State of Utah

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Department of
Environmental Quality

Kimberly D. Shelley
Executive Director

DIVISION OF WASTE MANAGEMENT
AND RADIATION CONTROL

Douglas J. Hansen
Director

MEMORANDUM

TO: File

THROUGH: Phil Goble, Manager *Phillip Goble*

FROM: Chris Leahy, P.G.

DATE: October 30, 2023

SUBJECT: Review of the Energy Fuels Resources (USA) Inc. (EFR), White Mesa Uranium Mill, Blanding, Utah September 27, 2023, Source Assessment Report for Selenium in Monitoring Well MW-11 and pH in Monitoring Well MW-37
Ground Water Discharge Permit No. UGW370004 (Permit)

Summary

A September 27, 2023, Source Assessment Report ("SAR") for selenium in Monitoring Well MW-11 and pH in MW-37 at the White Mesa Uranium Mill (Mill) was submitted to the Director by Energy Fuels Resources (USA) Inc. ("EFR") and received by the Utah Division of Waste Management and Radiation Control on September 29, 2023. The SAR was submitted for review and approval of source assessment investigation findings and proposed revised Ground Water Compliance Limits (GWCLs) for selenium in MW-11 and pH in MW-37.

Monitoring well MW-11 is located on the southern berm of the Mill Tailings Cell 3 and is hydraulically downgradient from portions of Cell 2, Cell 3, and from the chloride and nitrate/nitrite plume.

Monitoring well MW-37 is located on the southern berm of the Mill Tailings Cell 4B and is hydraulically downgradient from Cell 4B and portions of Cell 4A.

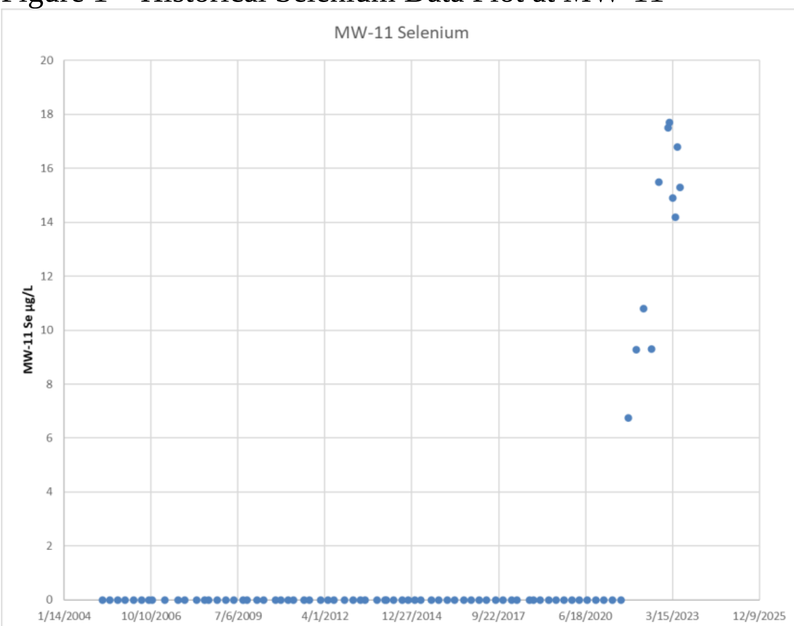
Monitoring well MW-11 has been evaluated in recent EFR reports, studies, and other SAR's including a 2007 EFR Revised Background Groundwater Quality Report, a 2008 University of Utah groundwater isotopic study, a 2012 EFR Sitewide SAR, a 2012 EFR Sitewide pH Report, a 2019 EFR SAR, and a 2021 EFR SAR. It is noted that the 2012, 2019, 2021 EFR SAR's included investigation of manganese and revised GWCL's were approved after submission. Both manganese and sulfate were found to have increasing trends per the 2007 Revised Background Groundwater Quality Report and were attributed to natural fluctuations not associated with Mill activities.

<u>SAR Review</u>

The SAR is broken up into four primary sections: 1. Categories and approach for analysis; 2. Results of the analysis; 3. Statistical evaluation and calculation of revised GWCL's for trending constituents, and; 4. Conclusions and recommendations.

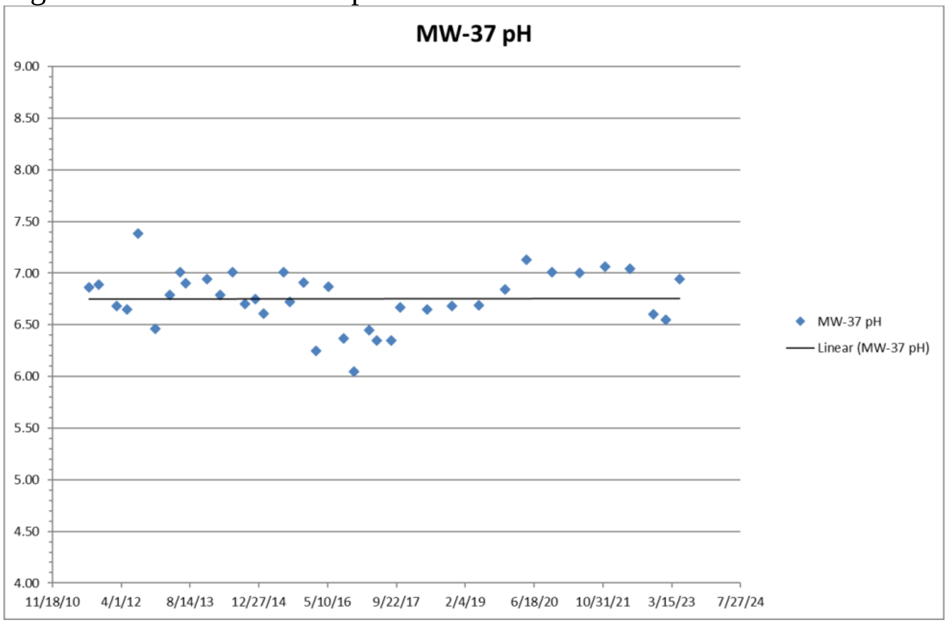
The figures below depict the time/concentration plot for selenium in monitoring well MW-11 and pH in monitoring well MW-37 (data through the 2nd Quarter 2023).

