TO: Johnny Zhan, Ph.D
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FROM: Adam Arguello, P.E.
DATE: March 2, 2022

RE: Grants Reclamation Project Uranium Mass Balance Memo

Introduction

Groundwater remediation has been ongoing at the Grants Reclamation Project since 1977 in varying forms. Groundwater collected from 1978 through 1990 was utilized in the mill circuit during mill operation. Following the closure of the mill, groundwater collected from 1990 through 1999 was discharged to evaporation ponds on-site. Since 1999, water has been treated by an onsite reverse osmosis (RO) plant and additionally, since 2016, by the zeolite treatment systems. An assessment of the historical uranium mass balance provides useful insight into historic site restoration progress as well as framing expectations of potential future progress in groundwater remediation.

In the past, it was believed that uranium is largely mobile in the alluvial groundwater. The geochemical characterization of the site identified weak adsorption to ferrihydrite as the primary geochemical mechanism that would attenuate uranium transport (WME, 2020b). However, it has become apparent that mechanism does not adequately explain the stagnation of progress in reducing concentrations and/or mass in the aquifer over the four decades of groundwater remediation at the site.

Base Case Evaluation

The following evaluation is based upon the mass balance of the onsite alluvial aquifer. The evaluation broke up impacted groundwater into 7 distinct geographical and/or hydrogeological areas/units:

1. the onsite alluvial aquifer mobile domain,
2. the onsite alluvial aquifer immobile domain,
3. the north offsite alluvial aquifer,
4. the south offsite alluvial aquifer,
5. the Upper Chinle water-yielding formation,
6. the Middle Chinle water-yielding formation, and
7. the Lower Chinle water-yielding formation.

Note: The mobile domain of the alluvial aquifer is defined as the coarse-grained sediments (gravels and sands) and the immobile domain is defined as the fine-grained sediments (silts and clays).

Figure 1 is a summation of the groundwater remediation history of the site and presents the cumulative mass loading of seepage from the Large Tailings Pile (LTP), cumulative mass removed from the alluvial aquifer, yearly average groundwater collection rate, mass present in the onsite alluvial aquifer mobile domain, and mass present in the onsite alluvial aquifer immobile domain. The off-site alluvial aquifer and Chinle water-yielding formations contribution of collection and mass removal were not accounted for in this assessment as the mass in those areas is estimated to be less than 10% of the mass present in the on-site alluvial system (HE, 2005, 2010, 2012, 2013, 2015, 2020a). The mass present in each area is presented on Figure 2. In addition, the Small Tailings Pile is not included in this evaluation as its relative smaller size (1 million tons vs. the LTP's 21 million tons) and the lack of saturation makes its mass loading of minor significance. Table 1 presents the yearly values used for plotting Figure 1. Table 2 presents the historic uranium mass balance for LTP. Table 3 summarizes the uranium mass balance for the onsite alluvial aquifer. The following paragraphs describe the basis for each of the values presented.

LTP Seepage Mass Loading to Alluvium: The seepage mass loading from the LTP to underlying saturated and unsaturated alluvial material from 1958 through 2000 is based upon a water balance presented in Table 5.3-1 in the 1981 Discharge Permit Report for the site and an average of tailings solution water quality samples presented in the same report (Table 5.4-1) (HE,1981). The mass loading from 2000 through 2012 is based upon the reformulated mixing model developed by Hydro-Engineering and was used to assess the water and mass balance of the tailings pile during the flushing program (HMC, 2020). From 2012 through the present, the mass loading is estimated by the draindown model (HE, 2020b), which utilizes the Brooks Corey method to estimate the seepage and toe drain rates.

Mass Removal from Alluvium: The mass removed is based upon the historical reporting in the 2020 Annual Performance Report in Table 2.1-1 (HE, 2021).

Yearly On-Site Average Pumping Rate: The yearly average pumping rate is also based upon the historical reporting in the 2020 Annual Performance Report in Table 2.1-1 (HE, 2021).

Mobile Domain Dissolved Mass Remaining ≥0.16 mg/L: The dissolved mass remaining is calculated for select years based on analytical data, interpolated concentration contours generated using the mapping software Surfer, and a porosity of 0.18 for the mobile portion of the alluvial aquifer (Hoffman 1976, HE, 1983, 1986, 1991, 1997, 2000, 2005, 2010, 2015, 2020a). The 0.16 mg/L contour was used as the lower concentration limit for calculating mass, such that mass in the saturated alluvium with concentrations below 0.16 mg/L, the current site standard, (HE, 2001) is not accounted for in the total.

Immobile Domain Dissolved Mass Remaining ≥0.16 mg/L: The mass remaining within the immobile domain was calculated by subtracting the mass removal and amount remaining in the mobile domain from the total mass loading from the LTP (eq. 1).

$$(LTP\ seepage\ mass\ loading\ to\ alluvium) - (mass\ removal\ from\ alluvium) - (mobile\ domain\ dissolved\ mass\ remaing) = (immobile\ domain\ dissolved\ mass\ remaining) \tag{1}$$

Estimated Maximum Soluble and Adsorbed Mass in LTP: The basis for the maximum soluble and adsorbed mass present in the LTP uses the following assumptions:

- 21 million tons of ore processed (WME, 2020b),
- 0.3% as U_3O_8, the upper bound the ore grade presented in Skiff and Turner, 1981,

- 95% mill recovery (Geochem, 1992), and
- 28.8% of the uranium present being in the soluble or adsorbed phase as reported from a sequential extraction done on a slimes tailings sample (the highest percentage of soluble and adsorbed phase uranium) from borehole WME-6 (WME, 2020a).

