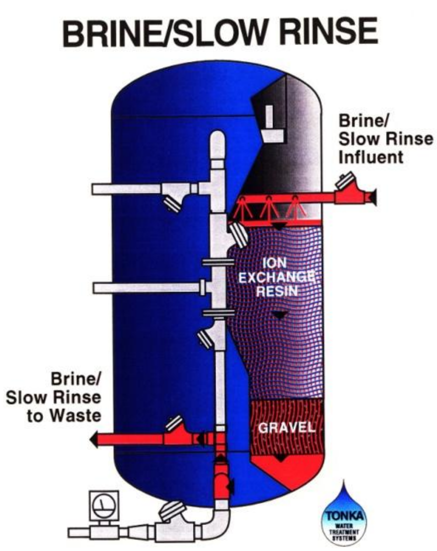
Batch Regeneration

General: The flow split of the water is obtained by the head loss through the piping and the resin bed. As contaminants are removed from the water and the resin bed reaches a break-through point, the vessel that has been in service longest is taken out of service.

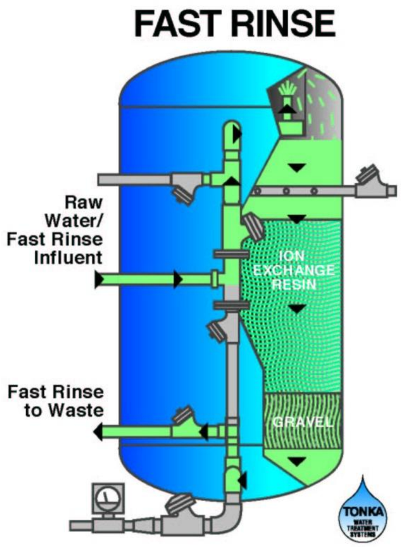
Displacement/Backwash: The Displacement/Backwash step displaces raw water with treated water, done in an up-flow manner to fluidize and backwash the media.



Brine Regeneration: A mixture of 50% saturated brine and 50% water is pumped through the ion exchange resin to facilitate the exchange of contaminants with sodium ions. The internal brine distributor directly above the resin provides for even flow over the media. The slow rinse process continues with water-only to push the brine through the bed.



Rinse: After the resin bed has been exposed to the batch brine needed for regeneration, the vessel is placed into fast rinse step, which rinses out the left over brine from the resin, vessel and gravels, all of which is discharged to waste. This step is terminated on time, based on salinity measurement taken by field tech at startup. When finished, the vessel batch meter is re-set.



Summary of Operation

The system goes through treatment until one vessel reaches its break-through point, as determined by a set point of number of gallons treated. At this time, one vessel is taken out of service, increasing the loading rate on the remaining vessels. Each vessel has 6 electrically operated valves that operate to send the vessel through the steps of the regeneration process. This vessel is then brought back online until the next vessel reaches its break-through point and taken out of service for regeneration.

Section 2 Treatment System Design

2.1 Raw Water Chemistry

This nitrate removal system is designed to treat raw water having the following characteristics:

Total Nitrate (as N)	15mg/l
Sulfate	30 mg/l

2.2 System Process Flow and Treatment

Figure 9 illustrates the system flow and relevant treatment parameters. Please note the hardness goal was higher, but more flow needs to be treated to meet radium removal requirements:

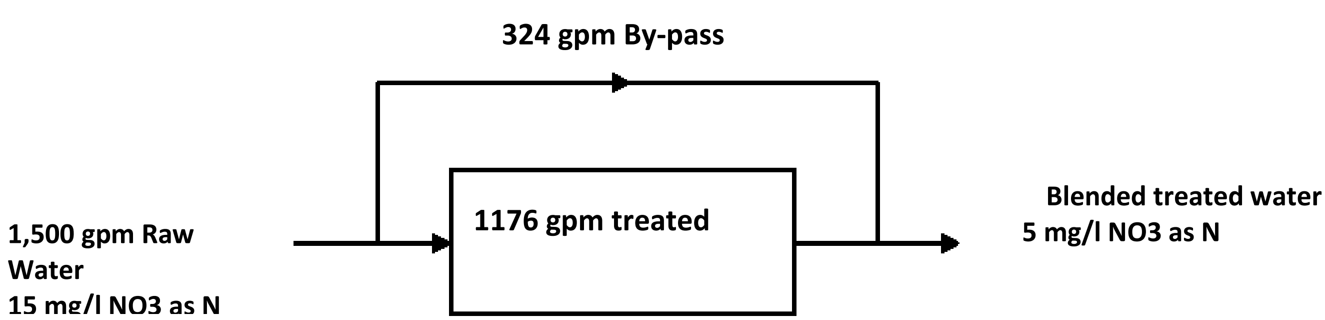


Figure 5: System Flow Diagram

2.3 Summary of Design Treatment Goals

Plant Flow: 1500 gpm
Blended water total nitrate approximately 5 mg/l NO3 as N

2.4 Design Data

Pur-IX™

Number of Vessels:	20
Diameter	30”
Valve and vessel piping size	2” NPT
Resin - Depth:	39 inches
Resin - Volume:	320 cu. ft.
Approx. Operating Weight Per Vessel:	1,500 lbs

Conventional

Number of Vessels:	3
Diameter:	9'-0''
Resin – Height:	36 inches
Resin - Volume	579 cu ft
Approx. Operating Weight Per Vessel:	42,000 lbs

2.5 Regeneration Requirements

Pur-IX™

Salt Usage: To meet design objectives, and based on operating 24 hours per day, the estimated sodium chloride salt consumption is as follows:

Approximately 3,778 lbs/day dry salt

Approximately 56.7 tons of dry salt per 30 days

Approximately 690 tons per year

Approximately 13,800 tons over 20 years

Waste Generation: The waste generated will be continuous flow from the Pur-IX™ system, which is estimated as follows:

4 GPM of waste

Approximately 5,760 gallons per day

Approximately 172,800 gallons per 30 days

Approximately 2,102,400 gallons per year

Approximately 42,048,000 gallons over 20 years

System recovery: 99.7% (finished water as % of treated)
Waste generation: ~ 0.3% of total plant flow

Conventional

Salt Usage: To meet design objectives, and based on operating 24 hours per day, the estimated sodium chloride salt consumption is as follows:

Approximately 4,708 lbs/day dry salt

Approximately 71 tons of dry salt per 30 days

Approximately 859 tons per year

Approximately 17,180 tons over 20 years

Waste Generation: The waste generated will be brine waste from the Pur-IX™ system, which is estimated as follows:

9,884 gallons per regeneration for all three vessels

2.47 regenerations per day

Approximately 24,455 gallons per day

Approximately 733,658 gallons per 30 days

Approximately 8,926,000 gallons per year

Approximately 178,520,000 gallons over 20 years

System recovery: 98.9% (finished water as % of treated)
Waste generation: ~ 1.1% of total plant flow

SUMMARY:

Pur-IX™ reduces salt consumption by nearly 20% and reduces waste generation by over 76%
Over a 20-year life cycle, Pur-IX™ saves 3,380 tons of salt and 136,472,000 gallons of water.

Section 3 Scope of Supply and Equipment Costs

Pur-IX™

Included in the price of this proposal are the following:

- Pur-IX™ multi-port valve assembly, including finished painted support skid, drive, and controller.
- Ion exchange fiberglass vessels including internal components to meet process parameters. Vessels to be blue fiberglass, with alternate colors available
- Nitrate specific ion exchange resin
- Skid for mounting of Pur-IX™ vessels at walkway level, in banks of ten (10).
- Walkway with stairs and railing, shipped loose for assembly and installation by others with limits as shown on the attached general arrangement drawing. Includes finish paint.
- Fully automated PLC control system and panel, Allen Bradley PLC, UL Listed, tested before shipment(to be shared with filter system).
- Electrically operated system function valves for automatic blending.
- Brine and rinse pumps, two each for redundancy
- Flow meters to measure treated water inlet, raw water bypass, rinse water inlet, displacement/backwash water inlet, and brine inlet flow rates.
- Salt storage system and brinemaker sized for 42 ton capacity, insulated for outdoor installation.
- Softening system for brine, backwash and rinse
- Multi-port valve spare parts, including 1 set spare gaskets and seals.
- Freight to the job site.
- Start-up services.
- Tonka Water Pur-IX™ process warranty.

Conventional

Included in the price of this proposal are the following:

- Ion exchange vertical pressure vessels with carbon steel construction, ASME code stamp. Each vessel to include the following:
- Header-lateral inlet distributor with PVC upturned elbows
- PVC header-lateral brine distribution grid
- Nitrate specific ion exchange resin
- 15” depth of graded support gravels
- PVC header-lateral underdrain with Tonka Water non-metallic gravel retaining nozzles (concrete subfill required by installing contractor)

- Full interior finish painting; exterior blasted and primed at factory (finish painting by others on site)
- Electrically actuated Bray wafer style butterfly valves
- Ductile iron system facepiping
- Vessel effluent flow meters, one per vessel
- Loss of head pressure gauge panel
- Backwash rate of flow gauge panel
- Fully automated PLC control system and panel, Allen Bradley PLC, UL Listed, tested before shipment(to be shared with filter system).
- Electrically operated system function valves for automatic blending.
- Brine pumps, two for redundancy
- Flow meters to measure raw water bypass, slow rinse water inlet, , and brine inlet flow rates.
- Softening system for brine and slow rinse
- Salt storage system and brinemaker sized for 42 ton capacity, insulated for outdoor installation.
- Freight to the job site.
- Start-up services.
- Tonka Water process warranty.

