Memorandum – Drain Down Model Modifications and Predictions

Drain Down and Mixing Model Concept and Introduction

The Reformulated Mixing Model (RMM) was developed as a mechanism to estimate or forecast water and constituent of concern (COC) mass balance and exchange within the Large Tailings Pile (LTP) at the Grants Reclamation Project (GRP) site, and to estimate or forecast the rates and water quality for seepage from the LTP. The RMM name was assigned to distinguish the model structure from earlier versions as described in the attached memorandum, but the name Mixing Model (MM) is also used generically to describe the modeling approach. As described in the remainder of this memorandum, the MM has been replaced with a Drain Down Model (DDM) which incorporates the Brooks and Corey (1964) method to estimate seepage and toe drain rates. In conjunction with the updated method for estimating seepage and toe drain rates, the DDM also includes refined estimates of the long-term infiltration rate and an updated mass balance for predicting COC concentrations in the LTP.

Transition to Drain Down Model and Update

With the flushing program ending in 2015 and only limited future dewatering effort anticipated, the MM has been effectively replaced by the DDM to estimate future seepage and toe drain discharge rates from the LTP. Because the flushing injection has been discontinued, the features of the MM that were incorporated to empirically estimate the change in COC concentrations with flushing or mixing are not needed after mid-2015. However, some formatting and presentation features of the MM remain useful because they provide a convenient avenue for presentation of DDM results including prediction of future COC concentrations. The output of the DDM described in this memorandum is based on the Brooks and Corey (1964) method to estimate seepage and toe drain rates as the LTP drains at a diminishing rate. This DDM output also provides an estimate of COC concentrations in the seepage and remaining in the LTP, but changes after flushing are limited to a minor dilution by a relatively small rate of infiltration. There are approximately three years of available LTP drain down or water balance data after the end of the flushing program that is useful in estimating seepage rates from the tailings. The DDM spreadsheet effectively begins in 2015 to incorporate the drain down data occurring after flushing injection.

Seepage Rate Estimation

The primary modification of calculation methods in the DDM for this analysis was a change in estimation of seepage rates and toe drain discharge rates using the Brooks and Corey approach and the available data for years 2015 through 2018. Since the flushing program was discontinued in 2015, the water-level elevation in the LTP has dropped and the rate of seepage can be estimated using the change in LTP water storage and the measured toe drain discharge rates. With the exception of a small rate of infiltration into the LTP and a small rate of dewatering in 2016 and 2017, the seepage and toe drain discharge represent the only exchanges of water and COC mass between the LTP and the surrounding environment over the last three years. The available estimates of seepage using the water volume changes in the LTP were developed for six months intervals since 2015 by smoothing and interpolating the volume calculations performed on an annual basis with the results shown in the following graph. The smoothing was required because year to year volume changes were based on annual potentiometric surfaces for the LTP that had varying numbers of measured water-level elevations and varying resolution/accuracy. The data points were also offset six months in time so they represented seepage during the year and additional data points were interpolated at six month intervals.

The information on the Brooks and Corey approach was provided by Johnny Zhan and it uses a relationship for estimating hydraulic conductivity (K) for partially saturated conditions as shown below.

$$K(\theta) = K_s \left(\frac{\theta - \theta_r}{\theta_{sat} - \theta_r}\right)^{\gamma}$$

Where: θ is the volumetric moisture content
K_s is the saturated hydraulic conductivity
θ_r is the residual moisture content
θ_{sat} is the porosity or saturated moisture content
γ is an empirical parameter related to grain size distribution

Reference: Brooks, R.H. and Corey, A.T. (1964) Hydraulic Properties of Porous Media. Hydrology Papers 3, Colorado State University, Fort Collins, 27 p.

The Brooks and Corey approach can also be converted to a volumetric formulation to predict seepage rate (Q) based on the volume of water remaining in the LTP as shown below.

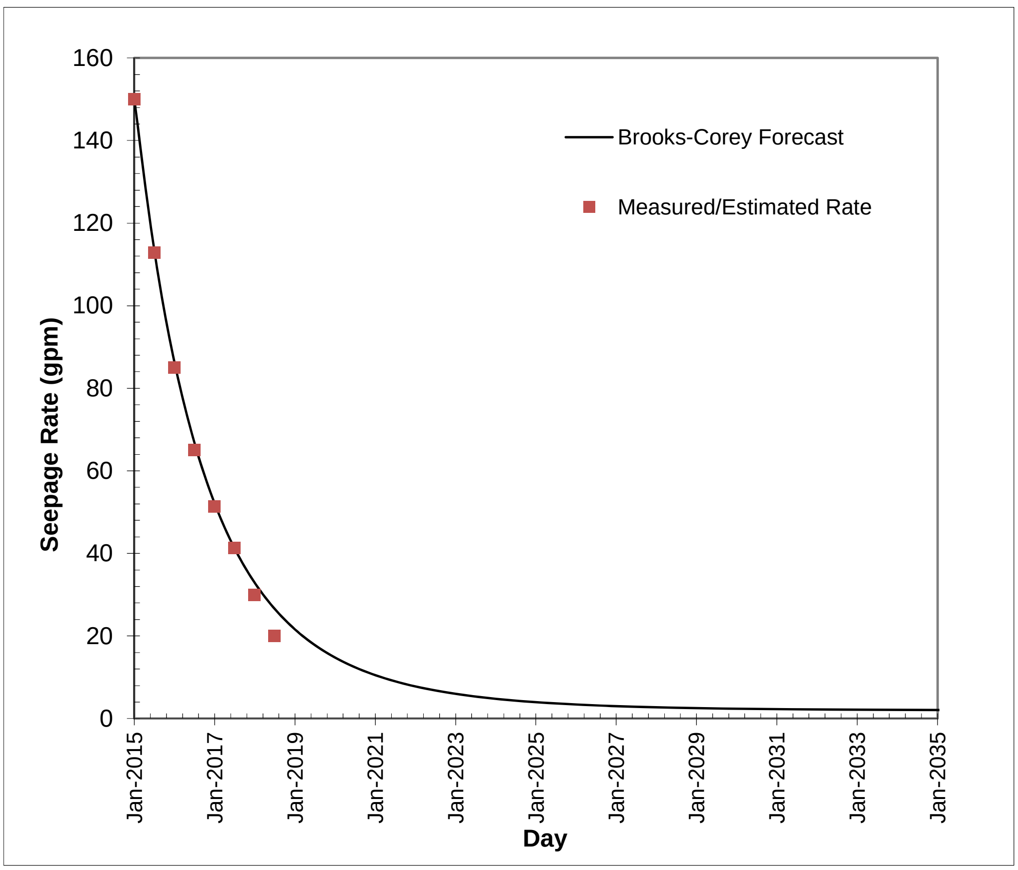
$$Q(V) = AK_s \left(\frac{V - V_r}{V_{sat} - V_r}\right)^{\gamma}$$

