Pilot Study Report
for
Z-92® Uranium Removal System

conducted at

Hastings Utilities
ASR Well No. 27
Hastings, Nebraska

January 29, 2018

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Executive Summary

A uranium radionuclide removal pilot study was conducted for Hastings Utilities at the ASR Well No. 27 groundwater reinjection well facility located in Hastings, Nebraska. Naturally occurring radionuclides in the North Platte River groundwater aquifer well water source exceed the current Maximum Contaminant Levels (MCL's) for uranium. Hastings Utilities has embarked on a groundwater uranium mitigation program to remove uranium from the groundwater aquifer drinking water source.

Hastings Utilities selected Water Remediation Technology's (WRT) Z-92® Uranium Treatment Process as a possible cost-effective solution to their uranium removal program. WRT provided a 1.5 GPM (gallons per minute) treatment system, which was delivered and installed on July 26, 2017.

The purpose of this pilot study is to document the effectiveness of the WRT system on high uranium-containing water and to provide information necessary to return uranium-free water to the drinking water source aquifer.

The treatment system has successfully met uranium removal objectives at all times during the pilot study. The system was in operation for 77 days prior to writing this report and effectively reduced the level of uranium (Figure 1) to less than the detection levels at all times.

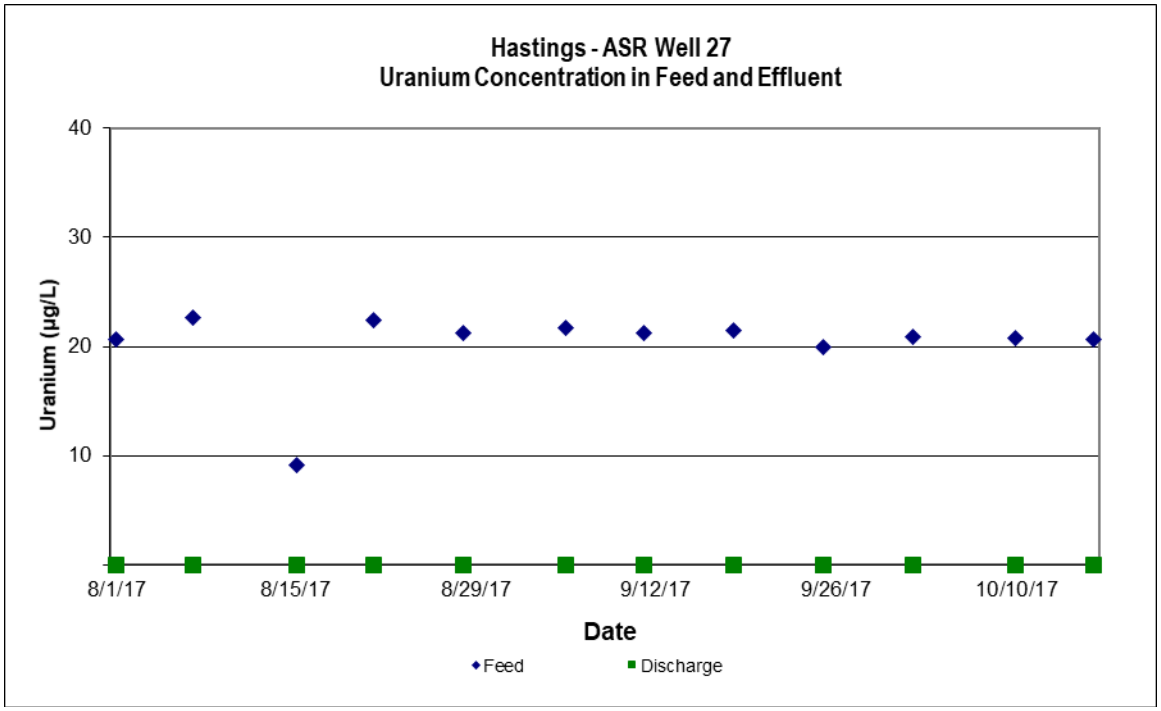

Figure 1

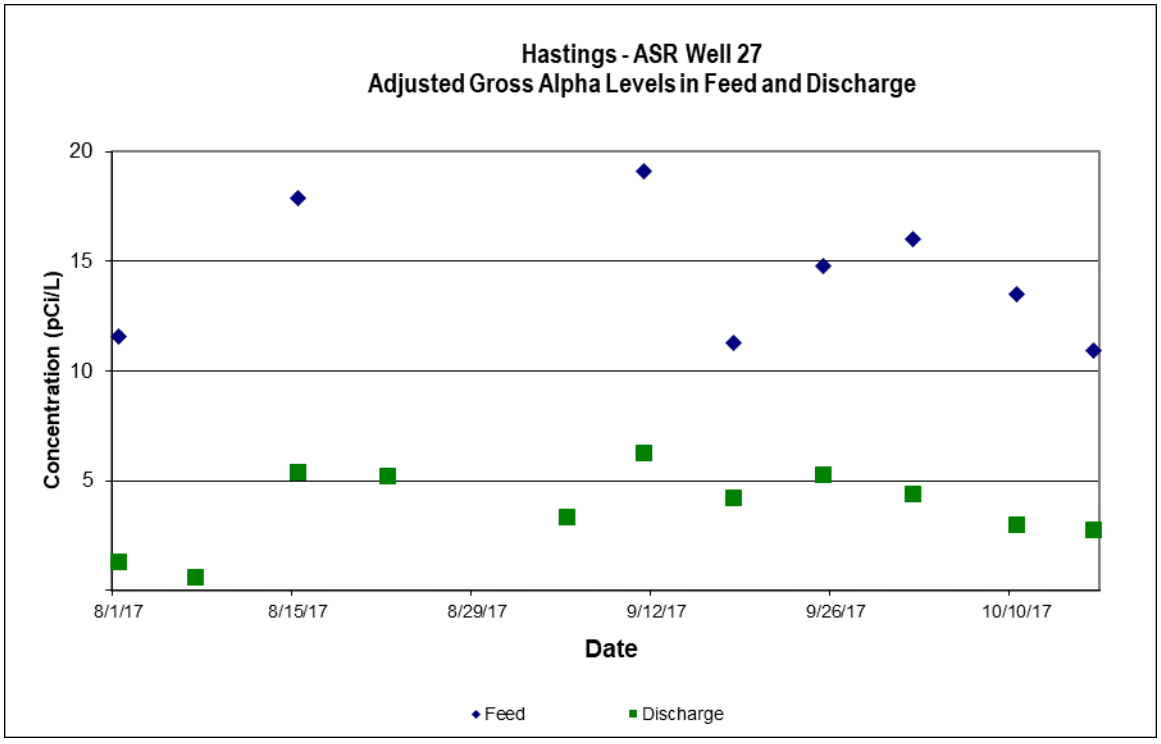

Figure 2

The results are also shown in Table 1. The average feed concentration of uranium, 16.5 µg/L, was reduced to non-detectable levels after column 2 of a 3 column system during the full length of the pilot study. The average feed concentration of gross alpha, 12.4 pCi/L was reduced to an average of less than 3 pCi/L after column 3 and never exceeded 5.3 pCi/L.

Table 1. Uranium and Gross Alpha levels in feed and discharge water.

Uranium	Feed (µg/L)	Discharge @ Column 3 (µg/L)
Uranium MCL	**—**	**30.0**
Average	16.5	0.0
Highest value	23.0	0.0
Lowest Value	15.4	0.0
Gross Alpha	**Feed (pCi/L)**	**Discharge @ Column 3 (pCi/L)**
Gross Alpha MCL	**—**	**15.0**
Average	12.4	2.4
Highest value	20.2	5.3
Lowest Value	6.8	0.6

Application Information

Hastings Utilities / City of Hastings, NE is a public utility company serving the City of Hastings, Nebraska and its wholesale customers. Hastings Utilities serves approximately 25,000 customers in the Platte River area of Central Nebraska. The pilot study was conducted at the ASR Extraction Well No. 27 in Hastings, Nebraska approximately 90 miles west of Lincoln, Nebraska. The ASR wells will be used to purify groundwater for aquifer reinjection. The aquifer is a drinking water source for Hastings, Nebraska and surrounding residents. The ASR Extraction Well No. 27 has capability for producing approximately 1,250 gallons per minute while operating.