Flushing Program Collection: The mass removed by the flushing program from vertical wells completed in the saturated tailings is based upon the historical reporting in the 2020 Annual Performance Report in Table 2.1-1 (HE, 2021).

Toe Drain Collection: The mass removed by the toe drains around the base of the LTP is based upon the historical reporting in the 2020 Annual Performance Report in Table 2.1-1 (HE, 2021).

2019 Average LTP Porewater Concentration Mass: The dissolved mass remaining is calculated based upon the concentration contours and analytical data compiled for 2020 (HE, 2021) and applied across the saturated volume of the LTP using an effective porosity of 0.14 for the sands portion of the LTP and 0.08 for the slimes. Given the low permeability of the material and long-screened completion of the tailings' wells, the concentrations likely reflect primarily the most mobile portions of the LTP.

Remaining Soluble or Adsorbed Uranium Mass: The remaining mass presented is calculated by subtracting the flushing program collection, the toe drain collection, the 2020 average LTP porewater concentration, and the seepage from the estimated maximum soluble and adsorbed mass in the LTP (eq. 2 below).

$$\begin{aligned}(maximum\ soluble\ and\ adsorbed\ mass) - (seepage) - (flushing\ program\ collection) \\ - (toe\ drain\ collection) - (2020\ average\ LTP\ porewater\ mass) \\ = (remaining\ soluble\ or\ adsorbed\ uranium\ mass)\end{aligned} \tag{2}$$

Bulk Saturated Volume: The bulk saturated volume was calculated using the base of alluvium and the piezometric surface for the specified year using the mapping software SURFER from Golden Software (Hoffman 1976, HE, 1983, 1986, 1991, 1997, 2000, 2005, 2010, 2015, 2020a).

Bulk Uranium Mass: The bulk uranium mass was calculated using the previously calculated bulk saturated volume, point data, and iso-contours of uranium concentrations in the alluvial aquifer within the SURFER Software.

Mobile Water Volume: Calculated assuming that the mobile domain of the alluvial aquifer is 0.18, as referenced previously, of the total bulk saturated volume.

Immobile Water Volume: Calculated assuming that the mobile domain of the alluvial aquifer is 0.13 of the total bulk saturated volume (based upon alluvial materials being 25% clay with a porosity of 0.5)

Mobile Uranium Mass: see “Mobile Domain Dissolved Mass Remaining ≥0.16 mg/L” description from Table 1.

Average Mobile Uranium Concentration: Calculated using the total mass and total mobile water volume presented in Table 3.

Cumulative Mass Seepage: Summation of values presented in Table 1.

Cumulative Mass Removed: Summation of values presented in Table 1.

Immobile Uranium Mass: See “Immobile Domain Dissolved Mass Remaining ≥0.16 mg/L” description from Table 1.

Total Mass in Alluvium: Addition of mobile and immobile domain uranium masses.

Tailings Seepage Sensitivity

Given the base case assumption that seepage rate and concentration of the seepage was constant from 1958 through 2000, an assessment of the potential ranges of seepage and concentrations is necessary to understand its relative significance to the mass calculated to be present in the immobile domain. Three sensitivity runs were assessed. The results of these evaluations are presented in Table 4 and Figures 3 and 4.

1. The first was increasing the assumed concentration of seepage to the highest concentration observed (54 mg/L) from Table 5.4-1 in the 1981 Discharge Permit Report and applying it across the entire timeframe evaluated (shown in magenta on Figures 3 and 4).
2. The second was taking the lowest concentration value (21 mg/L) presented in Table 5.4-1 in the 1981 Discharge Permit Report and applying across the timeline until the average concentration observed in the tailings pile dropped below that value in 2008 (shown in light purple on Figures 3 and 4). From 2008 forward, the assumed concentration is half of what was used for the base case.
3. The third evaluation was done assuming the seepage was 50% higher than the assumed values for the entire timeframe (shown in green on Figures 3 and 4).

The estimated maximum soluble and adsorbed mass in the LTP (dark red) and base case assumptions (shown in purple) are shown on Figure 3 for comparison to the sensitivity runs. Both the high concentration and the increased seepage variations exceed the estimated maximum mass present in the LTP in the soluble and adsorbed phases and thus aren’t realistic expectations of historic seepage mass loading. The low concentration (2nd run) produced a cumulative mass loading through 2020 approximately 57% of the mass loading from the base case run.

Figure 4 and Table 5 present what the calculated immobile domain estimates for each of these sensitivity runs assuming all other variables remain constant in the same color as presented on Figure 3. The mobile domain mass (blue) and the base case immobile domain mass (purple) are presented for comparison. The low concertation run (light purple) produces an unrealistic result that would, in essence, assume the groundwater remediation at the site collected all mass from seepage by 1990. Both the high concentration and increased seepage runs show increasing mass in the immobile domain through 2009, with the increased seepage run showing a decrease after that time while the high concentration run continues to increase.