Figure 1 – Historical Selenium Data Plot at MW-11



The selenium data set in MW-11 depicts a significantly increasing trend since first testing over the reporting limit during the 4th Quarter 2021 sampling event.

Figure 2 – Historical Field pH Data Plot at MW-37



The field pH data set in MW-37 does not exhibit a significant decreasing trend and exhibits a non-parametric distribution.

EFR Investigations of Potential Sources of Increasing Trends at MW-11 and MW-37

1. *Site-Wide pH Changes*

DWMRC review of the SAR notes that field pH in nearly all MW-series monitoring wells, including MW-11 and MW-37, was decreasing prior to about 2016 (Figure 2 and Figure 3). This has resulted in mobilization of pH sensitive metals and increases in concentrations of these metals in groundwater. However, since about 2016, the site-wide decreasing pH trend has reversed in nearly all MW-series monitoring wells (including MW-11 and MW-37), and pH is now generally stable to increasing (Figure 4 and Figure 5). This includes upgradient and far cross-and downgradient monitoring wells. The SAR states that the post-2016 increase in pH is inconsistent with a TMS source as TMS solutions have a low pH, and mixing of potential seepage of TMS solution with groundwater would cause a decrease (rather than increase) in pH. The increasing pH post-2016 shows that MW-11 and MW-37 are unimpacted by the TMS.