Technology Overview

Water Remediation Technology's (WRT) Z-92® Uranium Treatment Process utilizes proprietary adsorptive ion exchange media in a series of upflow treatment vessels to remove uranium and reduce gross alpha from drinking water. The water is moved through the treatment system using the water pressure generated from the well source. No chemicals are added to the water for the treatment process. After the media is loaded with uranium and other radionuclide contaminants, it is removed from the circuit and stripped of collected uranium metal and reconditioned for continued service in uranium removal operations. WRT designs, manufactures and provides the equipment and media used in the facility. The handling and exchange of new media to replace spent media with reconditioned or new media, as well as the licensed shipping and reconditioning services, is handled by WRT. The treatment media, including reconditioned Z-92®R media is ANSI/NSF Standard 61 certified for use in drinking water.

Equipment Overview

The pilot equipment was installed at the Hastings Utilities Well No. 27 site located in Hastings, Nebraska. The treatment system used consisted of three 6-inch diameter by 40-inch vertical height treatment vessels, each containing 36-inches of Z-92® process media. The source water entered the unit through a control valve and enters the bottom of the first treatment vessel. All three columns were operated in an up-flow direction, with the flow exiting the top of the first column, then following the same flow path through columns 2 and 3 (see Figure 3). The last component in the system was a safety filter. Sample ports were located prior to each vessel, and at the end of the system.