Sensitivity to Mass Removal

Given that the mass removed from 1978 and 1990 was a product of the collected water being utilized in the mill circuit, the removal rate of that mass collected is unknown.

1. A 4th sensitivity run was assessed with the assumption that only 50% of the mass collected prior to 1990 was removed in the mill circuit, and thus not removed from the mass balance.

The resulting remediation history plot is presented on Figure 5, and is analogous to Figure 1, with the except of the variation on the mass removed and the subsequent change to the immobile domain mass as a result of that variation. The variation in mass removed produces total mass present in the immobile domain over double that of the base case and, remains relatively steady near 400,000 lbs from 1995 through 2019. The total mass removed in the sensitivity run is estimated at 798,300 lbs, or 64.9% of the total mass from LTP seepage. The mass balance for the sensitivity run is presented in Table 6.

Discussion

The base case alluvial mass balance analysis (shown on Figure 1) indicates that 1,074,300 pounds have been collected of the 1,230,100 pounds estimated to have seeped out of the LTP, a removal percentage of 87.3%. The analysis also shows that despite of an average mass removal rate of approximately 15,700 pounds of uranium per year for the period of 1999 to 2019 (total of 330,400 lbs), the mass remaining in the mobile domain of the alluvial aquifer has not been reduced at the expected rate. The mass loading due to seepage doesn’t adequately explain this stagnation in behavior as the base case over that period estimates 214,700 lbs seeping from the LTP, or 115,700 less than has been removed via groundwater remediation. In comparison, the mass in the mobile domain has only been reduced by 73,700 lbs, or 63% of the difference.

A more recent timeframe of 2009 through 2019 produce an even starker difference in spite of the total mass calculated in the mobile domain remaining nearly unchanged, 66,700 lbs in 2019 and 62,100 lbs in 2009. Total mass removed via groundwater remediation during that period was 158,800 lbs while total seepage was estimated at 43,600 lbs, a difference of 115,200 lbs.

The difference between total mass seepage and the mass removed is not accounted for in the mobile domain throughout the entire period of monitoring. Given the expansive investigation and monitoring that has taken place on the site, the interpretation of the data is that this mass resides in the immobile domain of the alluvial sediments (silts and clays) and within the vadose zone between the tailings pile and the saturated alluvium.

The primary geochemical mechanism that would attenuate uranium transport does not adequately explain the stagnation of progress in reducing concentrations and/or mass over the course of groundwater remediation at the site. In addition, the primary source of mass loading from the LTP seepage does not sufficiently explain the stagnation of groundwater remediation either. The diffusion of mass into the immobile domain of the alluvial aquifer has created a secondary source of mass to the mobile domain of the alluvial aquifer via back-diffusion due to concentration contrast and is the likely source of stagnating concentrations observed in the alluvial aquifer.

The sensitivity runs included in this memo show that while the historic mass loading from seepage may vary depending upon the assumptions made, there's no way to effectively explain the groundwater remediation stagnation utilizing only seepage from the tailings pile and geochemical attenuation. In addition, the sensitivity runs also show there are no simplifying assumptions that would that would eliminate the imbalance between mass loading from seepage, mass present in the mobile domain, and mass removed via remediation.

Although geochemical characterization has indicated that uranium is largely mobile in the alluvial groundwater, weak adsorption to ferrihydrite also plays a role in the retention of uranium within the immobile domain as well (WME, 2020b). Desorption of the adsorbed uranium within the immobile domain may therefore further contribute to the apparent stagnation of the uranium plume as it continues to diffuse slowly into the mobile phase.

Conclusions

- The stagnation in groundwater remediation cannot be adequately explained by the primary source of the LTP seepage and attenuation due to adsorption.
- Across the entire period of record there is an imbalance between mass loading from the primary source, the mass in the mobile domain of the aquifer, and the mass removed via remediation.
- Diffusion of mass into the fine-grained material of the alluvial aquifer is the most plausible explanation of where the missing mass resides.
- The back-diffusion of the mass present in the fine grained material back into the coarse grained material is likely the primary cause of groundwater remediation stagnation.

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Table 1. Uranium Remediation History Yearly Values

Year	LTP Seepage Mass Loading to Alluvium	Mass Removal from Alluvium[1]	Yearly On-Site Average Pumping Rate	Mobile Domain Dissolved Mass Remaining ≥0.16 mg/L	Immobile Domain Dissolved Mass Remaining ≥0.16 mg/L
	(lbs)	(lbs)	(gpm)	(lbs)	(lbs)
1958	24,800				
1959	24,800				
1960	24,800				
1961	24,800				
1962	24,800				
1963	24,800				
1964	24,800				
1965	24,800				
1966	24,800				
1967	24,800				
1968	24,800				
1969	24,800				
1970	24,800				
1971	24,800				
1972	24,800				
1973	24,800				
1974	24,800				
1975	24,800				
1976	24,800			221,900	248,600
1977	24,800				
1978	24,800	8,100	53		
1979	24,800	13,500	88		
1980	24,800	11,500	75		
1981	24,800	26,800	174		
1982	24,800	46,700	304	250,900	261,700
1983	24,800	48,800	318		
1984	24,800	59,400	387		
1985	24,800	56,700	369	213,500	208,500
1986	24,800	58,200	379		
1987	24,800	52,800	344		
1988	24,800	48,600	317		
1989	24,800	51,300	334		
1990	24,800	48,000	313	198,500	88,300
1991	24,800	50,100	326		
1992	24,800	29,100	244		
1993	24,800	27,100	220		
1994	24,800	21,100	187		
1995	24,800	14,600	206		
1996	24,800	21,200	232	139,500	132,700
1997	24,800	20,900	180		
1998	24,800	18,400	142		
1999	24,800	16,300	224	140,400	150,500
2000	12,500	23,000	279		
2001	9,000	23,700	276		
2002	11,800	25,000	383		
2003	21,200	20,500	338		
2004	26,000	14,600	294	109,200	155,200
2005	23,100	12,900	249		
2006	16,500	10,600	252		
2007	14,100	11,800	262		
2008	12,100	13,200	261		
2009	12,600	17,000	250	62,100	215,200
2010	10,500	13,500	239		
2011	8,100	15,900	252		
2012	1,900	16,000	273		
2013	2,400	12,800	234		
2014	3,800	11,800	236	91,700	142,200
2015	1,800	9,900	208		
2016	1,100	21,400	595		
2017	800	22,900	497		
2018	300	7,200	436		
2019	300	10,400	324	66,700	99,700
2020	200	10,900	298		