Section 4 System Equipment Cost

Pur-IX™

The budgetary price for the Pur-IX™ system is $ 805,000.00

The budgetary price for replacement 320 cu. ft. of resin is $84,800.00

Conventional

The budgetary price for this system is $ 628,000.00

The budgetary price for replacement 462 cu ft of resin and gravels is $129,100.00

NOTE: We anticipate that resin will require replacement two times over a 20-year life cycle. As described in Section 5, the Pur-IX™ system resin replacement procedure is much less complicated than resin replacement on the conventional system. The Pur-IX™ system does not include gravels. Also note that neither of these systems are expected to see resin loss, and should not require resin top-off when operated properly.

Section 5 Description of Installation

Pur-IX™

The Pur-IX™ system will ship in several main components. The vessels will be secured to the skid support structure by the contractor. Extension of piping from the vessels to the multi-port valve will be by installing contractor. The vessels will include factory installed inlet distributors and effluent collectors, but other internals, such as resin, will be shipped loose for contractor installation.

The multi-port valve will be shipped in complete engineered assembly, to include a finish painted carbon steel stand and the multi-port valve itself, fully assembled with drive motor and controller. The valve assembly will arrive completely factory-tested and ready for connection to system piping. Connections will include raw water supply, treated water effluent, send and return piping between valve and resin vessels, and small line connections for brine, rinse water, and waste discharge.

The multi-port valve drive motor will require a protected 3-phase, 230/460V electrical power source. The system control panel will require a single-phase, 110V electrical source. All brine and rinse supply pumps can be single or 3-phase, and require protected power sources.

Walkway and stairs will be factory painted and shipped in loose components, to be assembled by the installing contractor.

Conventional

The conventional system will ship in several shipments. The vessels will arrive for off-loading by crane and installation by taking through large doorways. The vessels will be anchored to the floor. Ductile iron facepiping will be field assembled and require pipe supports. Valves and flowmeters in the facepiping will require conduit to be run from the panel to each location. The vessels will include factory installed inlet distributors and effluent collectors, but other internals, such as gravels and resin, will be shipped loose for contractor installation. The vessels will also require concrete subfill by the contractor. Finish paint will be by contractor

Section 6 Operation and Maintenance

Pur-IX™

Operation and replacement costs for the Pur-IX™ system consist of four general categories: (1) power required for treatment, (2) salt required for vessel regeneration, (3) periodic resin and structure replacement, and (4) preventative maintenance.

- Power: Power costs required for treatment consist of the energy required to process water through the system; this can also be expressed as the pumping energy through the system. When compared to any other pressurized treatment systems, Pur-IX™ is on par with typical pumping energy required; while membrane systems consume substantially more energy than Pur-IX™.

- Regenerant: Since Pur-IX™ has the most efficient regeneration system of all available ion exchange systems, regenerant costs will be lowest with Pur-IX™.. Regenerant costs are greatly influenced by the concentration of contaminant and ultimate treatment goals, and are outlined in above.

- Periodic resin and structure replacement: Operating under the Pur-IX™ design conditions, most resins are expected to have a long service life, similar to the longevity of granular media used in filtration. There is no anticipated resin attrition or loss with a Pur-IX™ system, so resin replacement due to loss is not an accountable cost. Pur-IX™ structure and resin life spans should be approximately equal to conventional ion exchange. However, replacement of the Pur-IX™ resin can be done one small vessel at a time, with the remainder of the system in operation with only a slight loss in salt usage. .

- Preventive Maintenance: Preventive maintenance for the Pur-IX™ system is minimal. There is a single moving part – the internal disc of the multi-port valve – so monitoring valve operation and wear is the key PM function. Automatic monitoring by the Pur-IX™ control system, along with periodic observation, are all that's required. Customary inspection and instrumentation maintenance will be required with any system, including Pur-IX™, but costly PM actions such as system de-watering, greasing, lubrication, resin top-off, and tank clean-up are eliminated with Pur-IX™.

Conventional

Operation and replacement costs for the conventional system consist of three general categories: (1) power required for treatment, (2) salt required for vessel regeneration, (3) periodic resin and structure replacement, and (4) preventative maintenance.

- Power: Power costs required for treatment consist of the energy required to process water through the system; this can also be expressed as the pumping energy through the system.

- Regenerant: Regeneration costs include salt and water usage as outlined above.

- Periodic resin and structure replacement: Conventional ion exchange requires replacement of resin and gravels, and is more of a large contractor-type procedure, with one of the few vessels taken off line, which results in a loss of capacity. Internal components such as the brine distributor are also replaced during resin replacement as they tend to get broken during the process.

- Preventive Maintenance: Preventive maintenance for the conventional ion exchange includes valve maintenance (six valves on each vessel), system de-watering, tank clean-up and tank paint touchup, and maintenance of instruments such as flow meters (one on each vessel). Because entering the vessels is a complicated process, operators tend to not do the proper inspections of the vessel to ensure that the internal components and resin are in good operating shape.

Section 7 Notes on Budgetary Pricing

Inclusions

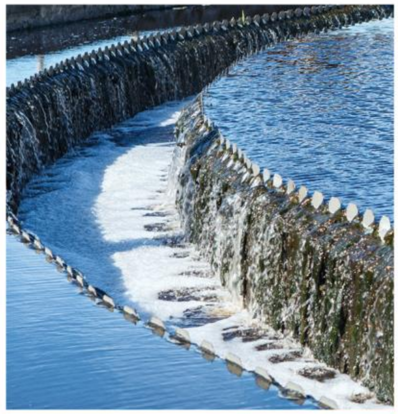
- Unless noted otherwise, Tonka Water includes complete system process warranty
- Incidentals such as controls programming, drains, couplings, and gauges are included unless otherwise stated
- Commissioning, start-up, and training services are included
- Operation and maintenance manuals - included
- Freight to jobsite; equipment quoted FOB factory, freight allowed
- Tonka Water standard warranty and terms apply – copies available upon request

Exclusions

- Pilot testing of process.
- Interconnecting piping between processes
- Non – automatic valves
- Pipe supports, process equipment support design, anchor bolts, embedded concrete items
- General, mechanical or electrical work of any kind
- Taxes, fees and permits

Expiration and Delivery

- Tonka Water will prepare shop drawings in approximately 6 weeks for approval prior to fabrication
- Manufacturing time: approximately 14 weeks after approval
- Quoted budgeting prices expire in 120 days


Pur-IX™ and Conventional Ion Exchange

To: Mr. Craig Reinsch, PE
Olsson Associates
1111 Lincoln Mall, Suite 111
Lincoln, NE 68508

Proposal number 20615

Proposal date: 5/23/2017

Tonka Water Contact:
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Tonka Water
ISO 9001:2008 Certified

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Trusted systems. Resourceful thinking.

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Tonka Water

Tonka Water has provided customized water treatment systems and solutions since 1956 through a broad range of products and services. Tonka Water systems provide cost-effective solutions for the most challenging surface and ground water applications having successfully furnished over 2,200 treatment systems in the U.S. Tonka Water is known for innovative, quality systems, and superior customer service.

Tonka Water is a proven leader in ion exchange technology, and has a long, successful track record in the industry, including nitrate, organics, uranium, softening, and other anion and cation exchange processes.

Through an exclusive licensing agreement, Tonka Water offers the Pur-IX™ advanced Ion Exchange System for potable and process waters throughout North America.