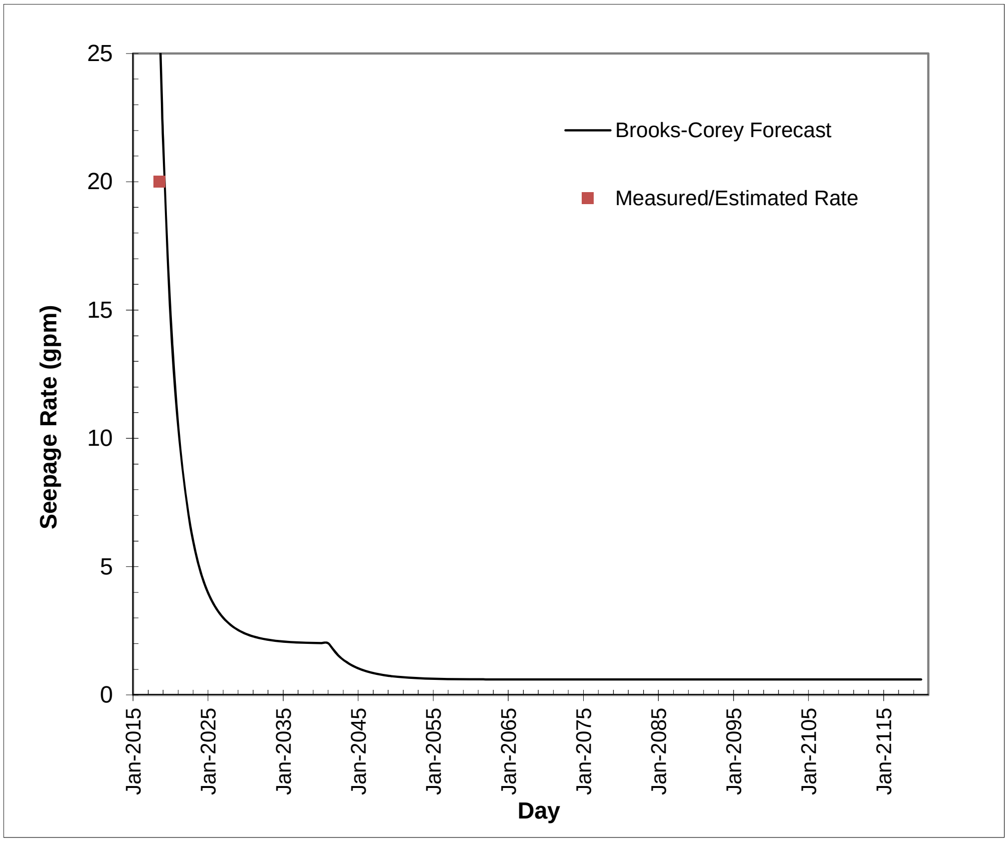
Where: V is the volume of water in the LTP
A is the area of the LTP
K_s is the saturated hydraulic conductivity
V_r is the residual water volume in the LTP
V_{sat} is the water volume in the LTP at saturation
γ is an empirical parameter related to grain size distribution

The implementation of the moisture content formulation of the Brooks and Corey in the DDM to estimate seepage is done by estimating the inputs of K_s, θ_r, θ_{sat}, γ and the moisture content θ in the LTP at the start of the simulation in 2015. The calculation of the seepage rate is performed on six month intervals with the calculated θ from the previous interval serving as the starting moisture content for the following time step. This formulation also allows incorporation of an infiltration rate as an input of water to the LTP. As seen in the volumetric formulation, the seepage rate can be calculated as the product of the partially saturated K and the area of the LTP. A preliminary estimate of K_s of 6E-06 cm/sec as a composite for the sand and slime tailings was made and the preliminary estimate of θ_{sat} was made by calculating the volume of sand and slime tailings in the LTP and then applying typical porosity estimates and retained water content estimates for the two different types of tailings. These estimates and the estimate of θ in 2015 were then refined by Johnny Zhan to achieve the best fit of the measured and smoothed seepage rates as shown in the following graphs.

Because the LTP is very heterogeneous with distinct sand and slime areas and tailings in various states of drainage, the estimate of starting θ in 2015 of approximately 0.2312 is a composite for a wide range of tailings conditions. In the Brooks and Corey method, this θ is then incrementally reduced by the rate of seepage over six month periods beginning in 2015 to produce a table of θ and predicted seepage rate through the end of the simulation. The seepage rate is calculated using the partially saturated K and the area of the tailings. The area of the LTP under which there is a measurable thickness of tailings or windblown tailings material is approximately 223 acres (902,459 square meters). After refinement of the Brooks and Corey variables to fit observed data by Johnny Zhan, the "composite" K_s was estimated at 5.5467E-06 cm/sec. The θ_r was estimated at 0.1907 and the θ_{sat} was estimated at 0.3579. The formulation is relatively sensitive to the exponent γ and the value was estimated at 1.174.

As shown in the following graphs, there was a relatively good fit of the Brooks and Corey prediction to the seepage rate estimated from the observed change in storage in the LTP. The Brooks and Corey prediction in the graph was extended through 2120, but it should be noted that the prediction includes two (2) gpm of infiltration through 2040 and 0.6 gpm of infiltration from 2041 through 2120 which slightly reduces the decay of the seepage rate.





In the preceding graphs, the rapid decay in seepage rate beginning at the start of 2015 reflects, in part, the operational conditions in 2014 and 2015. During 2014, the flushing injection rate was relatively high (308 gpm) with a modest dewatering rate (46 gpm) resulting in a rise in the potentiometric surface because of the excess injection. During 2015, flushing injection occurred for the first half of the year at a moderate rate and the decline in estimated seepage rate and the Brooks and Corey prediction reflects the declining water volume in the LTP after 2014. From 2016 through 2018, the continuing decay in seepage rate reflects the continuing reduction in estimated drainable water remaining in the tailings.