Footnotes:

1. Mass Removal from groundwater started in 1978

Table 2. Large Tailings Pile Historic Uranium Mass Balance (1958-2019)

Category	Cumulative Mass (lbs)
Estimated Maximum Soluble and Adsorbed Mass in LTP	1,524,100
Seepage (1958-2019)	-1,230,100
Toe Drain Collection (1992-2019)	-125,700
Flushing Program Collection (2000-2015)	-76,500
2019 Average Porewater Concentration Mass	-3900
Remaining Soluble or Adsorbed Uranium Mass	**=87,900**

Table 3. On-Site Alluvial Aquifer Uranium Mass Balance

Year	Bulk Satured Volume	Bulk Uranium Mass	Mobile Water Volume	Immobile Water Volume	Mobile Uranium Mass	Average Mobile Uranium Concentration	Cumulative Seepage Mass Loading	Cumulative Mass Removed	Immobile Uranium Mass	Total Mass in Alluvium
	(Ft^2)	($mg/L*Ft^2$)	(gal)	(gal)	(lbs)	(mg/L)	(lbs)	(lbs)	(lbs)	(lbs)
1976	583,511,000	19,751,842,000	785,639,000	556,494,000	221,900	33.9	470,500	0	248,600	470,500
1982	649,381,000	22,325,709,000	874,326,000	619,314,000	250,900	34.4	619,100	106,600	261,700	512,500
1985	543,606,000	19,004,465,000	731,911,000	518,437,000	213,500	35.0	693,400	271,400	208,500	422,000
1990	583,776,000	17,665,062,000	785,996,000	556,747,000	198,500	30.2	817,200	530,400	88,300	286,800
1996	649,815,000	12,411,469,000	874,911,000	619,729,000	139,500	19.1	965,800	693,700	132,700	272,100
1999	680,798,000	12,492,649,000	916,627,000	649,277,000	140,400	18.4	1,040,100	749,300	150,500	290,800
2004	753,127,000	9,722,866,000	1,014,010,000	718,257,000	109,200	12.9	1,120,600	856,100	155,200	264,500
2009	753,738,000	5,524,899,000	1,014,833,000	718,840,000	62,100	7.3	1,198,900	921,600	215,200	277,300
2014	870,077,000	8,161,321,000	1,171,471,000	829,792,000	91,700	9.4	1,225,600	991,700	142,200	233,900
2019	776,082,000	5,937,029,000	1,044,917,000	740,150,000	66,700	7.7	1,229,900	1,063,500	99,700	166,400