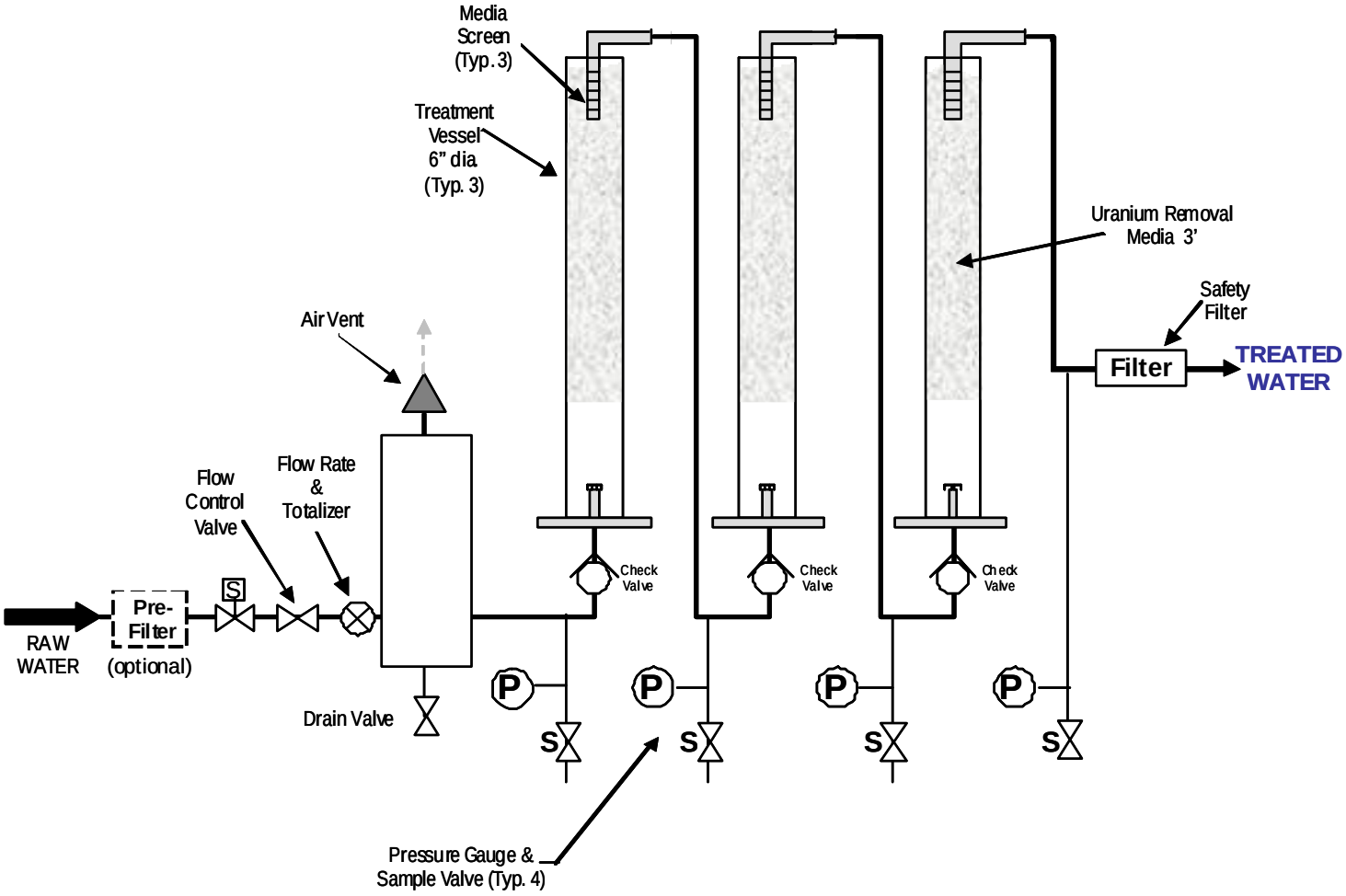

Figure 3. Simplified Process Flow Diagram

Typical Z-92® 3-Column Pilot Test Equipment.

Statement of Purpose

The uranium levels in the raw water during the pilot study were as high as 23 µg/L, and the gross alpha as high as 21.5 pCi/L. Hastings Utilities objectives are to consistently remove uranium constituents from the raw water stream to effectively low single digit values to provide pretreatment to the downstream membrane treatment system.

The purposes of this pilot study are:

- Demonstrate the ability of the WRT Z-92® Uranium Treatment Process to consistently and effectively reduce the uranium and gross alpha content to below 5 µg/L on this specific water.
- Demonstrate the reliability and ease of operation of the WRT Process.
- Develop Design Criteria for the Full-Scale System.

Delivery and Installation of the Treatment System

The treatment system was delivered at the Hastings Utilities Well No. 27 well site, on July 26, 2017 and start-up with first sampling on July 31, 2017. Set up consists of mounting the columns to a frame and connecting the water source and discharge line. The pilot study began the same day. Data was collected for 77 days prior to the writing of this report.

Operator training for system operation, monitoring and sampling was conducted on the day of installation and a schedule for sampling was established. Samples were collected by the Hastings Utilities personnel from sample valves located in the feed line and after discharge from each respective treatment vessel, at pre-determined sample intervals.

Analytical

The samples for gross alpha and radium were delivered to TestAmerica Laboratories in St. Louis, MO. The samples for inorganic water quality were delivered to TestAmerica Laboratories in Cedar Falls, IA or Servi-Tech Laboratories in Hastings, NE. The samples for uranium were delivered to Nebraska Public Health Environmental Laboratory in Lincoln, Nebraska for analysis. All laboratories used are National Environmental Laboratory Accreditation Program certified laboratory. Methods for analysis were:

Gross Alpha	EPA 900.0
Uranium	EPA 200.8
Radium 226	EPA 903.1
Radium 228	EPA 904.0

Results

The sampling results are shown in Table 2 and 3. Feed samples were collected immediately prior to the first treatment vessel. Intermediate column samples were collected immediately after column 1 and column 2 and the final discharge sample was taken after column 3. Analytical laboratory certificates are attached as Appendix A. Figure 4 and 5 shows uranium and gross alpha levels in the feed water entering the treatment system, and treated water exiting the system. The graphs clearly show that the system consistently and successfully reduced the uranium and the gross alpha in the treated water to levels below the objective values.

Table 2. Uranium Test Results

Uranium	Column Concentration (ppb)				
Date	Feed	C1	C2	C3	MCL
8/1/17	20.60	0.00	0.00	0.00	30.00
8/7/17	22.70	0.00	0.00	0.00	30.00
8/15/17	9.19	0.00	0.00	0.00	30.00
8/21/17	22.40	0.00	0.00	0.00	30.00
8/28/17	21.20	0.00	0.00	0.00	30.00
9/5/17	21.70	0.00	0.00	0.00	30.00
9/11/17	21.20	0.00	0.00	0.00	30.00
9/18/17	21.50	0.00	0.00	0.00	30.00
9/25/17	20.00	0.70	0.00	0.00	30.00
10/2/17	20.90	3.02	0.00	0.00	30.00
10/10/17	20.80	2.87	0.00	0.00	30.00
10/16/17	20.60	0.00	0.00	0.00	30.00

Figure 4 below, presents in graph format, the data in Table 2.