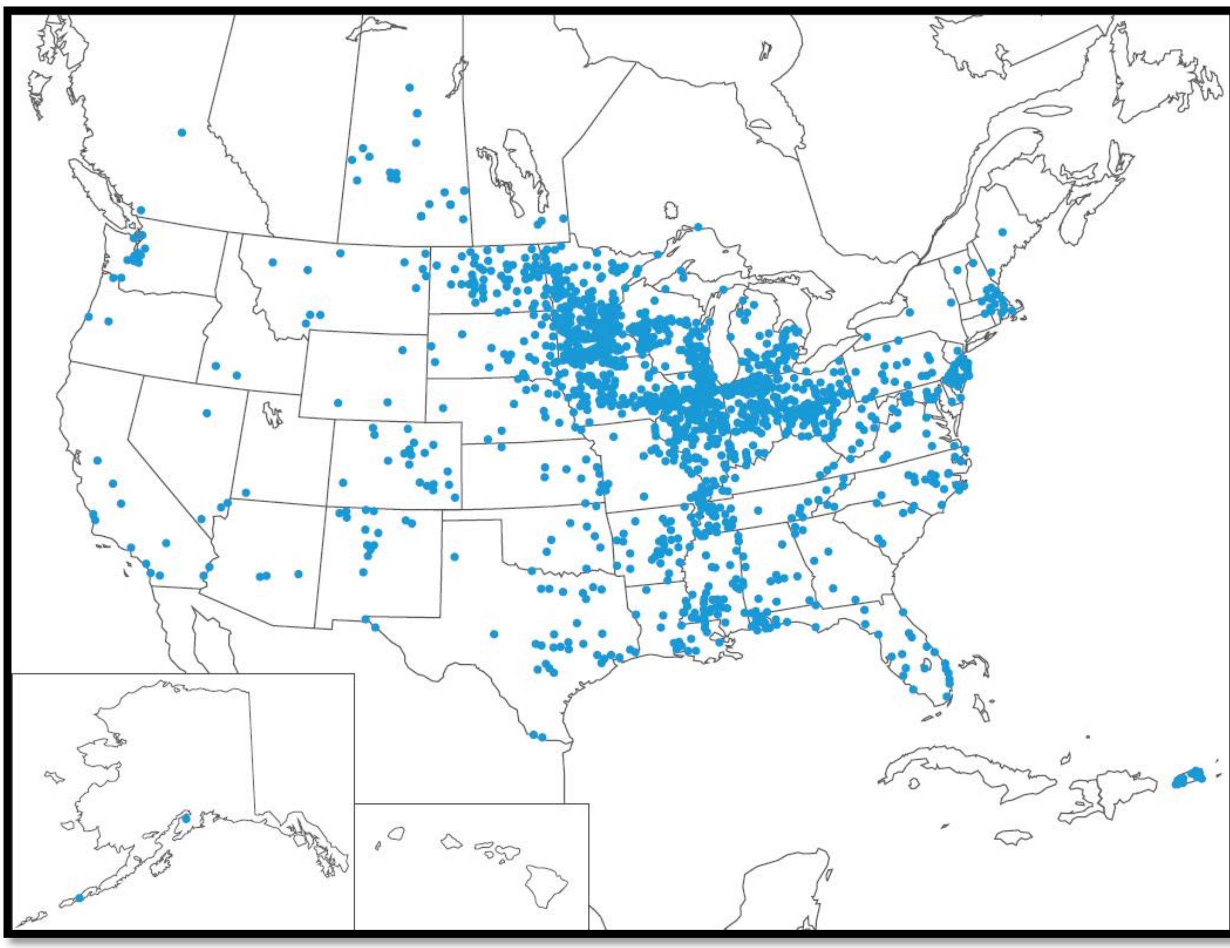


Figure 1: Tonka Water Treatment Installations

Section 1 Introduction

1.1 General System Description

Tonka Water is providing options for conventional ion exchange and Pur-IX™ to remove hardness and radium from municipal drinking water by the use of cation resin.

The Tonka Water Pur-IX™ system is the industry's most advanced ion exchange technology, resulting in unsurpassed efficiency and cost-effective removal of ionized contaminants from potable and process waters.

Pur-IX™ employs conventional ion exchange in a new, innovative way, allowing designers to minimize footprint while ensuring the lowest waste volume – all the while maintaining continuous and consistent flow of high quality treated water.

At the heart of the Pur-IX™ system is the centrally located Pur-IX™ multi-port valve, making Pur-IX™ the most simple and cost-effective continuous ion exchange technology available.

Figure 2: Pur-IX Valve

The Pur-IX™ Advantage

- **Lowest Cost of Operation**: The system's in-series cascade regeneration consumes minimal salt, much less than conventional or other types of ion exchange. Since salt consumption is the highest cost of operation, with Pur-IX™ your plant will be less expensive to operate, saving operating dollars for years and years to come.
- **Lowest Waste Volume**: The Pur-IX™ process generates a single continuous, low flow, waste stream, eliminating the need for enhancements such as waste equalization, gradual "bleeding" to final discharge, or large evaporative pond waste handling systems.
- **Consistent Product Water**: Pur-IX™ ensures a continuous and uniform treated water quality. There are no flow surges requiring adjustment in operation and product water quality stays consistent.

- **Simplicity of Operation**: The automatic controls and multi-port valve do all the work, directing process flow and regeneration as the inner disc intermittently indexes. This unique arrangement provides the highest level of process sophistication without the complexity of larger valve nests or brine recycle systems.

- **Compact Footprint**: Because flow is distributed among twenty individual vessels, the Pur-IX™ footprint is minimal – saving building space and clear height when compared to other ion exchange or treatment systems.

- **Minimal Energy Consumption**: The Pur-IX™ process has only one moving part – the interior disc of the multi-port valve. This disc momentarily indexes once every 30-60 minutes, in aggregate, operating less than 12 minutes per day. The only other moving parts are brine feed pumps, driven by fractional horsepower motors.

How Pur-IX™ Works

The Pur-IX™ valve performs several key ***treatment*** functions:

- Distributes untreated water to multiple in-service continuous ion exchange vessels.
- Collects treated water from multiple in-service continuous ion exchange vessels.

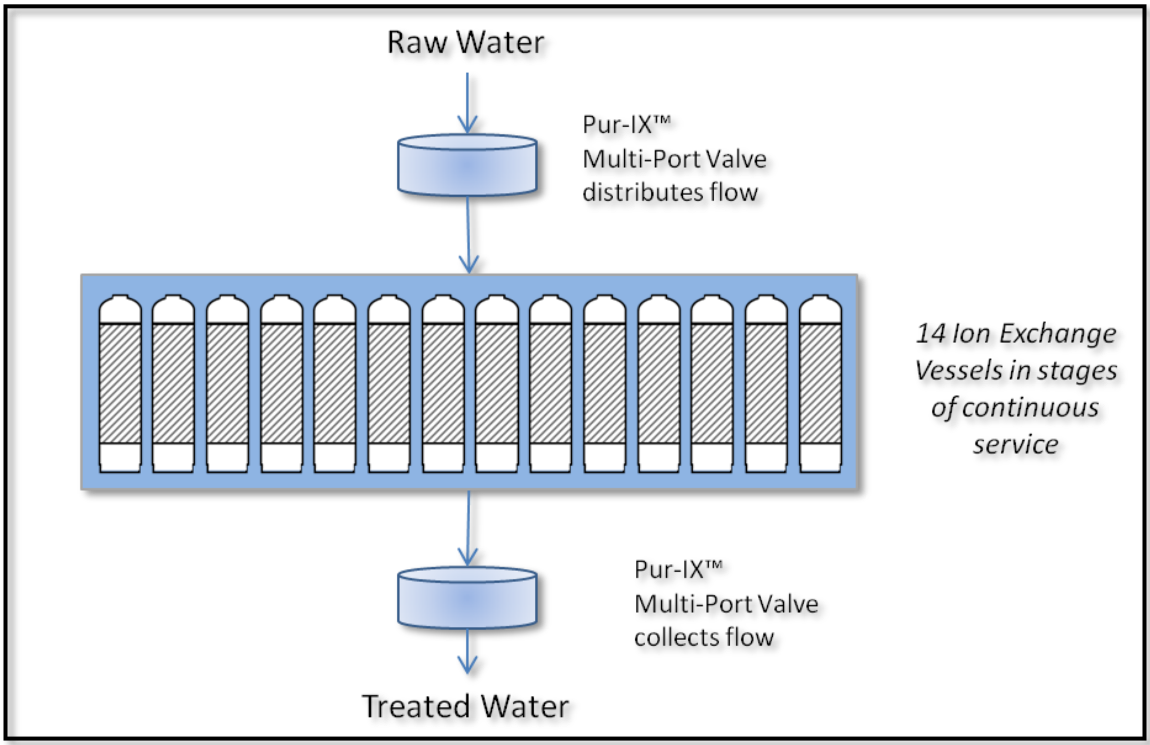


Figure 3: Continuous Ion Exchange

The Pur-IX™ valve performs several key ***regeneration*** functions:

- Automatically removes exhausted vessels from service.
- Continuously cycles out-of-service vessels through a multi-step regeneration process.
- Automatically returns regenerated vessels back into service.

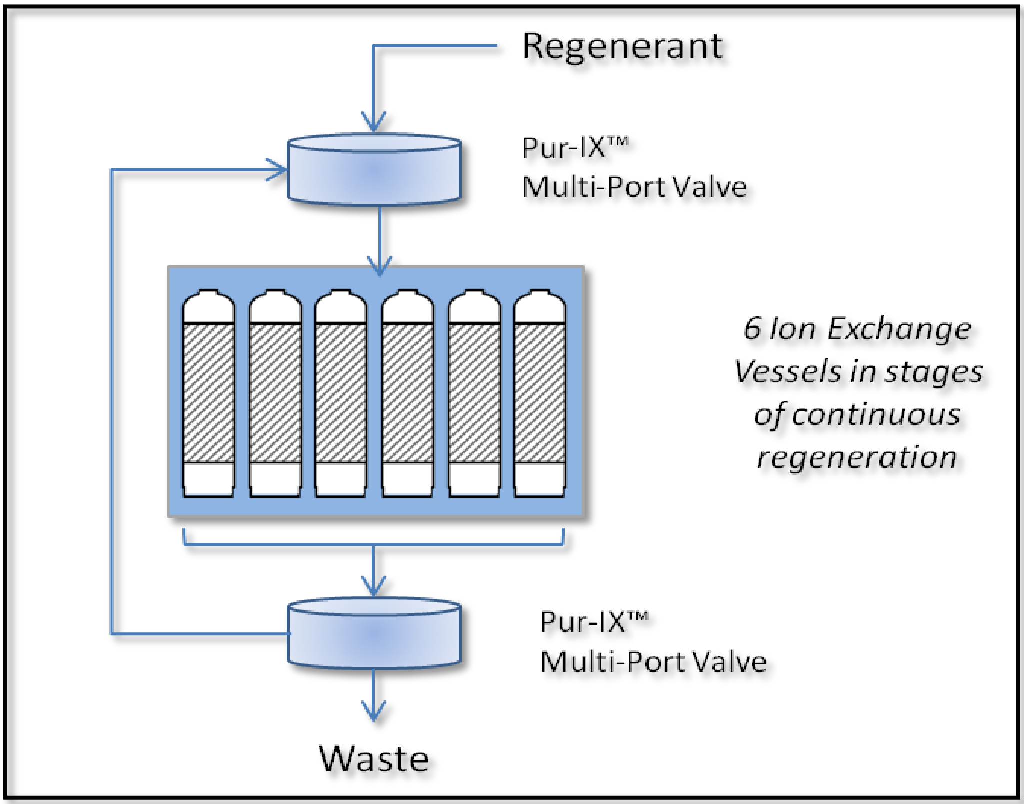


Figure 4: The Pur-IX™ valve performs automatic and continuous regeneration

1.2 Pur-IX™ Process: Description of Operation

Continuous, Parallel Ion Exchange

The Pur-IX™ process incorporates twenty ion exchange vessels, fourteen of which are treating water in parallel, while the remaining six are being regenerated. In many applications, a portion of raw water is designed to bypass treatment and blend with finished water to yield a targeted blended concentration:

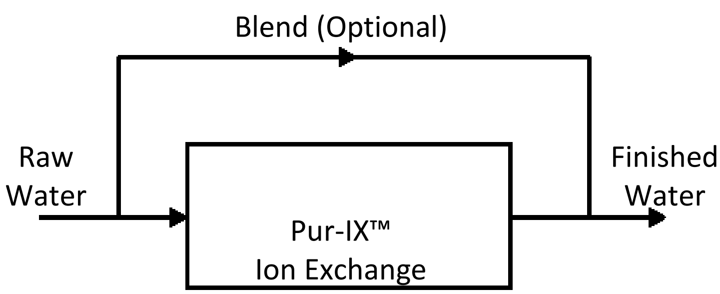


Figure 5: Typical System Configuration

Of the fourteen vessels treating water, each is at a different point in its run length, which is the amount of time a vessel can treat water before it must be regenerated. At any one time, as shown in Figure 6, one vessel has just been regenerated (vessel position 14), while another is nearly depleted in capacity and will soon need to be regenerated (vessel position 1). The other twelve are at varying stages of treatment capacity (vessel positions 2-13).

This unique arrangement allows the resin to be loaded completely to capacity before regeneration is required. Operating in this way ensures that the resin is used to its fullest and maximum capacity, making the Pur-IX™ process the most efficient possible.

At the point of complete resin bed exhaustion, the Pur-IX™ valve indexes, causing the exhausted vessel in position 1 to shift to position 20 and enter the regeneration phase, while returning the newly regenerated vessel (position 15) back to the first service position (position 14).

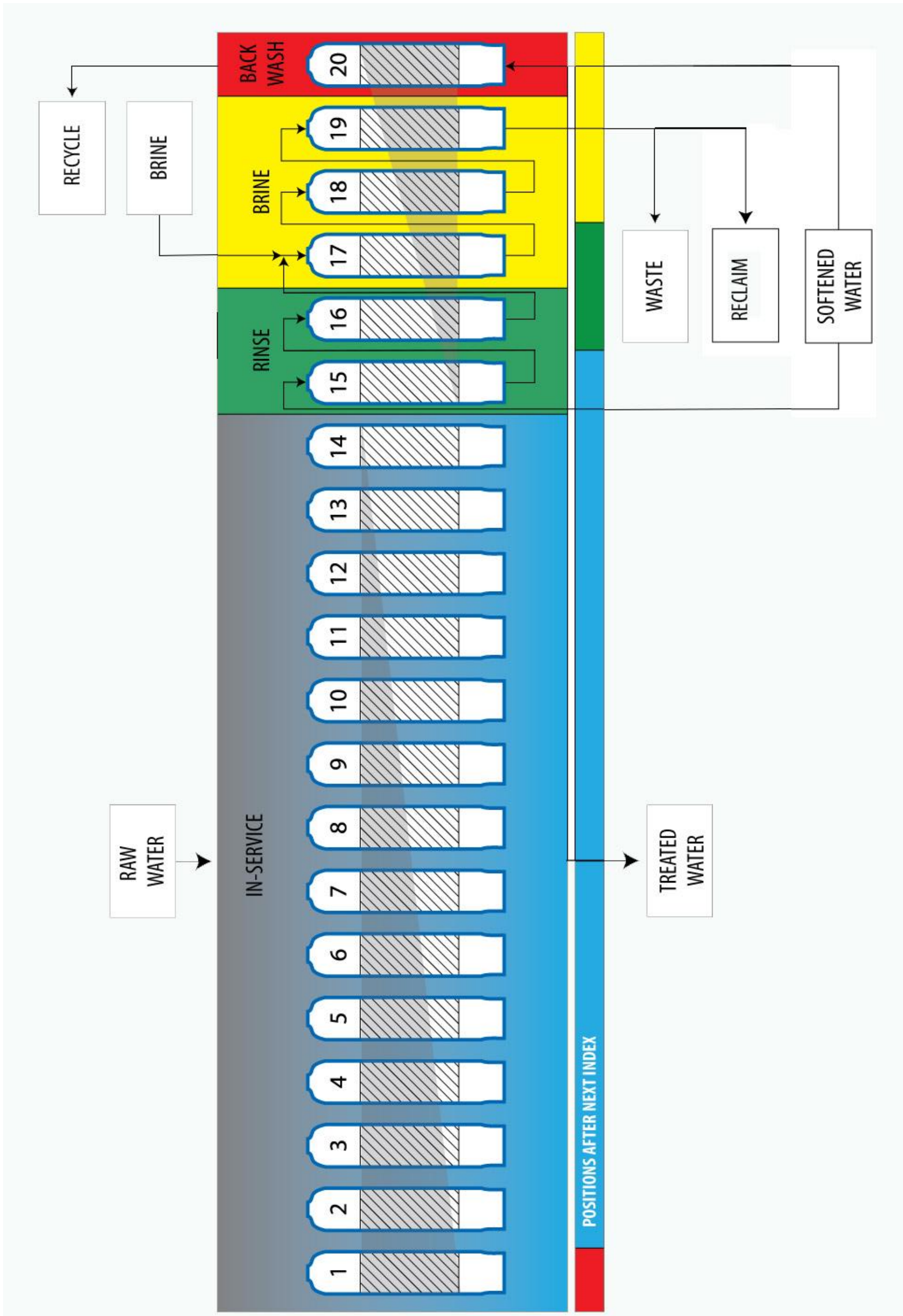


Figure 3: Pur-IX™ Process Schematic and Vessel Positions

Continuous Regeneration

General: As fourteen of the vessels are treating water in parallel, the remaining six are simultaneously being regenerated. Of the six vessels in regeneration, one is in Displacement/Backwash (vessel position 20), three are in Brine Regeneration (vessel positions 17-19), and two are in Rinse (vessel positions 15 and 16).

Displacement/Backwash: The Displacement/Backwash step displaces raw water with treated water, done in an up-flow manner to fluidize and backwash the media. The displaced water is recycled back to the front of the treatment process for recovery.

Brine Regeneration: A cascade-type, in-series regeneration utilizes a sodium chloride brine solution to its fullest, minimizing salt consumption. Three vessels (positions 17-19) are regenerated in series as shown in Figure 6, with a diluted sodium chloride brine solution. Fresh brine first enters at vessel position 17, then passes through the second vessel (position 18), and finally through the third vessel (position 19). By directing the brine through several vessels, it ensures that every last bit of regeneration capacity is extracted from the sodium chloride regenerant. This means less salt is needed for regeneration. This efficient salt usage is the key advantage Pur-IX™ offers over conventional ion exchange, which regenerates one vessel at a time and disposes of the waste immediately, in a "slug flow".

Rinse: After exposure to the cascading brine steps, the remaining two vessels at positions 15 and 16 are rinsed with soft water before being returned to service. The rinse water is used to displace any brine in the vessels remaining from the previous regeneration steps. Softened water enters the first vessel (position 15), and the effluent is then sent through the next vessel (position 16). The effluent from the second vessel combines with the incoming brine solution, which is done for two reasons: (1) any remaining brine being rinsed out of the vessels is re-used to regenerate other vessels – so no brine is being wasted; and (2) the rinse water mixes with saturated brine to effectively dilute the brine and prevent resin osmotic shock from occurring during regeneration. Osmotic shock is a phenomenon that sometimes occurs when ion exchange resin is exposed to an extreme concentration of brine, resulting in surface cracking and ultimate resin attrition. Diluting the saturated brine prevents this situation.

Final Waste/Disposal: Because displacement water is recycled, and rinse effluent combines with the incoming brine solution, there is only one low-flow waste stream from the Pur-IX™ system. This stream comes out of the third vessel in the brine regeneration series (vessel position 19). This waste stream is continuous and extremely low in volume.

Valve Indexing and Flow Distribution

The Pur-IX™ process steps, for both treatment and regeneration, occur simultaneously. This is accomplished through the multi-port valve, which has an inner disc with channels that appropriately direct the different flow streams to each vessel simultaneously.

When the vessel in position 1 is ready for regeneration, the inner disc “indexes,” or rotates, to line up with the next set of ports, effectively changing the process positions of all vessels. It should be noted that the vessels remain stationary; the only moving part is the inner disc of the multi-port valve as it indexes.

Along with the inner disc, the valve has an outer shell with twenty send ports. Both the inner disc and outer shell are machined from solid blocks of high density polypropylene, making them very strong and durable. The valve is furnished with internal o-rings to provide double-wall protection between ports and allow for early leak detection in the event of an unlikely o-ring failure. All wetted parts are certified to ANSI/NSF standards.