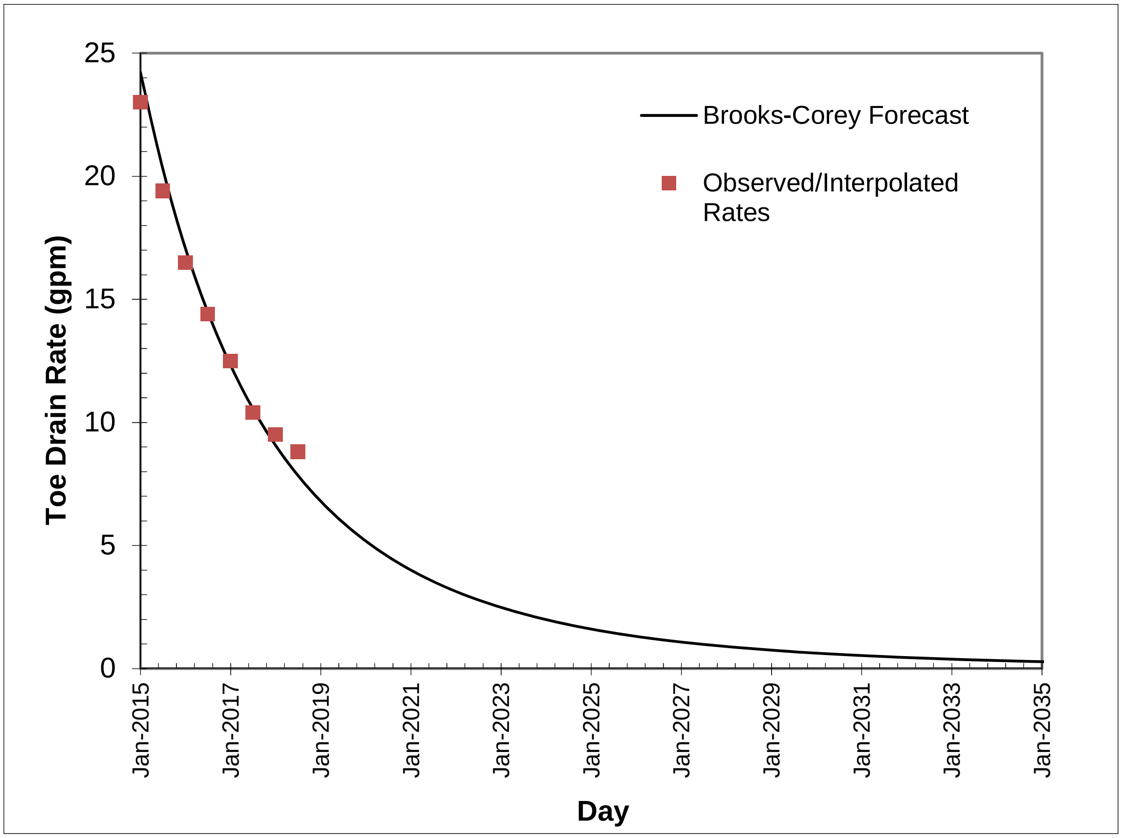
Toe Drain Rate Estimation

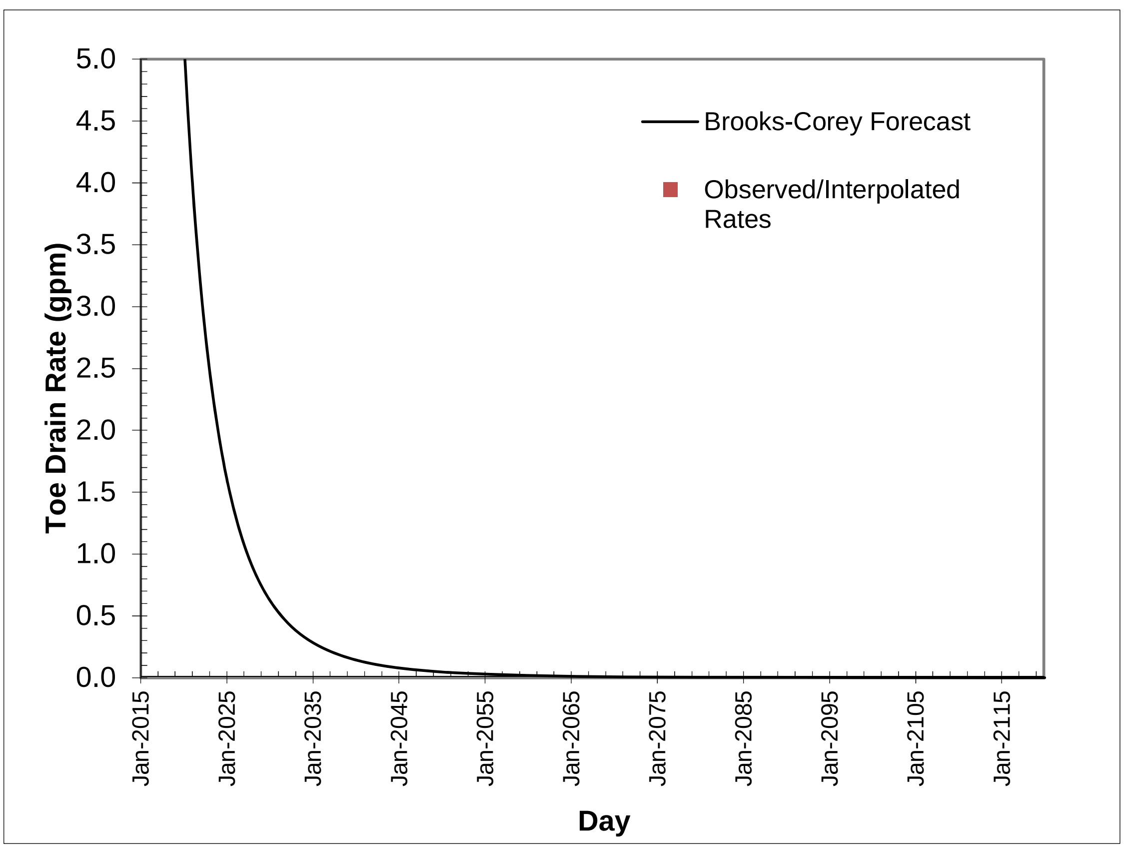
Like the predicted seepage rates, the DDM formulation estimates toe drain discharge rates as a function of moisture content in the tailings. The previous MM formulation used relationships between LTP water volume and toe drain rates developed from VADOSE/W modeling of the LTP by Johnny Zhan. This same VADOSE/W modeling indicated a highly correlated linear relationship between toe drain rates and seepage rates and this was supported by data prior to 2010. However, since approximately 2010, the toe drain rates declined significantly during a period when the LTP water volume and corresponding seepage rates remained relatively high. Because the toe drains are a perforated pipe, there is the potential for physical plugging or geochemical precipitation that restricts entry to the pipe, and this is a possible cause of the reduction. While the relationship between estimated seepage rate and observed toe drain rates may have changed since 2010, the toe drain discharge rates since 2015 have declined along with the declining water volume in the LTP. This consistent relationship between declining LTP water volume and declining toe drain rates allows the application of the Brooks and Corey method to the toe drains as discussed below. Also, the toe drain discharge is effectively additional seepage that is currently intercepted and pumped to the evaporation ponds. The maintenance of toe drain pumping systems will be increasingly difficult with declining rates, and for planning purposes it is assumed the toe drain sumps will no longer be pumped when discharge rates decline to two (2) to three (3) gpm. When the toe drain discharge reaches this rate, the discharge rate will be added to the seepage rate.

As mentioned above, the same methodology used for developing the Brooks and Corey prediction for the seepage rate is applicable for the toe drain discharge. While the physical processes for drainage from the LTP to the toe drains are analogous to those for seepage, the physical configuration for the toe drain does require some adaptation of the Brooks and Corey method. As an example, the area (A) variable in the Brooks and Corey volumetric formulation is not directly applicable for the toe drains because the LTP area is already represented in the seepage calculation. In order to apply the Brooks and Corey method to the toe drain discharge, the area term (A) was used as a variable to scale the predicted rates. A tabulation of observed toe drain rates with time allowed comparison with a Brooks and Corey prediction as shown in the following graphs. The measured toe drain discharge rates for each year were plotted as occurring in the middle of the year and intermediate points were interpolated for the beginning of each year as well as an extrapolated point for the beginning of 2015. The Brooks and Corey variables were then refined to give the best fit of these observed/interpolated toe drain rates.

The prediction of toe drain discharge using the Brooks and Corey method is independent of that for seepage, but the decline in rates occurs simultaneously as the LTP drains. After refinement of the Brooks and Corey variables to fit observed toe drain data by Johnny Zhan, K_s was estimated at 6.4057E-06 cm/sec and θ was estimated at 0.2724 at the start of 2015. The θ_r was estimated at 0.1344, θ_{sat} was estimated at 0.4740 and γ was estimated at 1.257. The effective area for the calculation of discharge from the partially saturated K was 18.28 acres (73,977 square meters).

The application of the Brooks and Corey method to the toe drain discharge as shown in the following graphs gives a reasonably good relationship between the predicted and observed rates. As noted previously, difficulty in continuing to pump the toe drain sumps at very low rates is likely to result in termination of the pumping from the sumps within a few years. Since the toe drain discharge will report to the alluvial aquifer as seepage once the pumping stops, the toe drain rate would then be directly added to the seepage estimate.


Brooks-Corey Forecast
Observed/Interpolated Rates
Toe Drain Rate (gpm)
25
20
15
10
5
0
Jan-2015
Jan-2017
Jan-2019
Jan-2021
Jan-2023
Jan-2025
Jan-2027
Jan-2029
Jan-2031
Jan-2033
Jan-2035
Day


Brooks-Corey Forecast
Observed/Interpolated Rates
Toe Drain Rate (gpm)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Jan-2015
Jan-2025
Jan-2035
Jan-2045
Jan-2055
Jan-2065
Jan-2075
Jan-2085
Jan-2095
Jan-2105
Jan-2115
Day

Estimation of Long-Term Infiltration

With the cessation of the flushing program and limited anticipated future dewatering, the future seepage rate from the LTP will continue to decline until it approaches the rate of infiltration into the tailings. The final tailings cover system includes a low permeability layer to limit infiltration through the cover to very small rates. The rate of infiltration through a low permeability cover is difficult to predict but past modeling has indicated an infiltration rate equivalent to a continuous rate of approximately 0.5 gpm over the area of the LTP. The following discussion describes the previous infiltration modeling and the features of the reclaimed LTP that will limit the future infiltration through the cover.