Table 4. Tailing Seepage Sensitivity Yearly Values

Year	Base Case Seepage Mass Loading (lbs)	High Concentration Seepage Mass Loading (lbs)	Low Concentration Seepage Mass Loading (lbs)	50% Increase in Seepage Mass Loading (lbs)
1958	24,800	36,500	14,100	37,200
1959	24,800	36,500	14,100	37,200
1960	24,800	36,500	14,100	37,200
1961	24,800	36,500	14,100	37,200
1962	24,800	36,500	14,100	37,200
1963	24,800	36,500	14,100	37,200
1964	24,800	36,500	14,100	37,200
1965	24,800	36,500	14,100	37,200
1966	24,800	36,500	14,100	37,200
1967	24,800	36,500	14,100	37,200
1968	24,800	36,500	14,100	37,200
1969	24,800	36,500	14,100	37,200
1970	24,800	36,500	14,100	37,200
1971	24,800	36,500	14,100	37,200
1972	24,800	36,500	14,100	37,200
1973	24,800	36,500	14,100	37,200
1974	24,800	36,500	14,100	37,200
1975	24,800	36,500	14,100	37,200
1976	24,800	36,500	14,100	37,200
1977	24,800	36,500	14,100	37,200
1978	24,800	36,500	14,100	37,200
1979	24,800	36,500	14,100	37,200
1980	24,800	36,500	14,100	37,200
1981	24,800	36,500	14,100	37,200
1982	24,800	36,500	14,100	37,200
1983	24,800	36,500	14,100	37,200
1984	24,800	36,500	14,100	37,200
1985	24,800	36,500	14,100	37,200
1986	24,800	36,500	14,100	37,200
1987	24,800	36,500	14,100	37,200
1988	24,800	36,500	14,100	37,200
1989	24,800	36,500	14,100	37,200
1990	24,800	36,500	14,100	37,200
1991	24,800	36,500	14,100	37,200
1992	24,800	36,500	14,100	37,200
1993	24,800	36,500	14,100	37,200
1994	24,800	36,500	14,100	37,200
1995	24,800	36,500	14,100	37,200
1996	24,800	36,500	14,100	37,200
1997	24,800	36,500	14,100	37,200
1998	24,800	36,500	14,100	37,200
1999	24,800	36,500	14,100	37,200
2000	12,400	13,100	5,000	18,700
2001	9,000	9,600	3,700	13,500
2002	11,800	14,900	5,700	17,600
2003	21,200	36,000	13,900	31,700
2004	26,000	47,900	18,500	39,000
2005	23,100	44,500	17,200	34,600
2006	16,500	33,800	13,000	24,700
2007	14,100	33,800	13,000	21,200
2008	12,000	32,900	6,000	18,100
2009	12,600	43,800	6,300	18,900
2010	10,500	42,500	5,200	15,700
2011	8,100	35,600	4,000	12,100
2012	6,500	33,100	3,300	9,800
2013	6,300	36,700	3,100	9,400
2014	7,000	47,700	3,500	10,500
2015	3,600	31,400	1,800	5,400
2016	1,800	18,500	900	2,700
2017	1,100	11,400	600	1,700
2018	700	7,400	400	1,100
2019	500	5,100	200	700
2020	400	3,600	200	500

Table 5. Tailings Seepage Sensitivity Mass Balance

Year	Mobile Uranium Mass	Cumulative Mass Removed	Base Case Seepage Cumulative Mass Loading	Base Case Immobile Uranium Mass	High Concentration Seepage Cumulative Mass Loading	High Concentration Immobile Mass	Low Concentration Seepage Cumulative Mass Loading	Low Concentration Immobile Mass	50% Increased Seepage Cumulative Mass Loading	50% Increased Seepage Immobile Mass
	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)
1976	221,900	0	470,500	248,600	692,700	470,700	267,400	45,500	704,800	482,800
1982	250,900	106,600	619,100	261,700	911,400	554,000	351,800	-5,600	927,300	569,900
1985	213,500	271,400	693,400	208,500	1,020,800	535,800	394,000	-90,900	1,038,600	553,700
1990	198,500	530,400	817,200	88,300	1,203,100	474,200	464,400	-264,500	1,224,100	495,200
1996	139,500	693,700	965,800	132,700	1,421,800	588,700	548,900	-284,300	1,446,600	613,500
1999	140,400	749,300	1,040,100	150,500	1,531,200	641,500	591,100	-298,500	1,557,900	668,300
2004	109,200	856,100	1,120,600	155,200	1,652,700	687,300	638,000	-327,400	1,678,400	713,100
2009	62,100	921,600	1,198,900	215,200	1,841,400	857,700	693,500	-290,200	1,795,800	812,100
2014	91,700	991,700	1,225,600	142,200	2,037,000	953,500	712,700	-370,700	1,853,400	769,900
2019	66,700	1,063,500	1,229,900	99,700	2,110,800	980,700	716,600	-413,600	1,865,000	734,800

Table 6. 1978-1990 50% Removal Sensitivity Mass Balance

Year	Bulk Satured Volume	Bulk Uranium Mass	Mobile Water Volume	Immobile Water Volume	Mobile Uranium Mass	Average Mobile Uranium Concentration	Cumulative Seepage Mass Loading	Cumulative Mass Removed	Immobile Mass	Total Mass in Alluvium
	(Ft^2)	($mg/L*Ft^2$)	(gal)	(gal)	(lbs)	(mg/L)	(lbs)	(lbs)	(lbs)	(lbs)
1976	583,511,000	19,751,842,000	785,639,000	556,494,000	221,900	33.9	470,500	0	248,600	470,500
1982	649,381,000	22,325,709,000	874,326,000	619,314,000	250,900	34.4	619,100	53,300	315,000	565,800
1985	543,606,000	19,004,465,000	731,911,000	518,437,000	213,500	35.0	693,400	135,700	344,200	557,700
1990	583,776,000	17,665,062,000	785,996,000	556,747,000	198,500	30.2	817,200	265,200	353,500	552,000
1996	649,815,000	12,411,469,000	874,911,000	619,729,000	139,500	19.1	965,800	428,500	397,900	537,300
1999	680,798,000	12,492,649,000	916,627,000	649,277,000	140,400	18.4	1,040,100	484,100	415,700	556,000
2004	753,127,000	9,722,866,000	1,014,010,000	718,257,000	109,200	12.9	1,120,600	590,900	420,400	529,700
2009	753,738,000	5,524,899,000	1,014,833,000	718,840,000	62,100	7.3	1,198,900	656,400	480,400	542,500
2014	870,077,000	8,161,321,000	1,171,471,000	829,792,000	91,700	9.4	1,233,700	726,500	415,500	507,200
2019	776,082,000	5,937,029,000	1,044,917,000	740,150,000	66,700	7.7	1,242,300	798,300	377,400	444,100