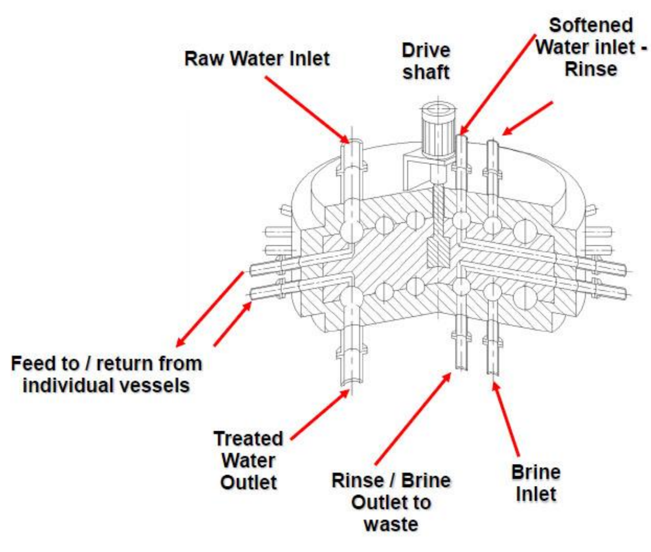
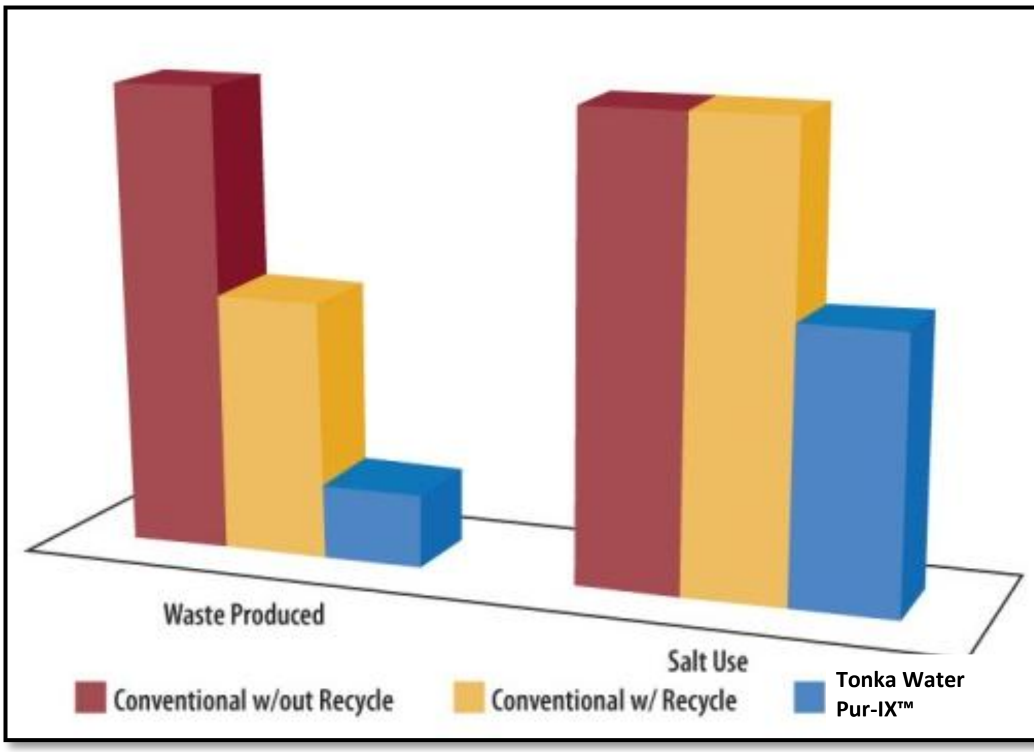


Figure 7: Cut-away of Pur-IX™ valve

Summary of Operation

All of the above functions (14 vessels in parallel operation; six vessels in regeneration) happen simultaneously through the Pur-IX™ valve. The multi-port valve facilitates the flow splitting to each vessel, directs cascade regeneration, and combines the rinse waste with the inlet brine, all kept within the valve's internal channeling. Vessel process positions are changed only when the valve changes internal channel positions, that is, when it indexes – typically occurring once or twice per hour of operation. The indexing interval is selected considering factors such as: inlet containment concentration; system flow; and facility treatment goals. The Pur-IX™ process, through superior valve innovation, minimizes salt usage and waste production, making it a much more efficient ion exchange technology.



1.3 Conventional Process: Description of Operation

Intermittent Ion Exchange
The conventional process incorporates a smaller number of ion exchange vessels, all of which are treating water in parallel, and one vessel is taken off and regenerated in a batch process. In many applications, a portion of raw water is designed to bypass treatment and blend with finished water to yield a targeted blended concentration:

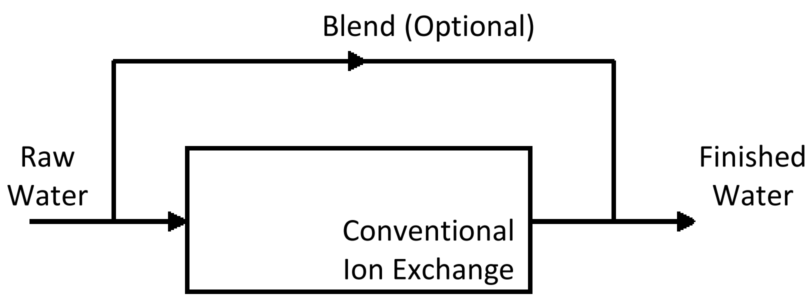


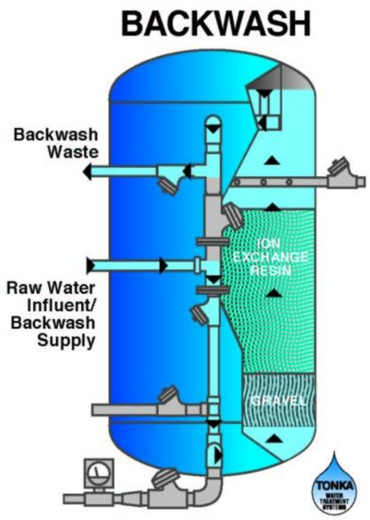
Figure 4: Typical System Configuration

With a small number of vessels in service, as a vessel reaches its design capacity and begins to produce water with higher contaminants, the vessel is taken off line. This point of "break-through" is experienced before a large amount of resin in the lower portion of the resin bed had used its capacity for ion exchange. This early breakthrough causes in increase in the amount of salt needed for regeneration in comparison to the amount of water treated.

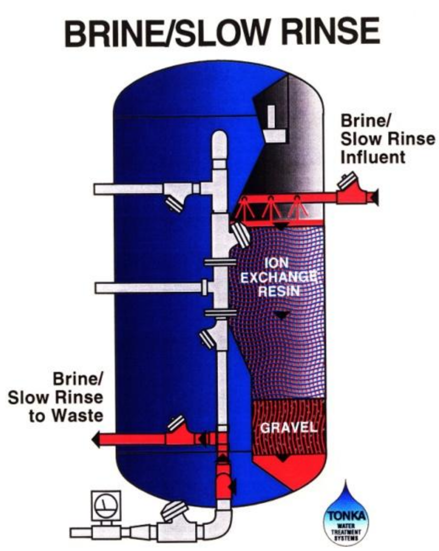
Batch Regeneration

General: The flow split of the water is obtained by the head loss through the piping and the resin bed. As contaminants are removed from the water and the resin bed reaches a break-through point, the vessel that has been in service longest is taken out of service.

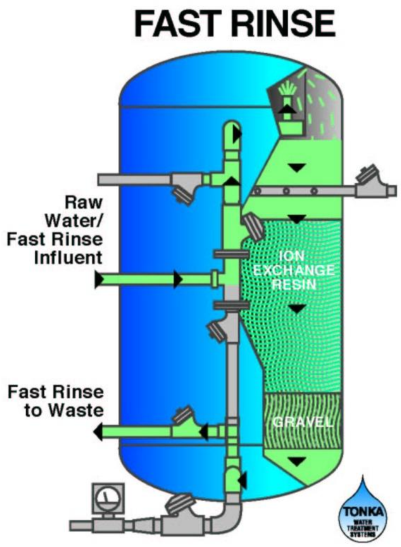
Displacement/Backwash: The Displacement/Backwash step displaces raw water with treated water, done in an up-flow manner to fluidize and backwash the media.



Brine Regeneration: A mixture of 50% saturated brine and 50% water is pumped through the ion exchange resin to facilitate the exchange of contaminants with sodium ions. The internal brine distributor directly above the resin provides for even flow over the media. The slow rinse process continues with water-only to push the brine through the bed.



Rinse: After the resin bed has been exposed to the batch brine needed for regeneration, the vessel is placed into fast rinse step, which rinses out the left over brine from the resin, vessel and gravels, all of which is discharged to waste. This step is terminated on time, based on salinity measurement taken by field tech at startup. When finished, the vessel batch meter is re-set.



Summary of Operation

The system goes through treatment until one vessel reaches its break-through point, as determined by a set point of number of gallons treated. At this time, one vessel is taken out of service, increasing the loading rate on the remaining vessels. Each vessel has 6 electrically operated valves that operate to send the vessel through the steps of the regeneration process. This vessel is then brought back online until the next vessel reaches its break-through point and taken out of service for regeneration.