Previous Infiltration Modeling

The previous infiltration modeling was conducted with the Leaching Estimation and Chemistry Model (LEACHM), a one-dimensional model utilizing a numerical solution of Richards equation. The modeling separated the LTP into four areas based on slope, cover configuration, and measured cover soil properties, and the model results are summarized in Table 1.

Table 1. Summary of LEACHM Modeling

Layer and Model Property	LTP Top	East Side	North, West and South Sides	Apron
Rock Mulch Thickness (inch)	6	10	10	10
Rock Mulch Density (gm/cm^3)	1.46	1.46	1.46	1.46
Rock Mulch Hydraulic Cond. (cm/sec)	2.3E-06	2.3E-06	2.3E-06	2.3E-06
Filter Thickness (inch)	--	6	6	6
Filter Density (gm/cm^3)	--	1.46	1.46	1.46
Filter Hydraulic Cond. (cm/sec)	--	2.3E-06	2.3E-06	2.3E-06
Frost-Affected Barrier Thickness (inch)	18	18	18	18
Frost-Affected Barrier Density (gm/cm^3)	1.5	1.5	1.62	1.5
Frost-Affected Barrier Hyd. Cond. (cm/sec)	1.9E-06	1.9E-06	3.2E-07	1.9E-06
Thickness above barrier (inch)	24	34	34	24
Unaffected Barrier Thickness (inch)	26	6	28	6
Unaffected Barrier Density (gm/cm^3)	1.59	1.59	1.7	1.59
Unaffected Barrier Hyd. Cond. (cm/sec)	3.8E-07	3.8E-07	6.4E-08	3.8E-07
Precipitation Reduction	Minimal	Moderate	Moderate	Moderate
Modeled Area (acre)	100	40	66	18
Predicted Annual Infiltration (mm)	1.4	0.05	0.09	0.67
Predicted Infiltration Rate (gpm)	0.28	0.004	0.012	0.02

As indicated in Table 1 and the previous discussion, the prediction of composite long-term infiltration rate into the LTP is less than 0.5 gpm. The distinction in areas of the LTP is made because the cover configuration differs for the top and side slopes (also termed outslopes), and, more importantly, because the slope of the land surface will have a dramatic impact on the quantity of runoff and lateral flow through the rock cover on the LTP. When much of the precipitation is discharged off the pile as runoff or flows laterally through the rock and/or filter layers to beyond the footprint of the LTP, the quantity of infiltration is significantly reduced. The previous modeling used an LTP top area of 100 acres at milder slope where nearly 90% of the predicted infiltration occurred. It should also be noted that the previous modeling included the assumption of some degradation of the cover by pedogenic processes. Along with a reduction in soil density, a five-fold increase in permeability was assumed for the upper 18 inches of the compacted radon/infiltration barrier material as a result of freeze-thaw cycles or other pedogenic processes. Depending on the location, this gave a thickness of 24 to 34 inches of the total cover thickness above the radon/infiltration barrier that was assumed to be unaffected by freeze/thaw. The increased hydraulic conductivity included in the modeling was as great as 1.9E-06 cm/sec. This degradation of compacted clay and other covers has been observed and measured in studies (e.g. studies described in NUREG/CR-7028) with dramatic increases in permeability or hydraulic conductivity over time with pedogenic processes. There are numerous factors that affect the degree and depth of long-term barrier degradation making it difficult to predict. However, the infiltration depths or rates are also significantly affected by climatic and other factors so an increase in hydraulic conductivity does not necessarily translate to a significant increase in infiltration rate. Additionally, the design of the LTP reclamation surface reduces the potential for infiltration and other methods can be used to support the estimates of infiltration rate predicted by the previous modeling.

LTP Features and Expected Infiltration Estimation

The reclaimed LTP will have a top surface area of approximately 104 acres at relatively mild slope and a side slope area of 119 acres at moderate slopes. This compares favorably with a top surface area of 100 acres and an outslope/apron area of 124 acres used in the previous modeling. Nearly all of the future infiltration is expected to occur on the top of the reclaimed LTP because runoff and lateral flow through the rock and filter layers will occur quickly on the side slopes. However, an important component in the final reclamation of the LTP is the creation of positive drainage to prevent ponding of water on the top or side slope surfaces. The present top surface of the LTP has an interim cover layer and has generally been graded and shaped to create a typical outward slope of greater than 1% from the general east to west center line of the LTP. With the exception of minor residual depressions and those resulting from the infrastructure and access roads that are maintained on the top of the pile, there is generally a positive drainage system that reduces ponding. When the final LTP reclamation surface is completed, the surface will be graded to a typical land slope greater than 1% and the minor depressions will be eliminated. The final reclamation cover and rock erosion protection is completed on the side slopes of the LTP, so the expected infiltration on the side slopes is at very low levels.

The infiltration or recharge to the LTP can also be estimated by comparing with regional or local estimates of natural recharge. The GRP site is semi-arid with average annual precipitation of 10.48 inches as presented in the 2012 Corrective Action Plan. Numerous references present estimates of infiltration or recharge as a percentage of typical precipitation depths. When the climatic conditions, soil type, vegetation, topography and drainage conditions for these recharge estimates are considered, they can potentially be useful for estimating recharge at the GRP site. As an example, a United States Geological Survey (USGS) Open-File Report (OFR) 87-43 presents a "Summary of Infiltration Rates in Arid and Semiarid Regions of the World, with an Annotated Bibliography". While the data cited in USGS OFR 87-43 have a range of percentage of precipitation contributing to recharge from 0 to over 30%, the data for conditions which are more representative of those at the GRP site typically have small recharge rates. Many of the cited recharge rates for arid to semi-arid conditions are less than 1% of average precipitation depth with several values well below 0.5% of average annual precipitation depth. A study by Huntoon (1977) for an area in Arizona listed an infiltration depth of 2.5 mm or 0.9% of the annual precipitation of 280 mm (11.02 inches). As another example, Johnny Zhan supplied information indicating that eleven years of monitoring data for a heap leach pad in Nevada has indicated a percolation flux of 0.63% of the annual precipitation of approximately 13 inches.

Other methods are available for estimating infiltration or recharge as a percentage of annual precipitation. One such method is the Maxey-Eakin method which is described in Epstein et al. 2010. The method indicates that expected infiltration as a percentage of annual precipitation is; 0% for a precipitation depth of <8 inches, 3% for a precipitation depth of 8 to 12 inches, 7% for a precipitation depth of 12 to 15 inches, 15% for a precipitation depth of 15 to 20 inches, and 25% for a precipitation depth of >20 inches. Because this method is intended to estimate natural recharge for a wide range of soil and other conditions, a dramatic reduction is warranted for the LTP where the final reclamation cover and grading plan is designed to shed runoff from the pile. For the GRP site with an annual precipitation of approximately 10.5 inches, the Maxey-Eakin infiltration estimate of 3% of annual precipitation is likely a reasonable or somewhat conservative estimate of infiltration over the top of the LTP without the grading to create positive drainage and the construction of the final cover.