Figure 3 –Plot of Historical pH Data at MW-11

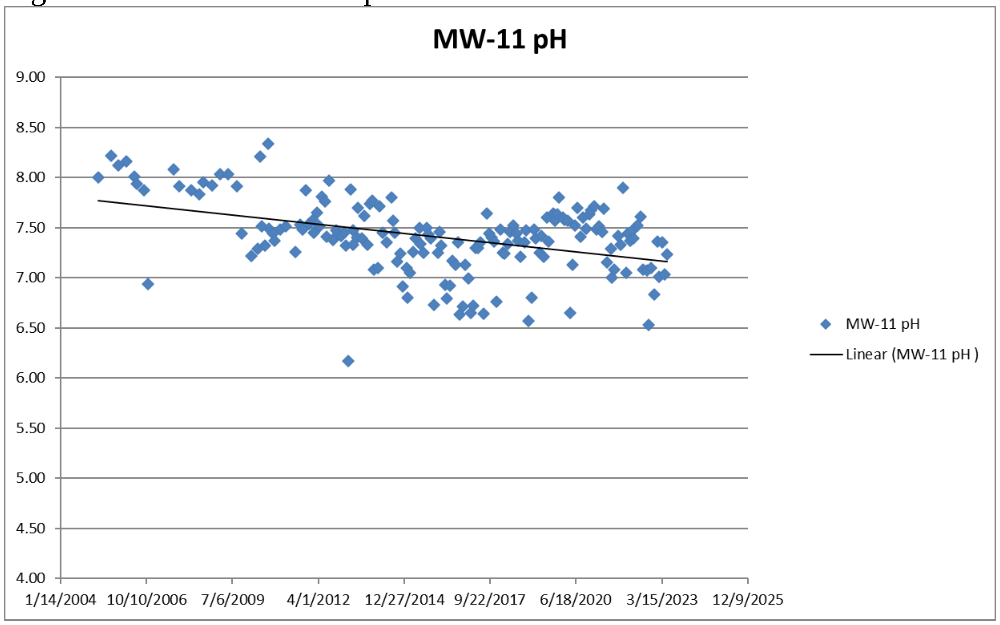


Figure 4 –Plot of Post-2016 pH Data at MW-11

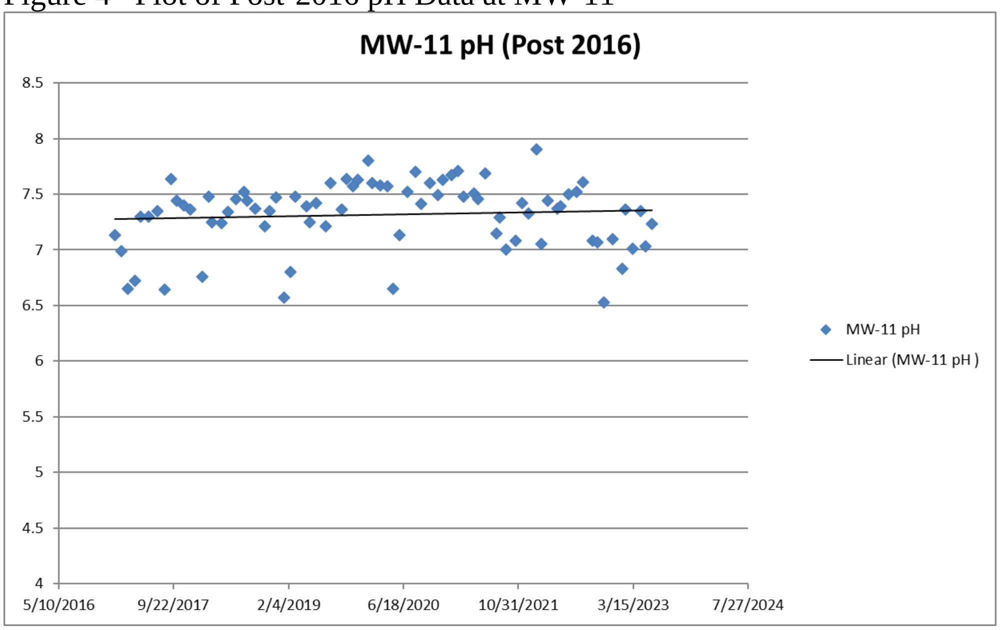
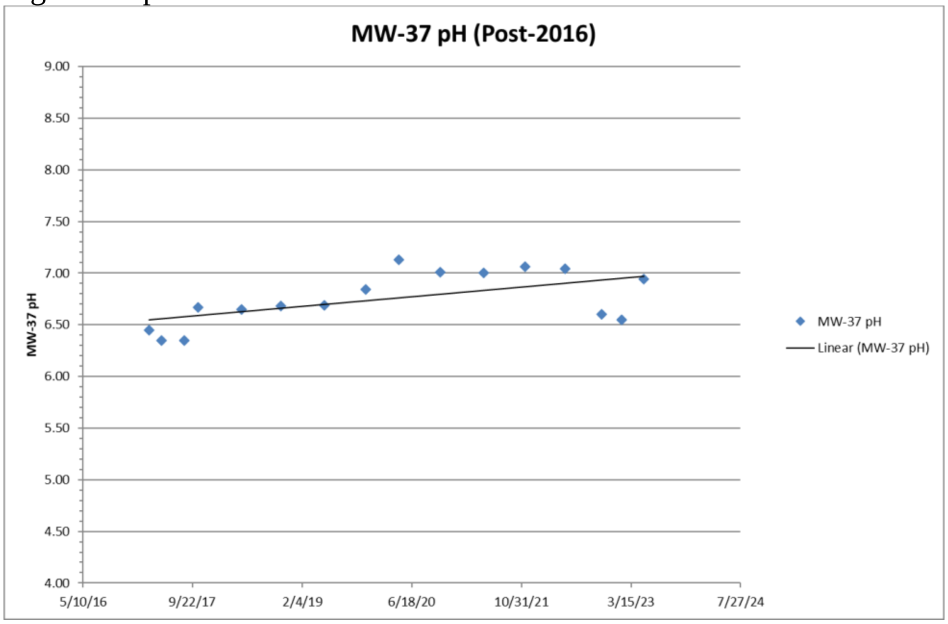


Figure 5 – pH Plot of Post-2016 Data at MW-37



2. ***Changes in Groundwater in MW-11 and MW-37***

DWMRC review of the SAR notes that substantial changes in water levels have occurred in the last 11 years due to cessation of water delivery to the wildlife ponds. Currently, although water levels have declined substantially in the center of the perched groundwater mound associated with the northern wildlife ponds, water levels have not returned to pre-pond seepage conditions, and the groundwater mound is still expanding. Changes in saturated thicknesses and rates of groundwater flow can result in changes in concentrations of dissolved constituents or pH for many reasons. For example, as discussed in HGC (2012), groundwater rising into a vadose zone having a different chemistry than the saturated zone will result in changes in pH and groundwater. If the rise in groundwater represents a long-term trend, long term changes in groundwater constituent concentrations or pH result.

MW-11 Groundwater Changes

The SAR notes that the trend of increasing selenium concentration in MW-11 correlates with increasing nitrate concentrations and is likely to result from mobilization from natural sources within the Burro Canyon Formation hosting perched groundwater at the site. Sources include naturally occurring pyrite in the formation. Literature cited in the SAR discussed Selenium mobilization by nitrate may result in whole or in part by oxidation of naturally occurring pyrite by nitrate. The SAR notes that the post-2018 decrease in ammonia and increase in nitrate not only indicate the increasing influence of the nitrate/chloride plume but are also consistent with increasingly oxidizing conditions which are favorable for mobilization of selenium. While DWMRC realizes this may be a possibility, more studies need to be performed to validate the oxidation of pyrite by nitrate hypothesis.

MW-37 Groundwater Changes

The SAR notes that pH at MW-37 was decreasing prior to 2016 and may have resulted from pyrite oxidation, since visible pyrite was noted in the drilling log. After 2016, the stable to increasing pH trend (reflected in most of the MW-series wells) cannot result from TMS seepage mixing into groundwater since the TMS solutions have a very low pH. The field pH data set in MW-37 does not exhibit a significant decreasing trend and exhibits a non-parametric distribution as shown in Figure 2.

3. *Tailings Solution Groundwater Indicator Parameters*

The SAR Section 3.3 discusses four primary indicator parameters (Chloride, Fluoride, Sulfate and Uranium) which would be detected in ground water in the event of a discharge from the Mill tailings cells.