Section 2 Treatment System Design

2.1 Raw Water Chemistry

This nitrate removal system is designed to treat raw water having the following characteristics:

Total Nitrate (as N)	15mg/l
Sulfate	30 mg/l

2.2 System Process Flow and Treatment

Figure 9 illustrates the system flow and relevant treatment parameters. Please note the hardness goal was higher, but more flow needs to be treated to meet radium removal requirements:

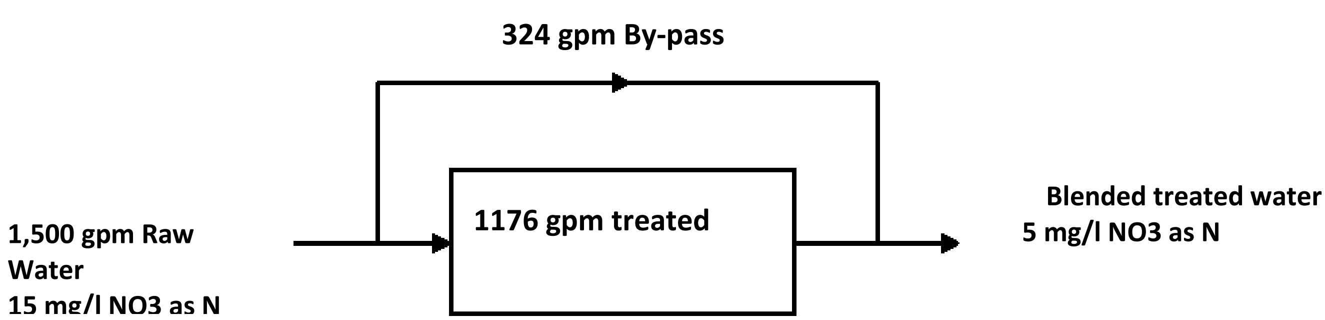


Figure 5: System Flow Diagram

2.3 Summary of Design Treatment Goals

Plant Flow: 1500 gpm
Blended water total nitrate approximately 5 mg/l NO3 as N

2.4 Design Data

Pur-IX™

Number of Vessels:	20
Diameter	30”
Valve and vessel piping size	2” NPT
Resin - Depth:	39 inches
Resin - Volume:	320 cu. ft.
Approx. Operating Weight Per Vessel:	1,500 lbs

Conventional

Number of Vessels:	3
Diameter:	9'-0''
Resin – Height:	36 inches
Resin - Volume	579 cu ft
Approx. Operating Weight Per Vessel:	42,000 lbs

2.5 Regeneration Requirements

Pur-IX™

Salt Usage: To meet design objectives, and based on operating 24 hours per day, the estimated sodium chloride salt consumption is as follows:

Approximately 3,778 lbs/day dry salt

Approximately 56.7 tons of dry salt per 30 days

Approximately 690 tons per year

Approximately 13,800 tons over 20 years

Waste Generation: The waste generated will be continuous flow from the Pur-IX™ system, which is estimated as follows:

4 GPM of waste

Approximately 5,760 gallons per day

Approximately 172,800 gallons per 30 days

Approximately 2,102,400 gallons per year

Approximately 42,048,000 gallons over 20 years

System recovery: 99.7% (finished water as % of treated)
Waste generation: ~ 0.3% of total plant flow

Conventional

Salt Usage: To meet design objectives, and based on operating 24 hours per day, the estimated sodium chloride salt consumption is as follows:

Approximately 4,708 lbs/day dry salt

Approximately 71 tons of dry salt per 30 days

Approximately 859 tons per year

Approximately 17,180 tons over 20 years

Waste Generation: The waste generated will be brine waste from the Pur-IX™ system, which is estimated as follows:

9,884 gallons per regeneration for all three vessels

2.47 regenerations per day

Approximately 24,455 gallons per day

Approximately 733,658 gallons per 30 days

Approximately 8,926,000 gallons per year

Approximately 178,520,000 gallons over 20 years

System recovery: 98.9% (finished water as % of treated)
Waste generation: ~ 1.1% of total plant flow

SUMMARY:

Pur-IX™ reduces salt consumption by nearly 20% and reduces waste generation by over 76%
Over a 20-year life cycle, Pur-IX™ saves 3,380 tons of salt and 136,472,000 gallons of water.

Section 3 Scope of Supply and Equipment Costs

Pur-IX™

Included in the price of this proposal are the following:

- Pur-IX™ multi-port valve assembly, including finished painted support skid, drive, and controller.
- Ion exchange fiberglass vessels including internal components to meet process parameters. Vessels to be blue fiberglass, with alternate colors available
- Nitrate specific ion exchange resin
- Skid for mounting of Pur-IX™ vessels at walkway level, in banks of ten (10).
- Walkway with stairs and railing, shipped loose for assembly and installation by others with limits as shown on the attached general arrangement drawing. Includes finish paint.
- Fully automated PLC control system and panel, Allen Bradley PLC, UL Listed, tested before shipment(to be shared with filter system).
- Electrically operated system function valves for automatic blending.
- Brine and rinse pumps, two each for redundancy
- Flow meters to measure treated water inlet, raw water bypass, rinse water inlet, displacement/backwash water inlet, and brine inlet flow rates.
- Salt storage system and brinemaker sized for 42 ton capacity, insulated for outdoor installation.
- Softening system for brine, backwash and rinse
- Multi-port valve spare parts, including 1 set spare gaskets and seals.
- Freight to the job site.
- Start-up services.
- Tonka Water Pur-IX™ process warranty.

Conventional

Included in the price of this proposal are the following:

- Ion exchange vertical pressure vessels with carbon steel construction, ASME code stamp. Each vessel to include the following:
- Header-lateral inlet distributor with PVC upturned elbows
- PVC header-lateral brine distribution grid
- Nitrate specific ion exchange resin
- 15” depth of graded support gravels
- PVC header-lateral underdrain with Tonka Water non-metallic gravel retaining nozzles (concrete subfill required by installing contractor)

- Full interior finish painting; exterior blasted and primed at factory (finish painting by others on site)
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Operation and replacement costs for the Pur-IX™ system consist of four general categories: (1) power required for treatment, (2) salt required for vessel regeneration, (3) periodic resin and structure replacement, and (4) preventative maintenance.

- Power: Power costs required for treatment consist of the energy required to process water through the system; this can also be expressed as the pumping energy through the system. When compared to any other pressurized treatment systems, Pur-IX™ is on par with typical pumping energy required; while membrane systems consume substantially more energy than Pur-IX™.

- Regenerant: Since Pur-IX™ has the most efficient regeneration system of all available ion exchange systems, regenerant costs will be lowest with Pur-IX™.. Regenerant costs are greatly influenced by the concentration of contaminant and ultimate treatment goals, and are outlined in above.

- Periodic resin and structure replacement: Operating under the Pur-IX™ design conditions, most resins are expected to have a long service life, similar to the longevity of granular media used in filtration. There is no anticipated resin attrition or loss with a Pur-IX™ system, so resin replacement due to loss is not an accountable cost. Pur-IX™ structure and resin life spans should be approximately equal to conventional ion exchange. However, replacement of the Pur-IX™ resin can be done one small vessel at a time, with the remainder of the system in operation with only a slight loss in salt usage. .

- Preventive Maintenance: Preventive maintenance for the Pur-IX™ system is minimal. There is a single moving part – the internal disc of the multi-port valve – so monitoring valve operation and wear is the key PM function. Automatic monitoring by the Pur-IX™ control system, along with periodic observation, are all that's required. Customary inspection and instrumentation maintenance will be required with any system, including Pur-IX™, but costly PM actions such as system de-watering, greasing, lubrication, resin top-off, and tank clean-up are eliminated with Pur-IX™.

Conventional

Operation and replacement costs for the conventional system consist of three general categories: (1) power required for treatment, (2) salt required for vessel regeneration, (3) periodic resin and structure replacement, and (4) preventative maintenance.

- Power: Power costs required for treatment consist of the energy required to process water through the system; this can also be expressed as the pumping energy through the system.
- Regenerant: Regeneration costs include salt and water usage as outlined above.
- Periodic resin and structure replacement: Conventional ion exchange requires replacement of resin and gravels, and is more of a large contractor-type procedure, with one of the few vessels taken off line, which results in a loss of capacity. Internal components such as the brine distributor are also replaced during resin replacement as they tend to get broken during the process.
- Preventive Maintenance: Preventive maintenance for the conventional ion exchange includes valve maintenance (six valves on each vessel), system de-watering, tank clean-up and tank paint touchup, and maintenance of instruments such as flow meters (one on each vessel). Because entering the vessels is a complicated process, operators tend to not do the proper inspections of the vessel to ensure that the internal components and resin are in good operating shape.