After the final cover is constructed, the expected infiltration rate as indicated by the previously cited modeling, data and studies is on the order of 0.5% to 1% of annual precipitation over the top of the pile. Because the final cover is not in place, the present infiltration rate over the top of the LTP may be greater than 1% of annual precipitation and an estimate of roughly 3% of annual precipitation as indicated above is likely a somewhat conservative estimate.

Effective Infiltration Rate Estimates

The DDM uses a composite infiltration rate that is converted to a long-term seepage discharge rate from the LTP. The previous modeling conducted in 1995 produced a somewhat conservative infiltration estimate of 0.5 gpm for the LTP with nearly 90% of the infiltration occurring on the top of the LTP. Because the contribution of the side slope area is expected to be a very small percentage of the total infiltration rate, the infiltration rates could be analyzed as occurring only on the top of the LTP. However, the use of the 223 acre LTP area in the Brooks and Corey method described previously makes it more straightforward to quantify the infiltration rate as being uniform over the effective LTP area. In the following forecasts of LTP seepage rates and drain down, total long-term infiltration rates equivalent to 0.6 gpm and 1.2 gpm are used. An infiltration rate of 0.6 gpm equates to a depth of infiltration over the 223 acre LTP of 0.052 inches or approximately 0.5% of average annual precipitation. Likewise, an infiltration rate of 1.2 gpm equates to a depth of infiltration over the 223 acre LTP of 0.104 inches or approximately 1.0% of average annual precipitation. If the infiltration is assumed to occur only on the top area of the LTP, the infiltration rates of 0.6 gpm and 1.2 gpm equate to approximately 1.07% and 2.1% of average annual precipitation, respectively.

The anticipated long-term infiltration rate is 0.6 gpm and a long-term infiltration rate of 1.2 gpm is considered in the drain down forecasting as a significantly more conservative infiltration estimate. During the interim period prior to construction of the final LTP top cover, the infiltration is estimated as 2.0 gpm which is approximately 1.7% of the annual precipitation over the LTP or 3.6% of the annual precipitation over the top of the LTP. This interim infiltration rate is applied through year 2040 in the DDM predictions, after which the infiltration rate is changed to the long-term infiltration rate. As a further measure of conservatism, a long-term infiltration rate of 2.4 gpm was considered in a modeling scenario for LTP drainage. In conjunction with the very conservative increase in estimated long-term infiltration rate, the interim infiltration rate was increased to 4.0 gpm to represent an expected worst-case DDM scenario.

Once the infiltration water enters the tailings, it will be in contact with the tailings solids and any residual water in the partially saturated tailings thickness. Hence the effective concentration of COCs in the water that is moving through the tailings is expected to increase through diffusive, exchange or displacement processes with the residual water in the tailings. The magnitude of this increase is difficult to predict, but several factors will likely affect the increase. Much of the tailings slimes have been flushed with large volumes of relatively fresh water and this should limit the COC mass available for exchange in much of the tailings. The more freely draining pore water in the LTP is continuing to report as seepage so future infiltration water will contact residual tailings water that is in smaller pore spaces where exchange and movement rates are slower. Additionally, as indicated by Worthington Miller Environmental, LLC (WME, 2018), no significant change in the geochemistry of the tailings is expected with the limited quantities of future infiltration, so significant mobilization of COCs presently in solid form is unlikely.

Estimated COC Concentrations in Infiltrate

While the increase in COC concentration in infiltrating water is not a new COC mass introduced to the LTP, the expected change in COC concentration by the time the water reports as seepage is incorporated in the DDM by assuming the water enters the LTP at a specified COC concentration. This introduction of infiltration at a specified COC concentration is not a major contribution to COC mass in the LTP, but it does have a noticeable impact on the estimate of long-term COC concentration in the seepage. Specifically, if the assumed COC concentration in the infiltration is less than the estimated average concentration in the LTP, the predicted COC concentration in the seepage will slightly decay over time. This is generally expected to be the case for the tailings as much of the tailings volume has already been flushed. The humidity cell testing conducted by Worthington Miller Environmental, LLC (WME, 2018) generally supports the limited increase in COC concentration for water passing through the tailings. The samples from the LTP subjected to humidity cell testing had a range of average effluent uranium concentrations from 0.11 to 1.26 mg/L and a range of average molybdenum concentrations from 0.087 to 0.28 mg/L. Although the humidity cell testing may not be a direct analogy to the expected mobilization of constituents as infiltrate passes through the tailings, it is likely a reasonable estimate of the range of COC concentrations in the infiltrate that will report as seepage. In the DDM, the range of uranium and molybdenum concentrations is incorporated in predictions for the expected infiltration rate of 0.6 gpm. For the remainder of the predictions, the upper concentration for the both the uranium and molybdenum is used.

DDM Seepage and Uranium Concentration Predictions

DDM predictions of uranium concentrations are presented in attached Figures 1 through 3 and in Figure 7 for the worst-case scenario. Each figure includes a tabulation of DDM predictions and three graphs that present combinations of model predictions of uranium concentration, measured uranium concentrations, and predicted seepage and toe drain rates. The average uranium concentration in the LTP is an input to the DDM model and the upper graph in each figure displays the measured average uranium concentration through 2018 along with the predicted concentration beginning in 2015. The observed concentrations shown in the upper plot in Figures 1 through 3 and in Figure 7 reflect a dramatic reduction in average concentration between 2010 and 2018 as a result of the flushing program. The unexpected temporary increase in observed average concentration in 2016 is likely a result of limitations of or anomalies in the available sample data used to estimate average concentration.