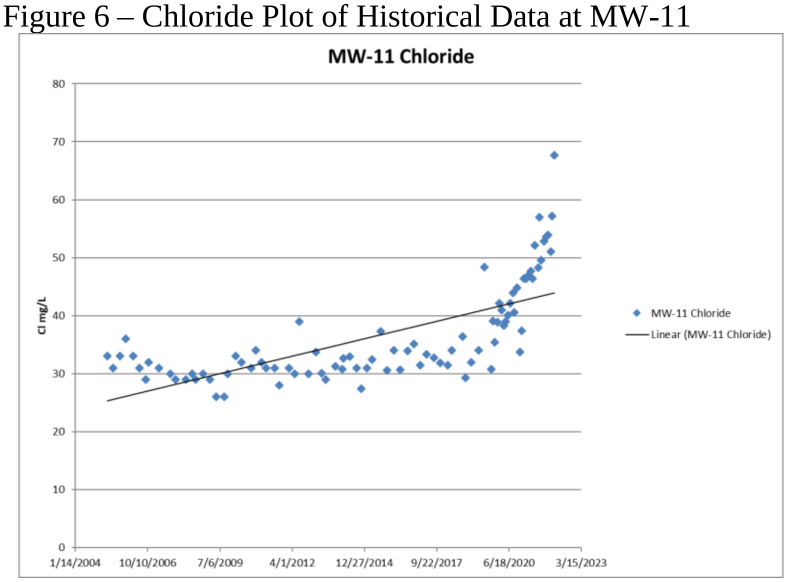
MW-11 Indicator Parameters

Per the SAR it was noted "*indicator parameters chloride, sulfate and uranium exhibit significantly increasing trends, whereas indicator parameter fluoride exhibits a significantly decreasing trend. The decreasing fluoride indicates that MW-11 is not impacted by any potential seepage from the TMS. The increase in chloride correlates to an increase in nitrate and is due to the migration of the nitrate/chloride plume towards MW-11.*"

<u>Chloride</u>

Per the SAR, the increase in chloride has occurred "*only since about 2018, correlates to an increase in nitrate, and is due to the migration of the nitrate/chloride plume towards MW-11*."

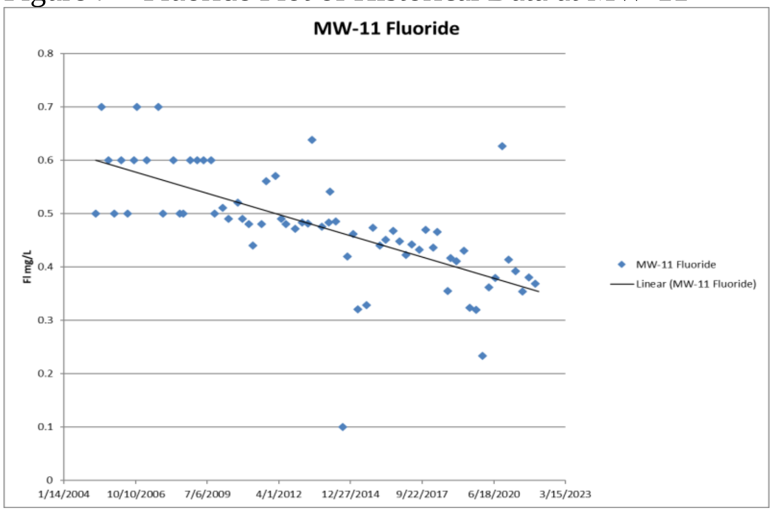
Figure 6 – Chloride Plot of Historical Data at MW-11



Fluoride

Fluoride is highly concentrated in tailings wastewater. Literature and transport modeling has shown fluoride to be highly mobile in the vadose zone and groundwater beneath the tailing cells. Per the figure below, fluoride is showing a decreasing concentration trend in MW-11 indicating that MW-11 is not impacted by potential seepage from the TMS.

Figure 7 – Fluoride Plot of Historical Data at MW-11



Uranium

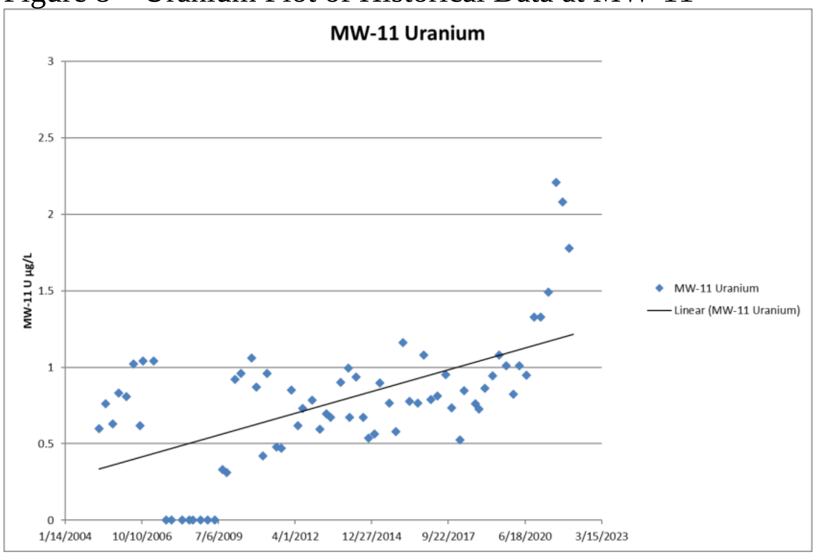
The SAR discusses that chloride, nitrate, and uranium show almost the same trend with respect to increasing concentrations. Chloride and nitrate are anions that do not sorb onto aquifer materials and are not retarded with respect to groundwater flow. In contrast, uranium is expected to have a mobility that is orders of magnitude lower than chloride or nitrate at the near-neutral pH conditions at MW-11.