Section 7 Notes on Budgetary Pricing

Inclusions

- Unless noted otherwise, Tonka Water includes complete system process warranty
- Incidentals such as controls programming, drains, couplings, and gauges are included unless otherwise stated
- Commissioning, start-up, and training services are included
- Operation and maintenance manuals - included
- Freight to jobsite; equipment quoted FOB factory, freight allowed
- Tonka Water standard warranty and terms apply – copies available upon request

Exclusions

- Pilot testing of process.
- Interconnecting piping between processes
- Non – automatic valves
- Pipe supports, process equipment support design, anchor bolts, embedded concrete items
- General, mechanical or electrical work of any kind
- Taxes, fees and permits

Expiration and Delivery

- Tonka Water will prepare shop drawings in approximately 6 weeks for approval prior to fabrication
- Manufacturing time: approximately 14 weeks after approval
- Quoted budgeting prices expire in 120 days

Craig Reinsch

From: Schneider, Alan <ASchneider@tonkawater.com>
Sent: Thursday, May 25, 2017 5:19 PM
To: Craig Reinsch; Chris Johnson (chrisj@bgagurney.com)
Subject: RE: Fairbury NE water treatment information request
Attachments: NE_Fairbury_Design Proposal_PurIX_IEX_5-23-17.pdf

Hi Craig-

Thanks so much for the patience.

Please see attached analysis of the Pur-IX™ system and the conventional system. Let me know if you would like this presented in a different way for your meeting.

I had to go back and look and see why the conventional system was so much higher than in 2011- $498K vs.$628K .

This is what I found:

-Vertical vessel prices have increased quite a lot (especially compared to other products, for some reason)
-Piping has increased dramatically.

-The resin used in the previous budget was not nitrate –specific, meaning that it would "dump" nitrates if the bed goes beyond its capacity. Using nitrate specific resin is important with higher sulfates, and is now our standard.

-I neglected to include a softening system for the regeneration makeup water. This is important with the higher hardness levels seen here.

So I apologize if the pricing change seen here causes any issues with the budgetary aspects of your design.

Please let me know if I can provide any additional information, or if you have any questions.

Best regards,

Alan Schneider
Territory Manager
Tonka Water | www.tonkawater.com
Direct: 763-252-0893 | Cell: 612-708-6517
aschneider@tonkawater.com
www.tonkawater.blogspot.com

Trusted systems. Resourceful thinking.

ISO 9001:2008 Certified

From: Craig Reinsch [mailto:creinsch@olssonassociates.com]
Sent: Thursday, May 25, 2017 4:42 PM
To: Chris Johnson (chrisj@bgagurney.com); Schneider, Alan
Subject: RE: Fairbury NE water treatment information request

Good afternoon,

I wanted to follow up to see when I might receive the updated project budget information?

Thanks, Craig

Craig Reinsch, PE, ENV SP | Olsson Associates
601 P Street, Suite 200 | Lincoln, NE 68508 | creinsch@olssonassociates.com
TEL 402.474.6311 | DIR 402.458.5671 | FAX 402.474.5059

From: Craig Reinsch
Sent: Friday, May 05, 2017 11:45 AM
To: Chris Johnson (chrisj@bgagurney.com) <chrisj@bgagurney.com>; 'Schneider, Alan' <ASchneider@tonkawater.com>
Subject: Fairbury NE water treatment information request

Good morning,

I am working with the City of Fairbury on an updated PER for their water system. In 2011/2012, you helped me to put together budgetary costs for a previous water treatment design report for the City (information attached). Since it has been a few years, I would like to request an update to the cost, layout, etc. Nitrate concentrations are still in the same range that they have been (7.5-9.5 mg/L). Flows haven't changed. I would like to receive updated costs by May 24, 2017 in preparation for meeting(s) with the City. Please let me know what additional information you need from me to provide the requested information. I appreciate your assistance!

Thanks, Craig

Craig Reinsch, PE, ENV SP | Water/Wastewater | Olsson Associates
601 P Street, Suite 200 | Lincoln, NE 68508 | creinsch@olssonassociates.com
TEL 402.474.6311 | DIR 402.458.5671 | FAX 402.474.5059

OLSSON ASSOCIATES

DWG: F:\2016\3501-4000\016-3570\40-Design\Exhibits\17-05-31_WTWW_Aerial.dwg USER: hdeboer
DATE: May 31, 2017 1:49pm XREFS:

PROJECT NO:	016-3570
DRAWN BY:	HGD
DATE:	05/31/2017

PROPOSED WATER TREATMENT PLANT LOCATION: ION EXCHANGE
FAIRBURY, NEBRASKA

OLSSON ASSOCIATES
601 P Street, Suite 200
P.O. Box 84608
Lincoln, NE 68508
TEL 402.474.6311
FAX 402.474.5160

FIGURE Q-1

APPENDIX “R”

Water Treatment Equipment – Vendor Information
Electrodialysis Reversal

GE Infrastructure
Water & Process Technologies

Patrick Girvin
EDR Commercial Developer

3 Burlington Woods
Burlington, MA 01803
USA

T +1 781 359 7102
F +1 781 229 0198
Patrick.Girvin@ge.com

May 26, 2017

To: Craig Reinsch, Olsson Associates

CC: Brittany Hirschbrunner, WTG Midwest
Dan Higgins, GE Water & Process Tech.

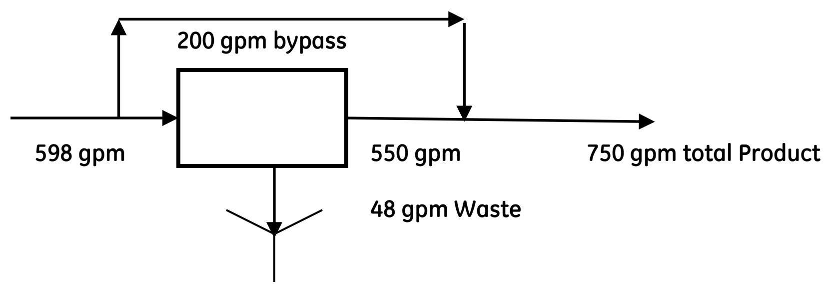
REF: Fairbury, NE

Typically, EDR water recovery is around 85-90% for drinking water application. The feed water analysis for this review was taken from the Crystal Springs data presented by Olsson. The TDS of this water source is close to the secondary MCL, with nitrate being the main constituent of concern. A max nitrate value of 15 mg/L was used. Nitrate removal target could be either of two finished water goals: 7 mg/L and 3 mg/L. The 7 mg/l goal will be discussed first.

Based on the low sulfate and TDS levels, high recovery can be expected. The limiting factor for the design will be the calcium carbonate saturation in the brine stream. Water recovery can be pushed to 92%. In order to maintain this recovery, hydrochloric acid will be added to the brine stream to prevent any scale from forming on the membrane surface. Any changes to feed levels of these ions may impact recovery.

To achieve the product flow rate of **1500 gpm**, two EDR unit with 4 lines each are needed. Each line of stacks will have two stages in series. The EDR systems will treat 1100 gpm combined product. The remainder of the required product flow will be blended feed water sent downstream. Three units are included in the pricing to give redundancy. The same cleaning system can be used to CIP all three units.

Sample Flow Diagram



At 93% recovery, the system delivers 48 gpm of waste. This waste flow includes concentrate blowdown, electrode waste, and off-spec waste (when system reverses). It does not include flush water when the system is starting up or shutting down. The system typically takes 2-3 minutes to reach steady state on start up, and the flush cycle runs for 2 minutes when the system shuts down.

The system is also cleaned for maintenance. These cleanings typically are conducted every 1,000 hours of operation. For each cleaning, a good preliminary estimate would be 2500 gallons of waste. The cleaning solution is acidic but can be neutralized prior to going to waste if needed.

Depending on the frequency of start up, shutdown, and cleanings, the total waste can fluctuate.

Cost for the EDR scope mentioned above will be **$2.25MM**.

This number includes EDR control skids, stacks, chemical/cleaning systems, and electrical power enclosure room. Any required pretreatment to reduce the turbidity down to the acceptable level of 0.5NTU is not included in this number.

Expected Water Quality

		Raw Feed	Product	Conc. BD
Calcium	mg/l	76.5	34.6	1311.7
Magnesium	mg/l	10.3	4.9	169.0
Sodium	mg/l	65.5	34.5	982.6
Potassium	mg/l	0.0	0.0	0.0
Strontium	mg/l	0.2	0.1	3.6
Barium	mg/l	0.1	0.0	1.7
Bicarbonate	mg/l	261.0	137.9	3501.8
Sulphate	mg/l	28.7	11.8	527.2
Chloride	mg/l	80.3	34.8	1653.3
Fluoride	mg/l	0.6	0.3	9.6
Nitrate	mg/l	15.0	6.7	260.1
Silica	mgl	Unknown		
Total Hardness	CaCO3	233.5	106.6	3972.8
TDS	mg/l	538.3	265.6	8422.6
Conductivity	uS/cm	763.5	395.3	9164.4
pH		6.80	6.52	7.27

For O&M costs, we include the following items:

Electrical Power to the System
Chemicals needed for daily operation and maintenance
Consumables in the system including membranes, filters, electrodes, and spacers

Estimates are based on operating two systems 24 hrs/day with the other in standby.

Power

The power is defined by our design program. It is broken out into two components. The Stack Power is the amount of power that is used by the stacks to drive the ion removal. This value will change with feed water quality changes including conductivity and temperature. For a well water, it should be pretty consistent. The other power estimate comes from the pumping power required to push the water through the stacks.

Pumping Power	1.56	kWh/kgal
DC Power	0.51	kWh/kgal
Total Power	2.07	kWh/kgal

The power requirements for the system will be approximately **2.07 kWh/kgal of treated water**, including both pumping power as well as DC power to the stacks. The pumping power estimate does not include extra power required if multimedia filters are installed upstream of the EDR system.