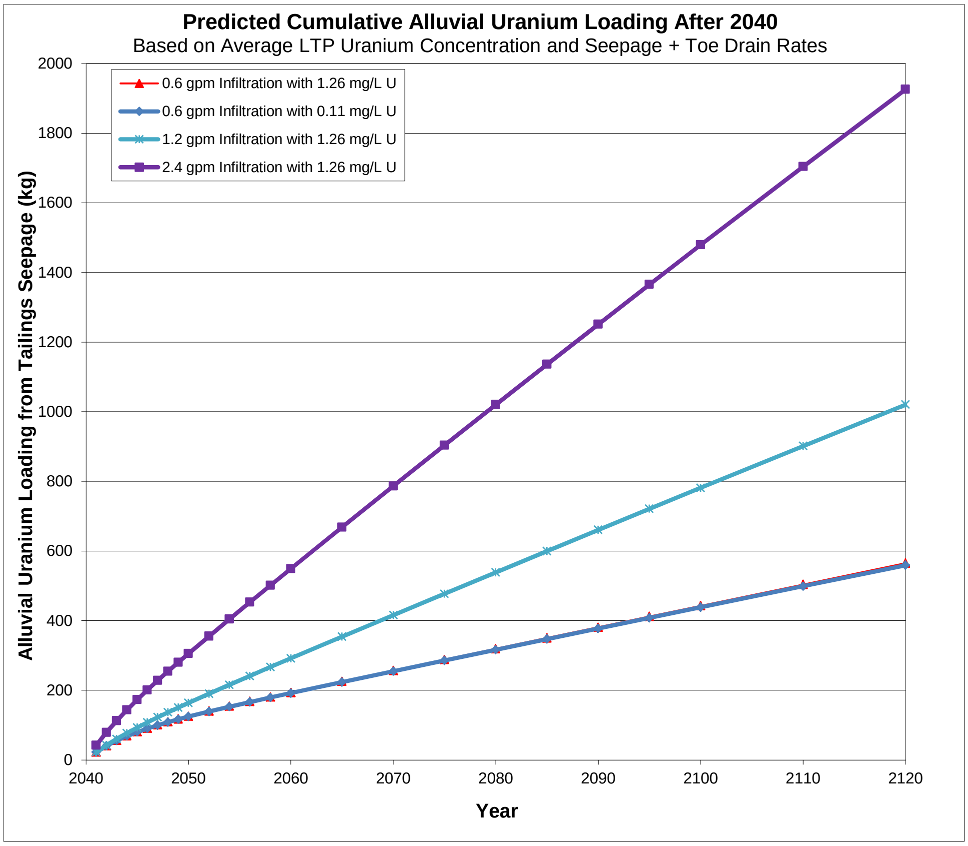
In all four figures, the graphs of seepage and toe drain rates indicate a dramatic decline in rates after 2015 followed by a gradual decay to approach the long-term infiltration rate for the particular simulation. Figure 1 presents the expected uranium concentrations and seepage rates for the condition where the long-term infiltration rate to the LTP is 0.6 gpm with the infiltrate having a uranium concentration of 1.26 mg/L after passing through the tailings. Figure 2 presents a similar simulation with the infiltrate uranium concentration reduced to 0.11 mg/L. In the graphs of seepage and toe drain rates for both figures, yellow shading is used to indicate toe drain rates where pumping of the toe drain discharge to the evaporation ponds may not be practical. When the pumping of the toe drain discharge is discontinued, the discharge simply reports to the alluvial aquifer as additional seepage. In comparing Figure 1 and Figure 2, there is a very slight reduction in predicted long-term uranium concentration in the LTP with the smaller uranium concentration in the infiltrate. For both simulations, the predicted long-term uranium concentration in the LTP is slightly greater than 5.0 mg/L and has a very gradual declining trend. For the simulation presented in Figure 3, the larger infiltrate uranium concentration is used for conservatism. Figure 3 presents a simulation where the long-term infiltration rate is doubled to 1.2 gpm over the baseline simulation rate of 0.6 gpm. The increased infiltration results in a slight decrease in predicted long-term LTP uranium concentration, but the uranium mass in seepage is increased because of the increased seepage rate after 2040. The doubling of the infiltration or seepage rates between the Figure 1 and Figure 3 simulations presented more than offsets the reduction in uranium concentration with a higher infiltration rate. Hence, the increasing infiltration rate increases the constituent loading to the alluvial aquifer. A similar dramatic increase in uranium mass in seepage occurs when both the interim and long-term infiltration rates are again doubled from those presented in Figure 3 to those presented in Figure 7. There is a relatively minor reduction in uranium concentration in seepage with the conservatively large infiltration rate estimate, but there is nearly a doubling of the estimated uranium mass in seepage.

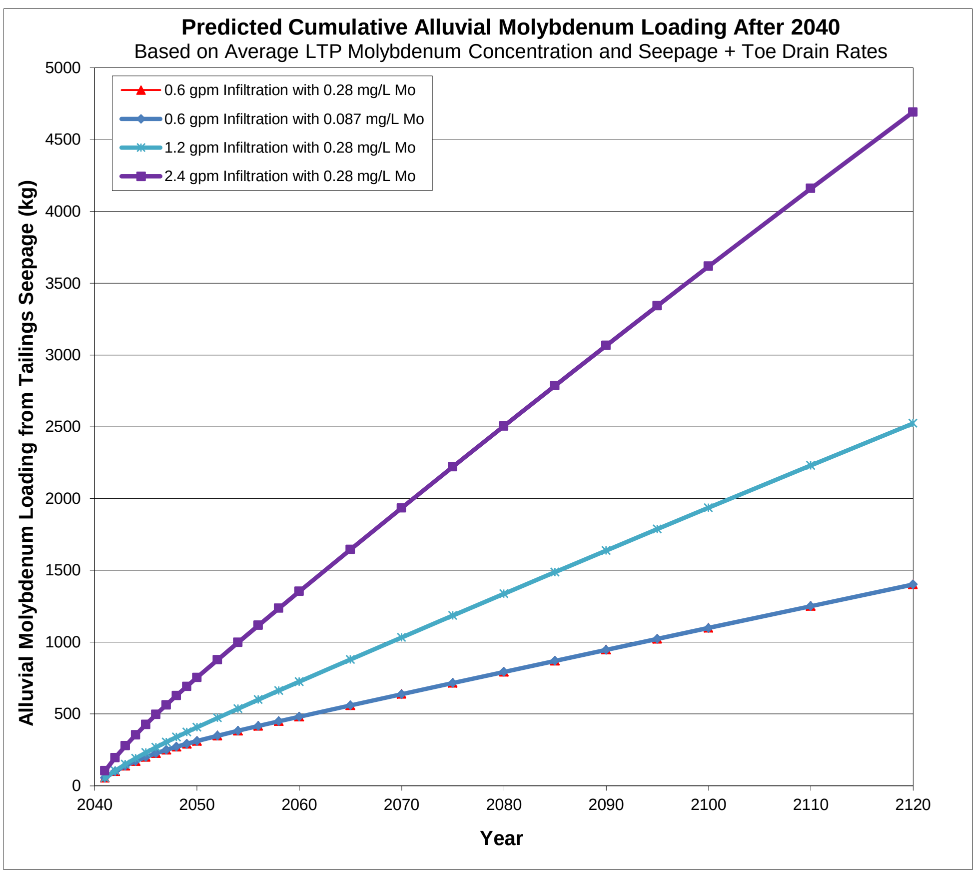
DDM Seepage and Molybdenum Concentration Predictions

DDM predictions of molybdenum concentrations are presented in attached Figures 4 through 6 and in Figure 8 for the worst-case scenario. Each figure includes a tabulation of DDM predictions and three graphs that present combinations of model predictions of molybdenum concentration, measured molybdenum concentrations, and predicted seepage and toe drain rates. The starting molybdenum concentration in 2015 for the simulation was set at 13.4 mg/L to produce a mid-2018 concentration of 13.35 mg/L which is consistent with observed concentrations. The observed concentrations shown in the upper plot in Figures 4 through 6 reflect a dramatic reduction in average concentration between 2010 and 2018 as a result of the flushing program. Like uranium, the temporary increase in average molybdenum concentration in 2016 is considered an anomaly. Figure 4 presents the expected molybdenum concentrations and seepage rates for the condition where the long-term infiltration rate to the LTP is 0.6 gpm with the infiltrate having a molybdenum concentration of 0.28 mg/L after passing through the tailings. Figure 5 presents a similar simulation with the infiltrate molybdenum concentration reduced to 0.087 mg/L. In comparing Figure 4 and Figure 5, there is a very slight reduction in predicted long-term molybdenum concentration in the LTP with the smaller molybdenum concentration in the infiltrate. For both simulations, the predicted long-term molybdenum concentration in the LTP ranges from greater than 12 mg/L to approximately 13 mg/L after 2040 and has a very gradual declining trend. For the remaining simulation presented in Figure 6, the larger infiltrate molybdenum concentration is used for conservatism. Figure 6 presents a simulation where the long-term infiltration rate is increased to 1.2 gpm. This condition results in a slight decrease in predicted long-term LTP molybdenum concentration, but the molybdenum mass in seepage is increased because of the increased seepage rate. Like uranium, the increase in long-term seepage rate more than offsets the reduction in molybdenum concentration and there is increased constituent loading to the alluvial aquifer. As occurred with uranium, a doubling of the interim and long-term infiltration rates over those in Figure 6 to the worst-case scenario results in a dramatic increase in molybdenum mass in seepage (see Figure 8).