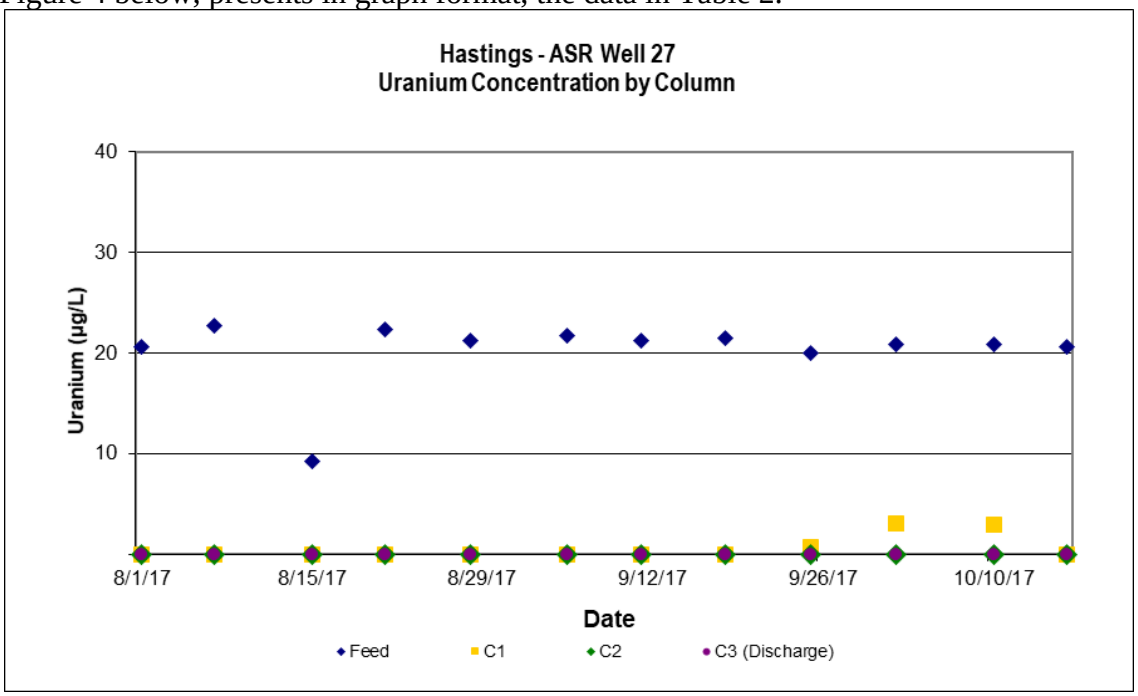

Figure 4

Table 3. Gross Alpha Test Results

Gross Alpha	Column Concentration (pCi/L)				
Date	Feed	C1	C2	C3	MCL
8/1/17	11.6	-0.1	3.2	1.3	15.0
8/7/17	21.5	1.3	3.9	0.6	15.0
8/15/17	17.9	4.5	5.4	5.4	15.0
8/22/17	20.5	5.3	5.3	5.2	15.0
9/5/17	20.7	4.1	4.1	3.3	15.0
9/11/17	19.1	5.1	4.8	6.3	15.0
9/18/17	11.3	4.03	3.66	4.22	15.0
9/25/17	14.8	3.99	3.99	5.25	15.0
10/2/17	16.0	4.33	3.95	4.39	15.0
10/10/17	13.5			2.99	15.0
10/16/17	10.9	4.16	4.26	2.77	15.0

Figure 5 below, presents in graph format, the data in Table 3.