Figure 1. Uranium Remediation History

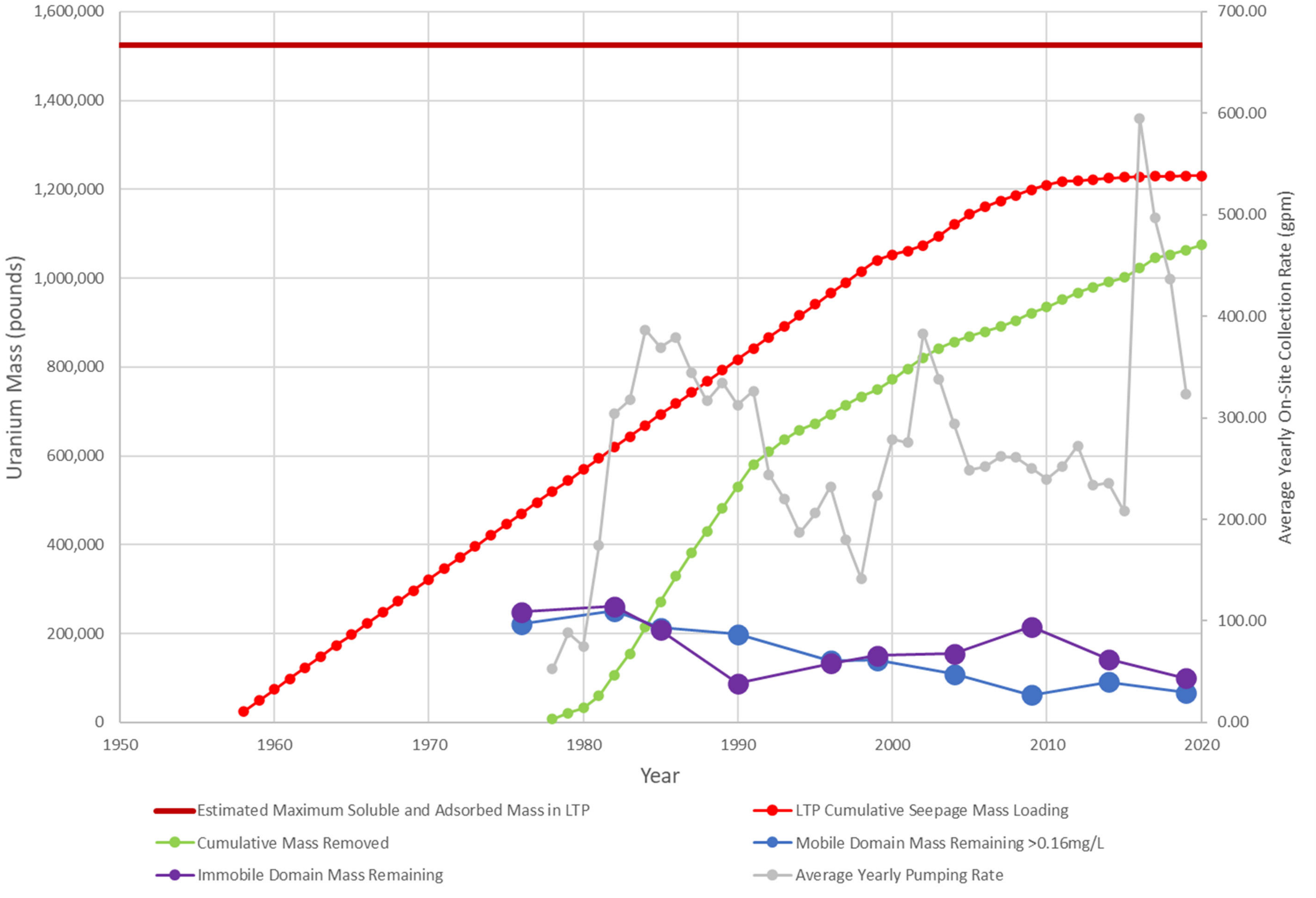
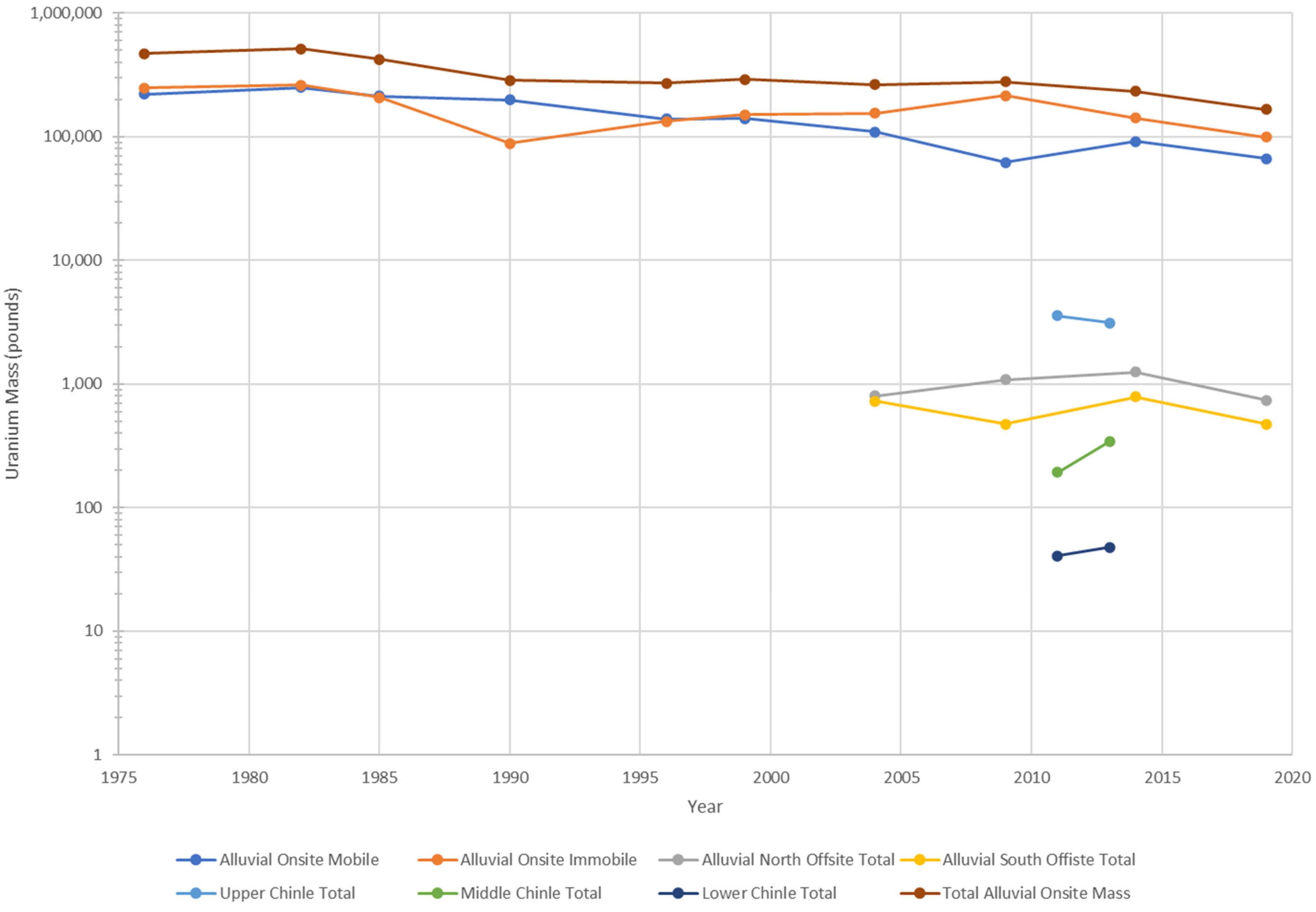