Comparison of Drain Down Model Predictions

The range of infiltration rates and uranium or molybdenum concentrations used in the DDM predictions results in a range of predicted long-term seepage impacts to the alluvium. As indicated in the preceding discussions, the anticipated long-term infiltration rate is expected to be the most important factor in long-term seepage impacts, with significantly increased constituent (uranium or molybdenum) loading with increased infiltration. The following graphs illustrate the expected change in cumulative constituent loading to the alluvium with a range of infiltration rates and the range of constituent concentrations in the infiltrate for an infiltration rate of 0.6 gpm. In the graphs, the constituent loading in kilograms (kg) for each year is calculated using the product of the predicted average concentration in the LTP and the sum of the seepage and toe drain rates. The cumulative constituent loading calculation is started after year 2040 because the estimated long-term infiltration rate applies after 2040, and the seepage rates and constituent loading prior to 2040 are much greater and this would obscure the differences in projected loading with differing infiltration rates.


Predicted Cumulative Alluvial Uranium Loading After 2040
Based on Average LTP Uranium Concentration and Seepage + Toe Drain Rates
0.6 gpm Infiltration with 1.26 mg/L U
0.6 gpm Infiltration with 0.11 mg/L U
1.2 gpm Infiltration with 1.26 mg/L U
2.4 gpm Infiltration with 1.26 mg/L U
Alluvial Uranium Loading from Tailings Seepage (kg)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2040
2050
2060
2070
2080
2090
2100
2110
2120
Year


Predicted Cumulative Alluvial Molybdenum Loading After 2040
Based on Average LTP Molybdenum Concentration and Seepage + Toe Drain Rates
0.6 gpm Infiltration with 0.28 mg/L Mo
0.6 gpm Infiltration with 0.087 mg/L Mo
1.2 gpm Infiltration with 0.28 mg/L Mo
2.4 gpm Infiltration with 0.28 mg/L Mo
Alluvial Molybdenum Loading from Tailings Seepage (kg)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
2040
2050
2060
2070
2080
2090
2100
2110
2120
Year

In the preceding graphs for uranium and molybdenum loading to the alluvium, the lowest predicted loading occurs for the modeled rate of infiltration of 0.6 gpm (dark blue line and symbols) with the lower uranium or molybdenum concentration in the infiltrate. With the uranium concentration in infiltrate increased to the upper humidity cell testing level with the infiltration rate of 0.6 gpm, there is a very slight increase in cumulative uranium loading to the alluvial aquifer. The molybdenum loading to the alluvium with model runs at 0.6 gpm of infiltration and molybdenum concentration in infiltrate of 0.087 mg/L and 0.28 mg/L is virtually the same. The DDM model runs (light blue line and symbols) at an infiltration rate of 1.2 gpm indicate a fairly dramatic increase in loading with the increased long-term seepage rate. As indicated in the preceding graphs, the constituent loading to the alluvium is increased by roughly 80% with a doubling of the infiltration rate from 0.6 to 1.2 gpm. A further doubling of the long-term infiltration rate to 2.4 gpm with an interim infiltration rate of 4.0 gpm results in a similarly dramatic increase in uranium and molybdenum loading to the alluvial aquifer (purple lines and symbols).

Summary of Model Predictions

The DDM predictions included in the attached figures are based on a more refined estimate of projected long-term seepage and toe drain discharge rates, an assumed long-term infiltration rate of approximately 0.5% and 1.0% of annual precipitation over the LTP, and an assumed increase in COC concentrations in the infiltrating water. Barring an artificial introduction of additional water into the LTP, the seepage and toe drain rates will continue to decline because there is a finite quantity of drainable water remaining in the LTP. The projected long-term infiltration rate does have a significant impact on future COC loading to the alluvium by seepage from the LTP. The expected rate of infiltration is approximately 0.6 gpm, and a more conservative rate of 1.2 gpm was also simulated. The assumed uranium concentration in infiltrate of 1.26 mg/L and assumed molybdenum concentration in infiltrate of 0.28 mg/L that are based on the humidity cell test results and observation of changes in COC concentration after cessation of flushing do result in a minor declining trend in predicted residual uranium and molybdenum concentration in the LTP.

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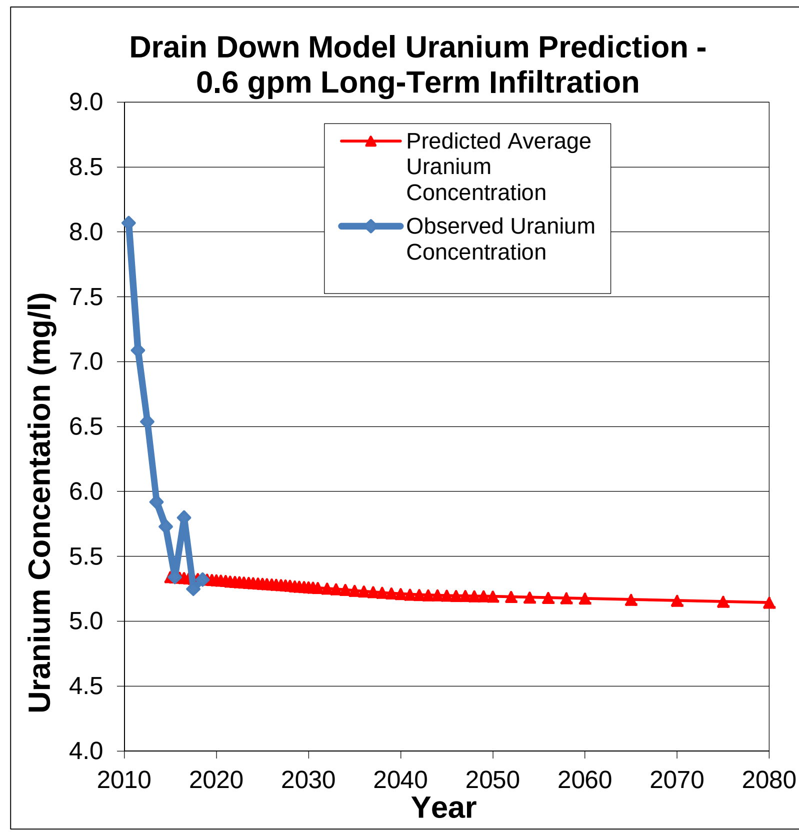
Figure 1

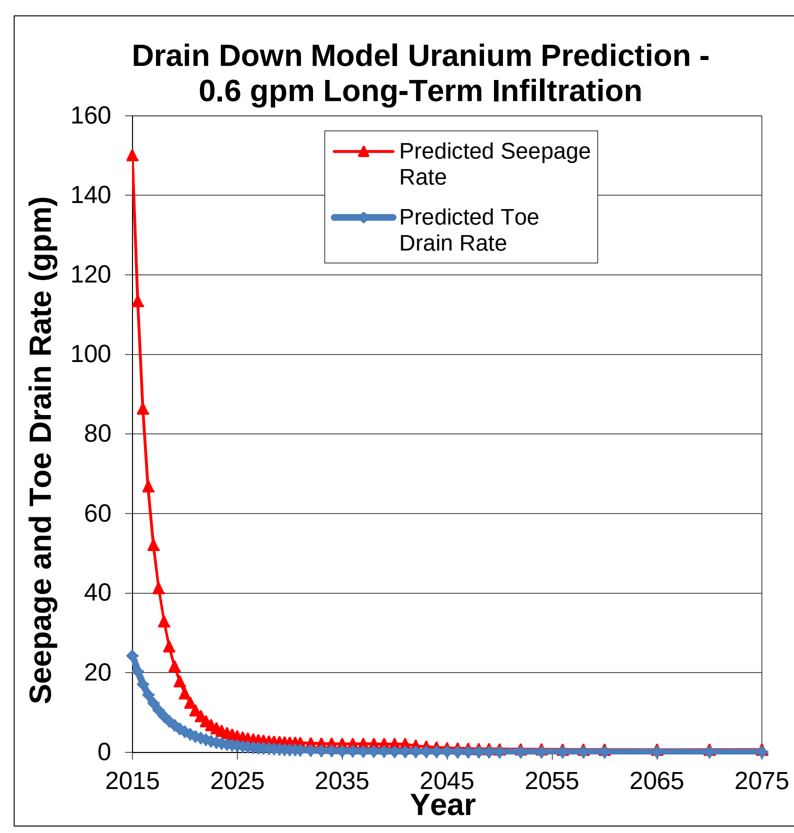
Drain Down Model Uranium Prediction with 0.6 gpm Long-Term Infiltration Rate and 1.26 mg/L Uranium Concentration in Infiltrate