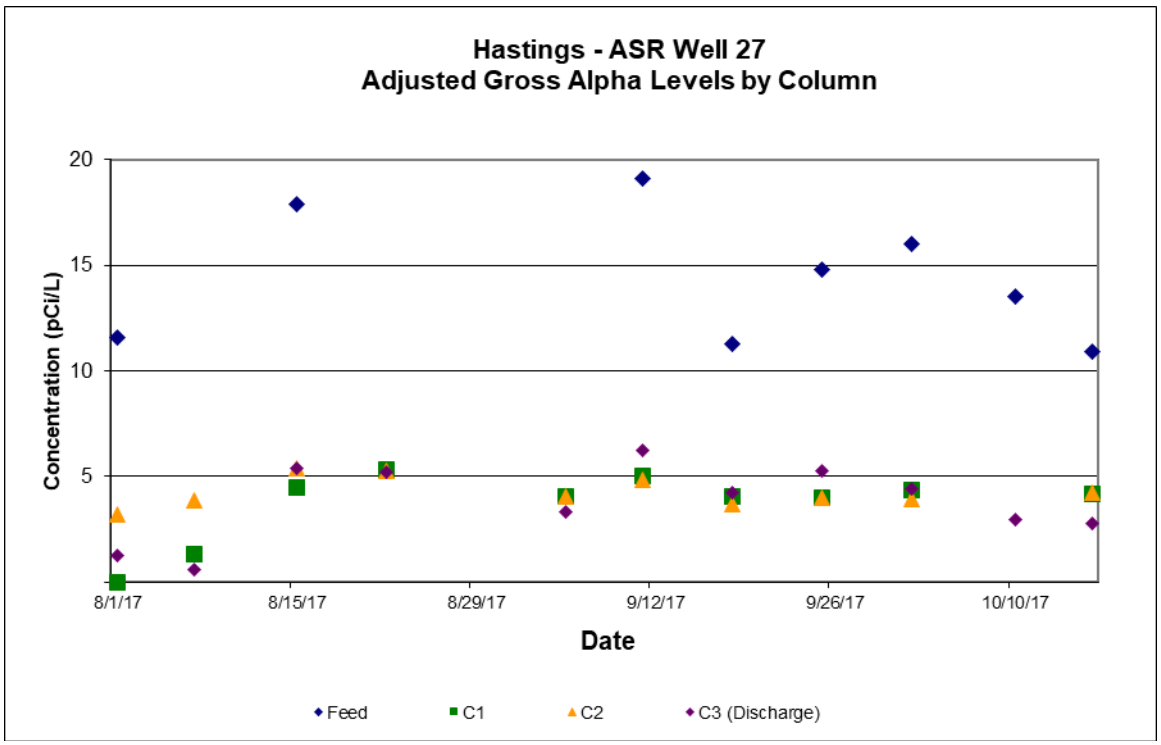

Figure 5

Radium Results

The radium sampling results are shown in Table 4. Samples from the feed water source for radium testing were collected periodically during the pilot test. The analytical laboratory certificates are attached as Appendix A. The results for radium sampling shows the feed water average combined Ra-226 and Ra-228 concentration is within compliance of the radium MCL. The Z-92® uranium removal media has a negligible effect on the radium activity of the incoming feed water as can be seen from the sampling results. Of the radium isotopes normally found in ground water, Ra-226 will contribute to the measured gross alpha of the water sample.

Table 4. Radium 226, 228 Raw Water Test Results

	Ra- 226 (pCi/L)		Ra- 228 (pCi/L)		Ra Combined (pCi/L)	
Date	Feed	Discharge	Feed	Discharge	Feed	Discharge
8/1/17	0.80	0.83	0.89	1.39	1.69	2.22
8/7/17	1.18	1.03	1.10	1.36	2.28	2.39
8/15/17	0.61	0.46	1.50	1.60	2.11	2.06
8/22/17	0.68	0.57	2.38	1.78	3.06	2.35
9/5/17	0.97	2.22	1.61	1.88	2.58	4.10
9/11/17	1.04	0.62	1.32	1.06	2.36	1.68
9/18/17	1.16	1.58	1.06	1.75	2.22	3.33
9/25/17	1.13	1.57	1.19	1.49	2.32	3.06
10/2/17	1.62	1.62	1.47	1.84	3.09	3.46
10/10/17	0.67	0.71	2.11	2.22	2.78	2.93
10/16/17	0.65	1.33	1.10	1.26	1.75	2.59

Water Quality

A water quality analysis was performed on the feed water to the treatment system and on the treated water exiting the WRT system to document any changes in water quality through the treatment process. The results of one representative sample set of those tests are shown in Table 5. Other than the reduction of uranium and adjusted gross alpha, there is no significant change to the water quality. Some removal of metal contaminants such as vanadium will occur early in the service run and may not continue throughout the expected uranium removal service period. Support documentation for Table 5 is attached as Appendix B.