Figure 2. Mass Distribution Across Aquifers



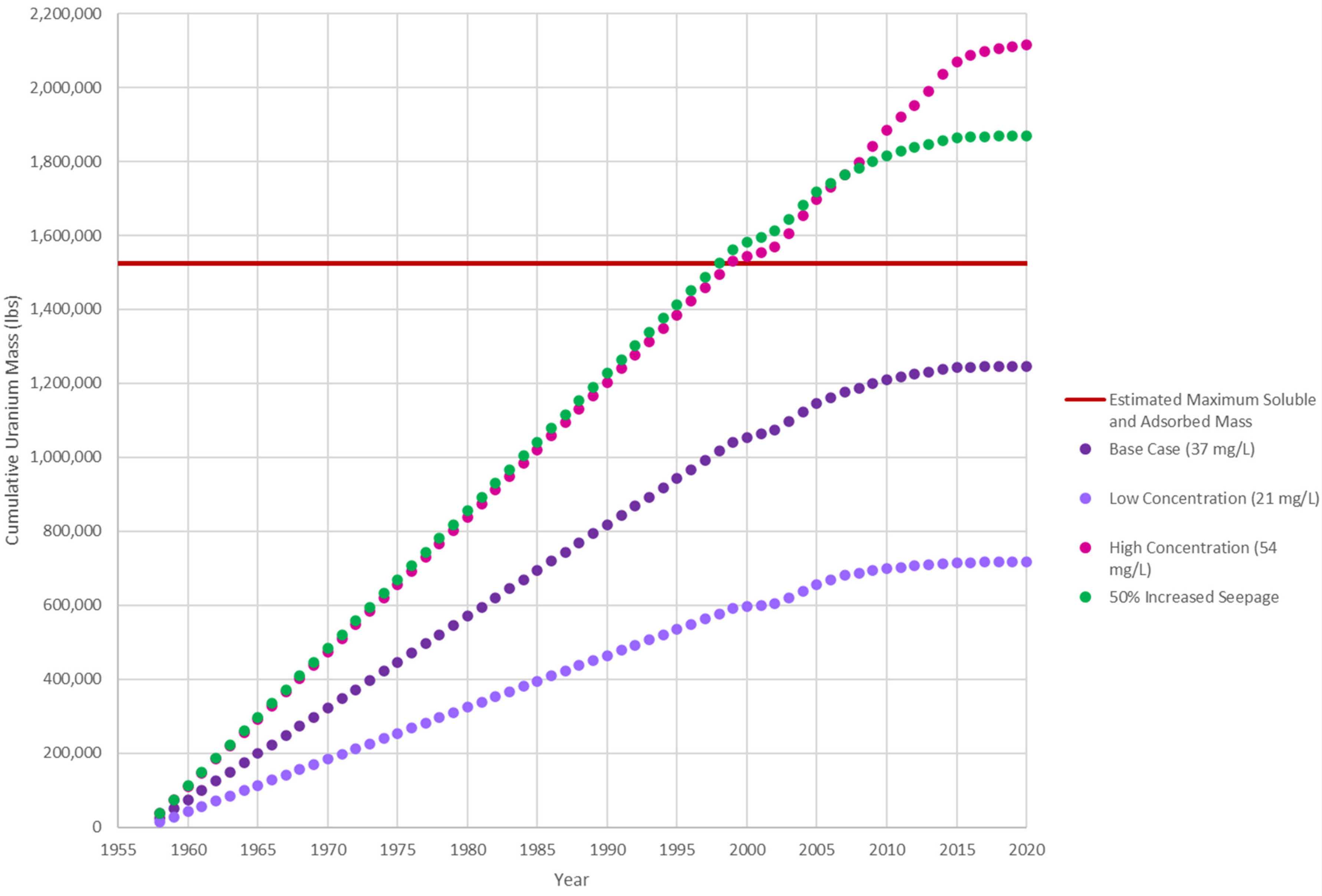


Figure 3. Cumulative Seepage Mass Loading Sensitivity