<u>Chemicals</u>

Chemicals will be used in the EDR system for three purposes: scale prevention, electrode stream cleanings, and full system cleanings

Hydrochloric Acid will be dosed into the brine stream to prevent $CaCO_3$ scale from forming in the concentrated stream. The dosage will be based on the brine blowdown flow only (not the full brine flow) since the EDR has a recirculating concentrate loop.

The system will also require HCl for the routine cleaning of the electrode compartments. This cleaning is conducted automatically by the PLC based on operation time of the system.

Amount required for this system is approximately **14 gallon of 36% HCl acid per day**. Final dosage will be determined in a full process analysis. This is the usage per unit. Chemicals can be reduced, but it will limit recovery. (For example, reducing the EDR recovery to 91% would require only 8 gal HCl per unit per day).

Full system cleanings will also be conducted on a regular basis, but the frequency is much less than the electrode clean. Frequency of the CIP should be similar to the RO frequency. Acid clean is a 5% solution, and each cleaning will use about 1200 gallons of solution for the clean.

<u>Consumables</u>

Stack components (membranes, spacers, electrodes) and cartridge filters are consumables in the system. They will have to be replaced at the end of their useful life.

Based on inlet water quality, the filter cartridges will need to be changed anywhere from once every two weeks to every few months. Replacement frequency can be determined during piloting or during operation of the plant. If changed out once per month, the costs will be about $10,000/yr.

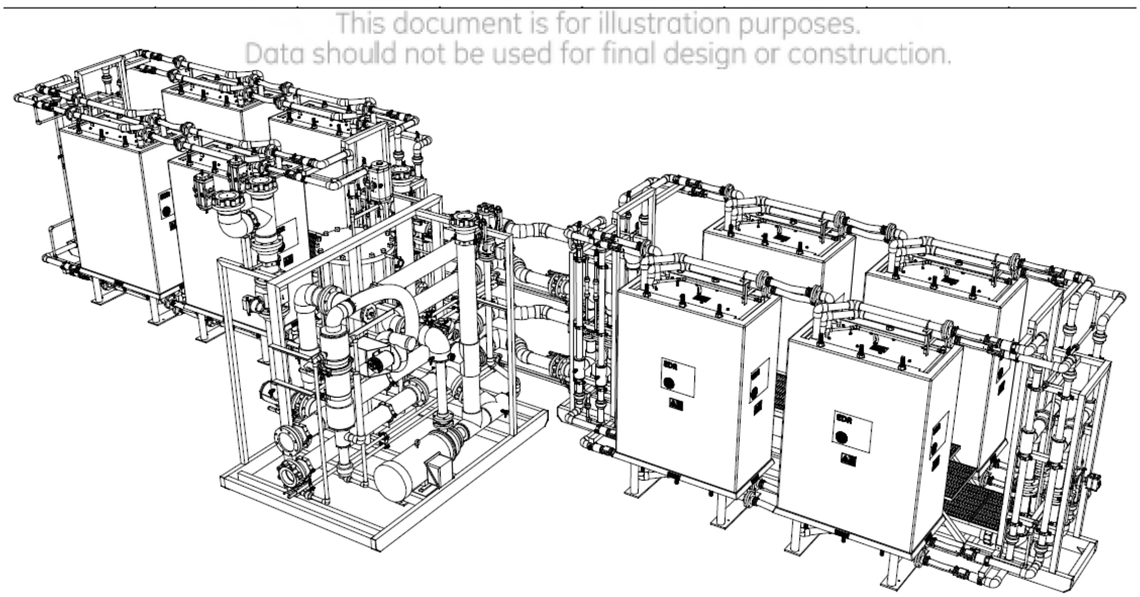
Membrane replacement within the first 10 years is rare, and only a few membranes would be replaced at a time. Membranes may be replaced during maintenance if damaged, scaled, or fouled. Therefore, the operating costs for membrane replacement are quite low. Membrane/spacer replacements should be in the area of $500-2,000 per year for at least the first 7 years.

Electrodes are a long life item as well, but they are significantly more cost than membrane. For the purposes of this evaluation, I am assuming electrode life around 8 years. This estimate is based on similar installations in Iowa. Actual electrode life is based on final operating amperages of the system and system operating hours.

Full replacement cost should be factored into the overall project timeline. This replacement can be done over time and spaced out to alleviate monetary burden on the customer. Full electrode replacement will cost around $24,000 for each system.

Evaluating the operating costs on a $ per gal of treated water produced, the consumables costs should be about $0.05/kgal.

Layout:
Each 4-line EDR unit will be approximately 42' x 15'. There should be a minimum of 10' clearance on each side of the system to allow operation and maintenance.
Typically with EDR systems, the chemicals and chemical systems are kept in a separate room. For a system this size, a 16' x 16' room would be sufficient.

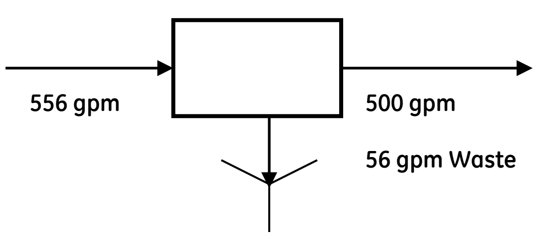


3ppm Nitrate Product Requirement
The 3ppm Nitrate case will require an additional unit to treat the water down to the required product water quality. The same units can be used to treat down to 3ppm Nitrate, but the blending function must be removed to achieve the low product levels.

Each system will now produce **500 gpm**, so three EDR systems will produce 1500 gpm combined. Four units are included in the pricing to give redundancy. The same cleaning system can be used to CIP all units.

Cost for the 4 system option will be **$2.88MM**.
If treated as a separate project, the cost for this project will be approximately $925,000

Sample Flow Diagram



The recovery has been lowered slightly since more ions need to be removed, and the brine stream would be more concentrated at the same recovery.

Product Quality Data

		Raw Feed	Product	Conc. BD
Calcium	mg/l	76.5	15.9	1380.8
Magnesium	mg/l	10.3	2.4	179.8
Sodium	mg/l	65.5	18.4	1081.4
Potassium	mg/l	0.0	0.0	0.0
Strontium	mg/l	0.2	0.0	3.7
Barium	mg/l	0.1	0.0	1.8
Bicarbonate	mg/l	261.0	76.1	3848.8
Sulphate	mg/l	28.7	4.5	548.5
Chloride	mg/l	80.3	14.3	1733.5
Fluoride	mg/l	0.6	0.2	10.3
Nitrate	mg/l	15.0	2.9	275.8
Silica	mgl	Unknown		
Total Hardness	$CaCO_3$	233.5	49.7	4190.2
TDS	mg/l	538.3	134.7	9067.1
Conductivity	uS/cm	763.5	206.8	9704.0
pH		6.80	6.26	7.31

Operating costs will be similar to the initial offering except that three units will treat the water instead of two. Power consumption goes up slightly to 2.24 kWh/kgal.

Please let me know if you have any questions or feel free to contact me regarding the contents of this document. I look forward to discussing this opportunity further.

Sincerely,

Patrick Girvin
EDR Commercial Developer

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DATE: May 31, 2017 2:01pm XREFS:

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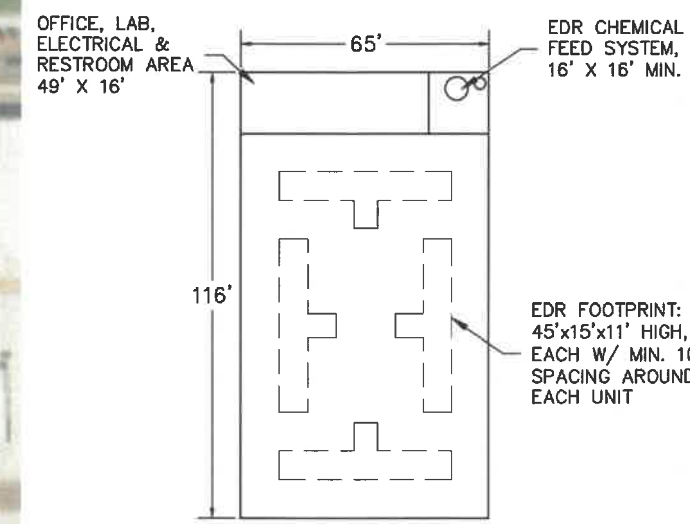
EDR FOR NITRATE REMOVAL
PUMP THROUGH UNITS



GENERAL NOTES:

1. DUAL 12 INCH TRANSMISSION MAINS ARE LOCATED UNDERNEATH 3RD STREET, NORTH OF CENTERLINE.
2. NEW VALVES, FITTINGS, AND PIPING WILL PROVIDE THE OPTION OF FULL SYSTEM BYPASS OF THE TREATMENT FACILITY.

PROJECT NO: 016-3570 DRAWN BY: HGD DATE: 05/31/2017	PROPOSED WATER TREATMENT PLANT LOCATION: ELECTRODIALYSIS REVERSAL FAIRBURY, NEBRASKA	OLSSON ASSOCIATES 601 P Street, Suite 200 P.O. Box 84608 Lincoln, NE 68508 TEL 402.474.6311 FAX 402.474.5160	FIGURE R-1

Preliminary Engineering Report
Water Study

Board of Public Works
Fairbury, Nebraska

OA Project No. 016-3570

August 2017

PROFESSIONAL CIVIL ENGINEER
CRAIG T.
REINSCH
E-12625
8/14/2017
STATE OF NEBRASKA