Table 5. Water Quality Test Results

Hastings - ASR Well 27 Water Quality Data (9/25/17)			
Item	**Pre WRT Process**	**units**	**Post WRT Process**
Alkalinity	280.0	mg/L	280
Antimony	<	µg/L	<
Arsenic	<	µg/L	<
Barium	0.2270	µg/L	0.2340
Beryllium	<	µg/L	<
Calcium	110.0	mg/L	110.0
Carbon, Total Organic	2.5	mg/L	<
Chloride	22.4	mg/L	22.6
Chromium	<	µg/L	<
Copper	<	µg/L	<
Hardness	340.0	mg/L	340.0
Iron	<	mg/L	<
Lead	<	µg/L	<
Magnesium	15.0	mg/L	15.0
Manganese	<	mg/L	<
Mercury	<	µg/L	<
Nickel	<	µg/L	<
Nitrate	11.0	mg/L	12.0
Potassium	11.0	mg/L	11.0
Selenium	0.0141	µg/L	0.0137
Silica	25.0	mg/L	
Sodium	46.0	mg/L	49.0
Sulfate	72.0	mg/L	72.0
Thallium	<	µg/L	<
Total Dissolved Solids	530.0	mg/L	523.0
Uranium	15.9	µg/L	<
Zinc	<	µg/L	<

Note: < is non-detectable levels.

Hydraulic Loading Rate, EBCT

The treatment unit operates only when the well is providing water to the distribution system. The average flow rate through the treatment unit, when operating, was 1.50 GPM. The HLR at this flow rate is 7.6 GPM per square foot. The total gallons treated during the pilot study are summarized in Table 6 and Appendix C.

The EBCT at this HLR through three treatment vessels, each containing 36 inches of media, is 2 minutes each, for a cumulative EBCT of 5.9 minutes.

Table 6. Cumulative treated flow in gallons

Date	Treated Flow in Gallons
7/25/17	0
7/26/17	41
7/31/17	138
8/1/17	2,311
8/2/17	4,446
8/3/17	6,650
8/4/17	9,065
8/7/17	15,154
8/8/17	17,665
8/9/17	19,328
8/10/17	22,136
8/11/17	24,161
8/14/17	30,230
8/15/17	32,342
8/16/17	35,060
8/17/17	37,167
8/18/17	38,947
8/21/17	45,302
8/22/17	47,744
8/23/17	49,817
8/24/17	51,888
8/25/17	54,371
8/28/17	59,997
8/29/17	62,034
8/30/17	64,024
8/31/17	66,119
9/1/17	68,162
9/5/17	76,434
9/6/17	78,578
9/7/17	80,526
9/8/17	82,684
9/11/17	88,767
9/12/17	91,496
9/13/17	93,543
9/14/17	95,889
9/15/17	97,812
9/18/17	103,906
9/19/17	105,837
9/20/17	108,315
9/21/17	110,998
9/22/17	113,127
9/26/17	121,188
9/28/17	125,113
9/29/17	127,112
10/2/17	133,639
10/3/17	135,247
10/4/17	137,779
10/5/17	139,434
10/9/17	147,708
10/10/17	150,112
10/11/17	151,642
10/12/17	154,182
10/13/17	155,661
10/16/17	161,776

Radiation Safety

The treatment system is designed to collect uranium, a naturally occurring radioactive material, while in operation. Because of this action, it gradually becomes radioactive during normal operation. WRT both predicts and monitors the level of radiation present in the treatment system.

The total amount of radiation that members of the public can be exposed to is 2 mrem per hour and 100 mrem over the course of a year. WRT's maximum measured activity is less than half of the hourly exposure limit. Due to the limited amount of operator attention necessary for the pilot test, the annual exposure limit is also readily met.

WRT has prepared a safety plan for its tests that includes radiation level monitoring, logging time spent in proximity to a test unit, emergency procedures to be followed and an introduction to radiation safety for operators. Operators are instructed in radiation safety before the pilot test is started.

Any full scale system will include appropriate equipment, radiation level monitoring, and a corresponding safety plan approved by regulatory authorities.

Operational Results

An operation log was maintained during the pilot study, and is attached as Appendix C. The treatment system operated throughout the course of this test without any operational problems.

Conclusion

The WRT Z-92® Uranium Treatment Process consistently reduced the adjusted gross alpha and uranium in the system discharge to levels to non-detectable values; well below the objective requirements for the system. The treatment system operated easily and reliably during the study. There was no equipment or operational problems of any kind reported in the course of this test.

WRT would like to thank the personnel and staff of Hastings Utilities for their assistance, cooperation and participation in this study.

Appendices available upon request