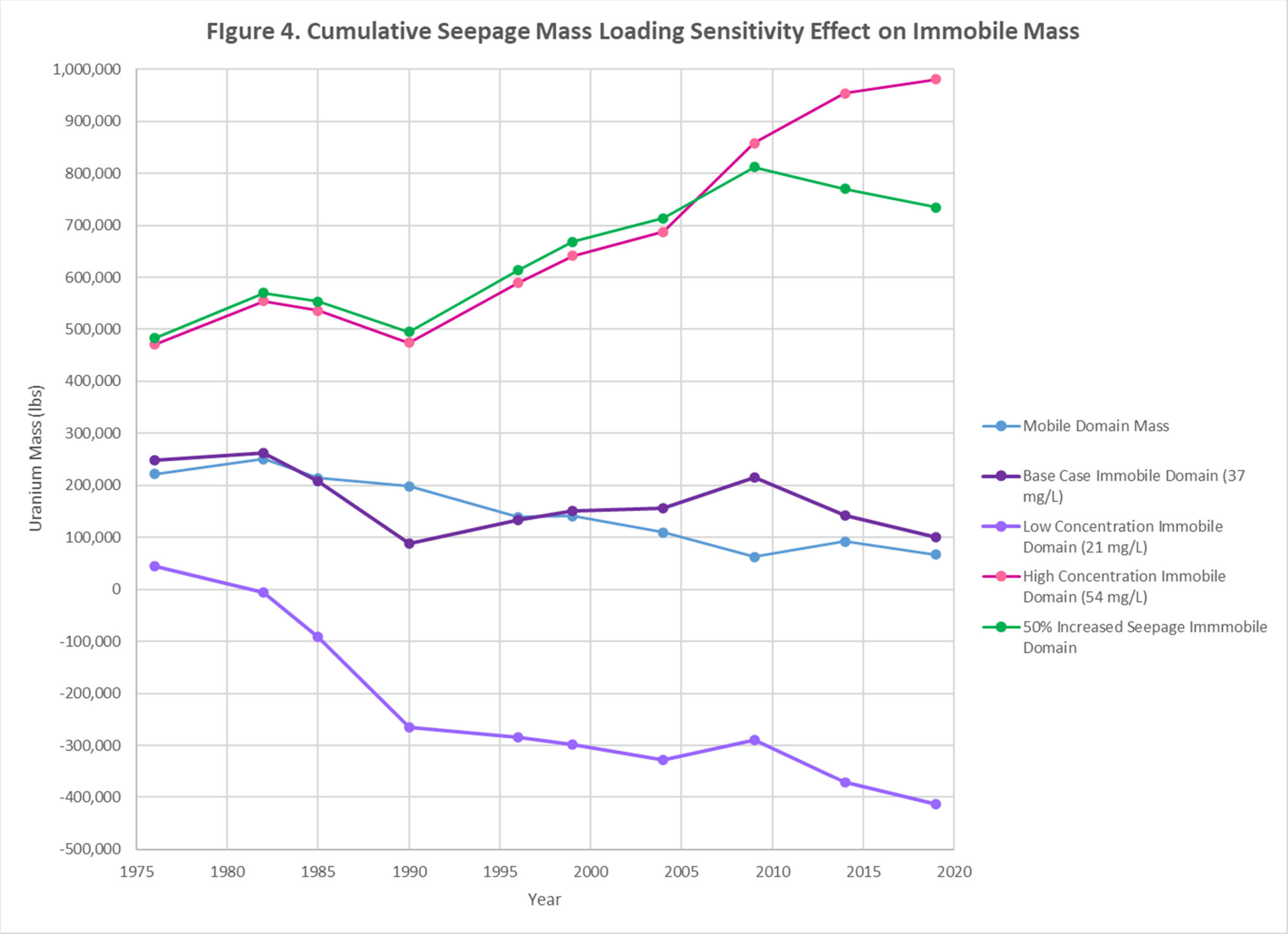


FIgure 4. Cumulative Seepage Mass Loading Sensitivity Effect on Immobile Mass

Figure 5. 1978-1990 50% Removal Uranium Remediation History