In order to impact groundwater at MW-11, any solution seeping from the TMS would have to penetrate more than 60 feet of vadose materials, then migrate within perched groundwater toward MW-11. Because the expected Kd for uranium is at least one or more orders of magnitude higher than the expected Kd for chloride and nitrate, the substantial retardation of uranium with respect to chloride and nitrate that would occur would prevent the nearly simultaneous increases in all three constituents that have been measured.

Based on the simultaneous increases, the SAR determines that these concentrations are caused by migration of the nitrate and chloride plume towards MW-11. The SAR discusses that if the increases in uranium were caused by tailings solution, then it would be expected that uranium would lag chloride and nitrate based on higher Kd values for uranium and the more than 60 feet of vadose zone between the tailings management system and groundwater at MW-11.

Literature cited in the SAR states that recent increases in uranium are attributable to mobilization of naturally-occurring uranium by nitrate and oxidation of pyrite by nitrate. Similar to selenium, uranium can exist as a contaminant in pyrite. Because nitrate oxidation of pyrite can proceed by a pathway that consumes rather than produces acid, and there is sufficient nitrate to produce the measured uranium, recently increasing uranium at MW-11 can result from pyrite oxidation with stable to increasing pH. In addition, as discussed in Section 3.1.1, bottle roll test solutions generated as much as 64.9 µg/L selenium from the 'generic' pyrite sample; and as much as 303 µg/L selenium from a pyritic core sample. While DWMRC realizes this may be a possibility, more studies need to be performed to validate mobilization of naturally-occurring uranium by nitrate and the oxidation of pyrite by nitrate hypotheses.

Figure 8 – Uranium Plot of Historical Data at MW-11



Sulfate

Per the SAR, the increase in sulfate concentrations in the complete data set is more gradual than the increase in chloride and uranium concentrations. Sulfate has been increasing since the time of the Existing Wells Background Report (INTERA, 2007a); and was increasing at the time of the Hurst and Solomon isotopic investigation report (Hurst and Solomon, 2008). Because the isotopic analysis concluded that there were no impacts to groundwater from the TMS, the trend in sulfate is indicative of background conditions unrelated to the disposal of materials to the TMS. Furthermore, isotopic measurements indicated that MW-11 contained the largest component of water that predated the TMS (Hurst and Solomon, 2008), additional demonstration of the lack of a TMS impact.

Although sulfate concentrations in MW-11 have been increasing since the time of the Background Report, post-July 2019 data are not increasing significantly, and average historical concentrations remain within the sitewide range of sulfate concentrations at nearby monitoring wells at the Mill as summarized in Table 1 below.

Table 1 - Average Sulfate Concentrations at Select Monitoring Wells

Monitoring Well No.	Location Relative to Tailings Cells	Average Sulfate Concentration (Complete Data Set) (mg/L)
MW-11	Downgradient Cell 2 and 3	1,159
MW-1	Upgradient	812
MW-18	Upgradient	1,815
MW-19	Upgradient	611
MW-20	Far Downgradient	3,351
MW-03A	Far Downgradient	3,526
MW-29	Downgradient Cells 1 and 2	2,662
MW-30	Downgradient Cell 2	776

MW-37 Indicator Parameters

Mann-Kendall test results included in the SAR show that no significant trends exist for MW-37 indicator parameters. Linear regression test results for normally distributed constituents, chloride and uranium show a decreasing trend in chloride (Figure 10) and a significantly decreasing trend in uranium (Figure 9), indicating that there has been no impact to MW-37 from potential TMS seepage.

Figure 9 – Historical Uranium Data Plot at MW-37

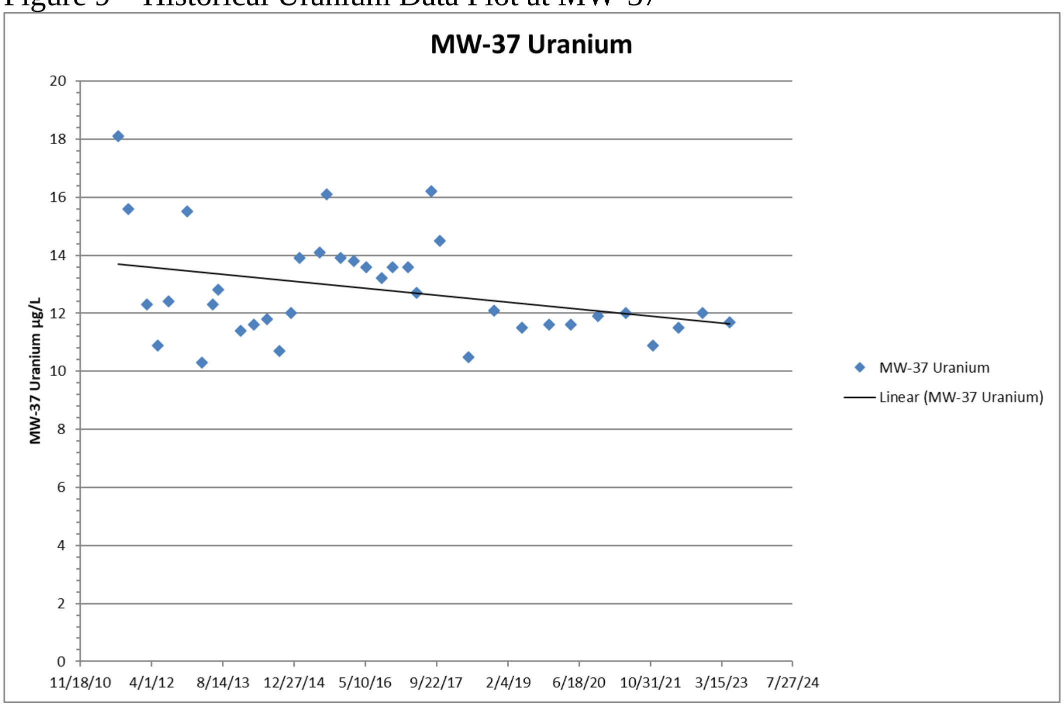
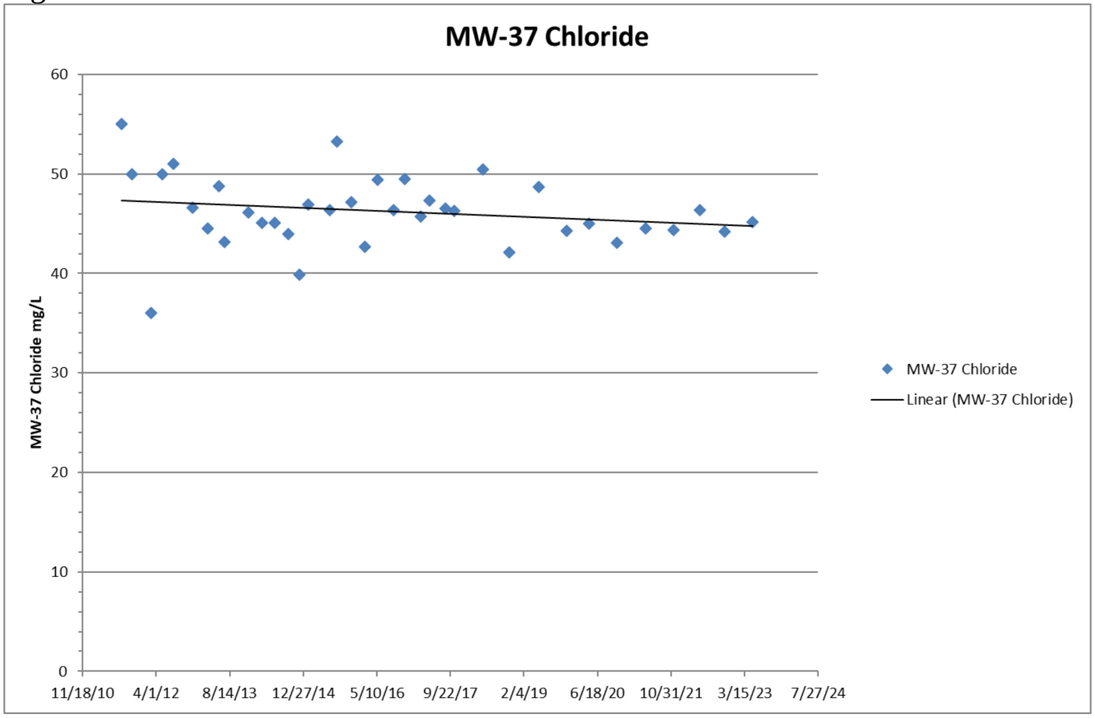


Figure 10 – Historical Chloride Data Plot at MW-37



4. Mass Balance Analysis

MW-11 Mass Balance Analysis

Section 3.4.1 of the SAR discusses mass balance analysis at MW-11. Since 1990, the water levels at MW-11 have risen by more than 17 feet and the saturated thickness has increased from 29.8 to 47.1 feet. The SAR provides an evaluation of expected chloride concentrations (projecting a 37% tailings solution component) which would be expected if the rising levels were due to tailings solution. The chloride concentration would be expected to exceed 10,000 mg/L, since the tailings solution is highly concentrated in chloride (average concentration 28,000 mg/l). However, current chloride concentrations at MW-11 are approximately 69 mg/L.

Similar evaluation of fluoride, another conservative tracer, indicate if a tailing source, then MW-11 concentrations should be on the order of 1,200 mg/L rather than the current concentration of approximately 0.28 mg/L. The sulfate concentration would exceed 67,000 mg/L rather than the current approximately 1,340 mg/L and uranium would exceed 143,000 µg/L rather than the current approximately 2.6 µg/L. Selenium concentration would exceed 3,400 µg/L rather than the current 15.3 µg/L.

MW-37 Mass Balance Analysis

Section 3.4.2 of the SAR discusses mass balance analysis, noting that: since sampling began in the 3rd quarter of 2011, the water levels at MW-37 have risen by more than 6 feet and the saturated thickness has approximately doubled.

If the water level increase were the result of TMS seepage, the chloride concentration (currently 45 mg/L) would exceed 14,000 mg/L; the fluoride concentration (currently about 0.2 mg/L) would exceed 1,700 mg/L; the sulfate concentration (currently 2,580 mg/L) would exceed 91,000 mg/L; and the uranium concentration (currently 11.7 µg/L) would exceed 194,000 µg/L.

Similar evaluation of fluoride, another conservative tracer, indicate if a tailing source, then MW-11 concentrations should be on the order of 1,200 mg/L rather than the current concentration of approximately 0.28 mg/L. The sulfate concentration would exceed 67,000 mg/L rather than the current approximately 1,340 mg/L and uranium would exceed 143,000 µg/L rather than the current approximately 2.6 µg/L. Selenium concentration would exceed 3,400 µg/L rather than the current 15.3 µg/L.

5. *Source Assessment Conclusions*

MW-11

Per Section 3.5.1 of the SAR, EFR finds that based on assessment, and factors demonstrating that MW-11 has not been impacted by seepage from the tailings cell, current changes in groundwater chemistry and selenium OOC at monitoring well MW-11 are due to groundwater background and impacts from the nitrate/chloride plume migration. The SAR includes discussion of the assessment and Section 3.5.1.1 lists the 8 factors supporting that EFR conclusion. Specifically, per the SAR:

1. *"Key indicator parameter fluoride is decreasing.*
2. *pH has been stable to increasing since 2016.*
3. *Iron (which is the constituent having the highest concentration in the TMS) has been decreasing since the first quarter of 2012.*
4. *A statistically significant increasing trend in sulfate was present in MW-11 at the time of the Hurst and Solomon (2008) isotopic investigation report which included MW-11 in its analysis and that concluded there were no impacts to groundwater from the TMS, indicating that these trends are not the result of potential TMS seepage. In addition, while the complete data set for MW-11 sulfate exhibits a significantly increasing trend, the post-inflection (post-July 2019) data set for MW-11 sulfate exhibits no significant trend.*
5. *Although not within the plume, concurrently increasing chloride and nitrate at MW-11 since 2018 result from the increasing influence of the nitrate/chloride plume. The increasing influence of the nitrate/chloride plume, which originates approximately 1,000 feet upgradient of the TMS, results from continued downgradient migration of the plume towards MW-11. One consequence of the increasing nitrate is mobilization of naturally occurring uranium (and selenium) at MW-11.*

6. *Because uranium is substantially less mobile than nitrate or chloride at the near neutral pH conditions at MW-11, concurrently increasing uranium, nitrate, chloride (and selenium) indicate geochemical changes in the immediate vicinity of MW-11 (caused in part by the increasing influence of the nitrate/chloride plume) rather than transport from a remote source such as the TMS.*
7. *Increasing water levels are expected to impact the MW-11 groundwater chemistry and contribute to trends in dissolved constituents.*
8. *Mass balance analysis indicates that water level increases at MW-11 do not result from potential TMS seepage."*

In addition to those above, the SAR discussed several lines of evidence to support that mill activities are not the source of the selenium exceedance in monitoring well MW-11, including 1. Decreasing pH effects on monitoring well geochemistry; 2. Evaluation of tailings solution indicator parameters (chloride, sulfate, fluoride, and uranium); 3. Mass balance calculations for chloride, fluoride, sulfate, uranium and selenium 3. Previous findings in the EFR Existing Wells Background Report that the SAR parameters showed long standing upward trends; 4. Potential effects of pyrite oxidation releasing selenium and other trace metals into solution; 5. Location of MW-11 within the nitrate/chloride plume, and 6. Findings of the 2007/2008 University of Utah Groundwater Study.

MW-37

Per Section 3.5.2 of the SAR, EFR finds that based on assessment, and factors demonstrating that MW-37 has not been impacted by seepage from the tailings cells, current changes in groundwater chemistry are responsible for pH OOC at MW-37. The SAR includes discussion of the assessment and Section 3.5.2.1 lists the 4 factors supporting that EFR conclusion. Specifically, per the SAR:

1. *"Key indicator parameters chloride, fluoride, sulfate, and uranium are stable to decreasing.*
2. *pH has been stable to increasing since 2016.*
3. *Increasing water levels are expected to impact the MW-37 groundwater chemistry and contribute to trends in dissolved constituents.*
4. *Mass balance analysis indicates that water level increases at MW-37 do not result from potential TMS seepage."*

Per Division review of the SAR and historical data for MW-11 and MW-37, the out-of-compliance status for selenium in MW-11 and pH in monitoring well MW-37 does not appear to be associated with contamination from a tailing wastewater source. Based on these findings it is appropriate to adjust the Permit groundwater compliance limits consistent with the currently Division approved groundwater data statistical process flow chart for the Mill and associated guidance.

Note that the evaluation of the comprehensive list of monitoring parameters and evaluation of data by EFR and the Division at monitoring well MW-11 is ongoing. Out-of-compliance status is being continuously monitored to ensure that a tailings source is not evident.

EFR Proposed Modified GWCL Statistical Evaluation of Data:

MW-11 Proposed Modified GWCL Statistical Evaluation

Based on Division review of the SAR statistical analysis it was noted that analysis for MW-11 was conducted for the complete historic data set and for a post July 1, 2019 data set. After July 2019, a steady increase in nitrate concentrations occurred and a point of inflection is observed. This post July 1, 2019 data point of inflection is used to define a recent subset of representative data that was used to calculate a revised GWCL for selenium. The proposed GWCL was calculated by selecting the greater of the following values for both the complete dataset or post July 1, 2019 subset:

(1) mean + 2σ
(2) highest historical value
(3) mean x 1.25 using a complete dataset or subset of the data defined by a point of inflection (July 1, 2019)

Although the complete data set and the post July 1, 2019 data set were evaluated, the modified selected approach for the proposed GWCL for selenium is based on the mean + 2σ of the post-July 1, 2019 data set. The Division approved statistical flow chart for the White Mesa Mill groundwater monitoring wells clarifies that if an upward trend is apparent for a constituent, then a modified approach should be considered. The modified approach should allow for a GWCL which considers the increasing concentration.

MW-37 Proposed Modified GWCL Statistical Evaluation

Based on Division review of the SAR statistical analysis it was noted that field pH in MW-37 does not exhibit a significant decreasing trend and is not normally distributed. The DWMRC approved flowsheet dictates that the greater (lower for pH) of the fraction approach or the highest historic value (lowest for pH) is selected for the proposed GWCL in these circumstances. Because field pH is measured on a logarithmic scale, the fractional approach results in a value that is unnecessarily low, so the proposed GWCL for field pH in MW-37 is based on the lowest historical value.

EFR Statistical methods used in the SAR included: 1. Descriptive statistics for the complete and modified data sets; 2. Mean and Standard Deviation Calculation; 3. Shapiro-Wilk Test for normality; and 4. Mann-Kendall Trend Analysis (non-normally distributed data sets) and Linear Trend Analysis. The calculations and findings are summarized in the SAR on Appendix A-1 and A-10.

Table 2 below summarizes the EFR calculations and rationale for the proposed modified GWCL's.

Table 2 - EFR Proposed Revised GWCL for Selenium in MW-11 and pH in MW-37:

Well Number	Parameter	Current GWCL	EFR Proposed GWCL Revision	Method to Determine GWCL	DWMRC Finding – Is Proposed GWCL in Conformance with the Statistical Flow Chart?
MW-11	Selenium	12.5 µg/L	20.49 µg/L	Mean + 2σ*	Increasing Trend allows for modified approach on Flow Chart. The revised Mean + 2σ Background value appears appropriate based on review of data.
MW-37	pH	6.61-8.5	6.05-8.5	Lowest Historical Value	Not a significant decreasing trend and not normally distributed. Flow chart dictates that the greater (or lower for pH) of the fraction approach or the highest historic value (lowest for pH) is selected. The fractional approach results in a value that is unnecessarily low, so the lowest historical value is used.

*Based on Mean + 2σ of the Selenium background data from the post July 2019 data set.

Conclusions:

Regarding selenium in MW-11; based on DWMRC review of the background statistics and confirmation that the proposed parameters for a GWCL modification are showing an increasing trend not apparently associated with contamination from the Mill, it is appropriate to set the GWCL for this parameter as the Mean + 2σ of the Post July 1, 2019 data set. This modified approach is consistent with the DWMRC approved statistical flowchart for parameters showing increasing trends.

Regarding field pH in MW-37; based on DWMRC review of the background statistics and confirmation that the proposed parameters for a GWCL modification are showing a stable to increasing pH trend since 2016 not apparently associated with contamination from the Mill, it is appropriate to set the GWCL for this parameter as the Lowest Historical Value of the historical data set. This modified approach is consistent with the DWMRC approved statistical flowchart for parameters showing increasing trends.

Based on review, a letter will be sent to EFR of initial approval of the modified GWCL's on the table below. The letter will include notification that the modifications are subject to public notice and public participation requirements, and that the modifications will not be effective until formal issuance of a modified Permit.

Well Number	Parameter	Current GWCL	Modified GWCL	Method of Analysis
MW-11	Selenium	12.5 µg/L	20.49 µg/L	Mean + 2σ*
MW-37	Field pH	6.61-8.5	6.05-8.5	Lowest Historical Value

*Based on the Mean + 2σ of the Selenium background data set post July 2019

References

[1] Energy Fuels Resources (USA) Inc., September 27, 2023, *Transmittal of Source Assessment Report for MW-11 and MW-37 White Mesa Mill Groundwater Discharge Permit UGW370004*

[2] Energy Fuels Resources (USA) Inc., February 15, 2022, *White Mesa Uranium Mill Ground Water Monitoring Quality Assurance Plan (QAP), Revision 7.7*

[3] Energy Fuels Resources (USA) Inc., October 12, 2012, *Source Assessment Report*, Prepared by Intera

[4] Hurst, T.G., and Solomon, D.K. University of Utah, 2008, *Summary of Work Completed, data Results, Interpretations and Recommendations for the July 2007 Sampling Event at the Denison Mines, USA White Mesa Uranium Mill Near Blanding,* Utah, Prepared by Department of Geology and Geophysics

[5] Hydro Geo Chem, December 7, 2012, *Pyrite Investigation Report*

[6] Intera. 2007, *Revised Background Groundwater Quality Report: Existing Wells for Denison Mines (USA) Corp.'s White Mesa Uranium Mill site, San Juan County, Utah.*

[7] Intera, 2007, *Groundwater Data Preparation and Statistical Process Flow for Calculating Groundwater Protection Standards, White Mesa Mill Site, San Juan County, Utah*

[8] Utah Department of Environmental Quality, January 19, 2018, Modified on March 8, 2021, *Utah Division of Radiation Control, Ground Water Discharge Permit, Permit No. UGW370004, Energy Fuels Resources (USA) Inc.*