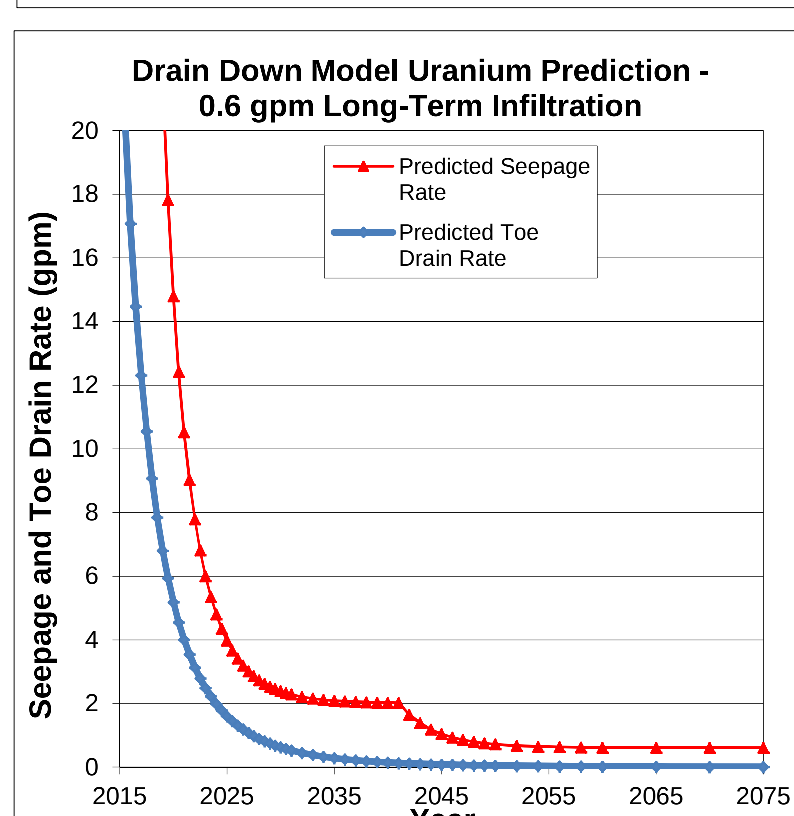
2015 Average U Concentration	5.34
Infiltration Water U Conc.	1.26
Humidity Cell Upper U Conc. (mg/L)	1.26
Humidity Cell Lower U Conc. (mg/L)	0.11

Estimated Drain Down and LTP Uranium Concentration

Year	Predicted Average Uranium Conc. (mg/l)	U Loading Seepage plus Toe Drain (kg/yr)	Infiltration Rate (gpm)	Seepage Rate (gpm)	Toe Drain Rate (gpm)
2012.5	6.54	2109.2	2.0	139.0	23.0
2013.5	5.92	2027.1	2.0	154.0	18.0
2014.5	5.73	2486.7	2.0	200.0	18.0
2015	5.34	1852.1	2.0	150.0	24.2
2015.5	5.34	1420.5	2.0	113.4	20.3
2016	5.34	1098.8	2.0	86.4	17.1
2016.5	5.33	862.7	2.0	66.8	14.5
2017	5.33	683.4	2.0	52.1	12.3
2017.5	5.33	549.4	2.0	41.2	10.6
2018	5.33	444.6	2.0	32.9	9.1
2018.5	5.32	364.7	2.0	26.6	7.8
2019	5.32	301.0	2.0	21.6	6.8
2019.5	5.32	251.5	2.0	17.8	5.9
2020	5.32	211.4	2.0	14.8	5.2
2020.5	5.31	179.5	2.0	12.4	4.6
2021	5.31	153.5	2.0	10.5	4.0
2021.5	5.31	132.7	2.0	9.0	3.5
2022	5.30	115.4	2.0	7.8	3.1
2022.5	5.30	101.3	2.0	6.8	2.8
2023	5.30	89.5	2.0	6.0	2.5
2023.5	5.30	79.8	2.0	5.3	2.2
2024	5.29	71.5	2.0	4.8	2.0
2024.5	5.29	64.6	2.0	4.3	1.8
2025	5.29	58.8	2.0	4.0	1.6
2025.5	5.29	53.9	2.0	3.7	1.5
2026	5.28	49.6	2.0	3.4	1.3
2026.5	5.28	46.1	2.0	3.2	1.2
2027	5.28	43.0	2.0	3.0	1.1
2027.5	5.28	40.4	2.0	2.9	1.0
2028	5.27	38.0	2.0	2.7	0.9
2028.5	5.27	36.1	2.0	2.6	0.8
2029	5.27	34.3	2.0	2.5	0.7
2029.5	5.27	32.9	2.0	2.5	0.7
2030	5.26	31.6	2.0	2.4	0.6
2030.5	5.26	30.4	2.0	2.3	0.6
2031	5.26	29.4	2.0	2.3	0.5
2032	5.25	27.8	2.0	2.2	0.4
2033	5.25	26.5	2.0	2.2	0.4
2034	5.24	25.5	2.0	2.1	0.3
2035	5.24	24.7	2.0	2.1	0.3
2036	5.23	24.0	2.0	2.1	0.2
2037	5.23	23.5	2.0	2.0	0.2
2038	5.22	23.1	2.0	2.0	0.2
2039	5.21	22.7	2.0	2.0	0.2
2040	5.21	22.4	2.0	2.0	0.1
2041	5.20	22.2	0.6	2.0	0.1
2042	5.20	18.2	0.6	1.6	0.1
2043	5.20	15.3	0.6	1.4	0.1
2044	5.20	13.2	0.6	1.2	0.1
2045	5.20	11.6	0.6	1.0	0.1
2046	5.20	10.4	0.6	0.9	0.1
2047	5.19	9.5	0.6	0.9	0.1
2048	5.19	8.8	0.6	0.8	0.1
2049	5.19	8.3	0.6	0.7	0.1
2050	5.19	7.9	0.6	0.7	0.0
2052	5.19	7.3	0.6	0.7	0.0
2054	5.18	7.0	0.6	0.6	0.0
2056	5.18	6.7	0.6	0.6	0.0
2058	5.18	6.6	0.6	0.6	0.0
2060	5.17	6.5	0.6	0.6	0.0
2065	5.17	6.4	0.6	0.6	0.0
2070	5.16	6.3	0.6	0.6	0.0
2075	5.15	6.3	0.6	0.6	0.0
2080	5.14	6.2	0.6	0.6	0.0
2085	5.14	6.2	0.6	0.6	0.0
2090	5.13	6.2	0.6	0.6	0.0
2095	5.12	6.2	0.6	0.6	0.0
2100	5.11	6.2	0.6	0.6	0.0
2110	5.10	6.1	0.6	0.6	0.0
2120	5.08	6.1	0.6	0.6	0.0







Note: Yellow shading indicates pumping from toe drain sumps will likely be discontinued at low rates.
Gray shading indicates values taken from measured/estimated water volume change and uranium concentration.

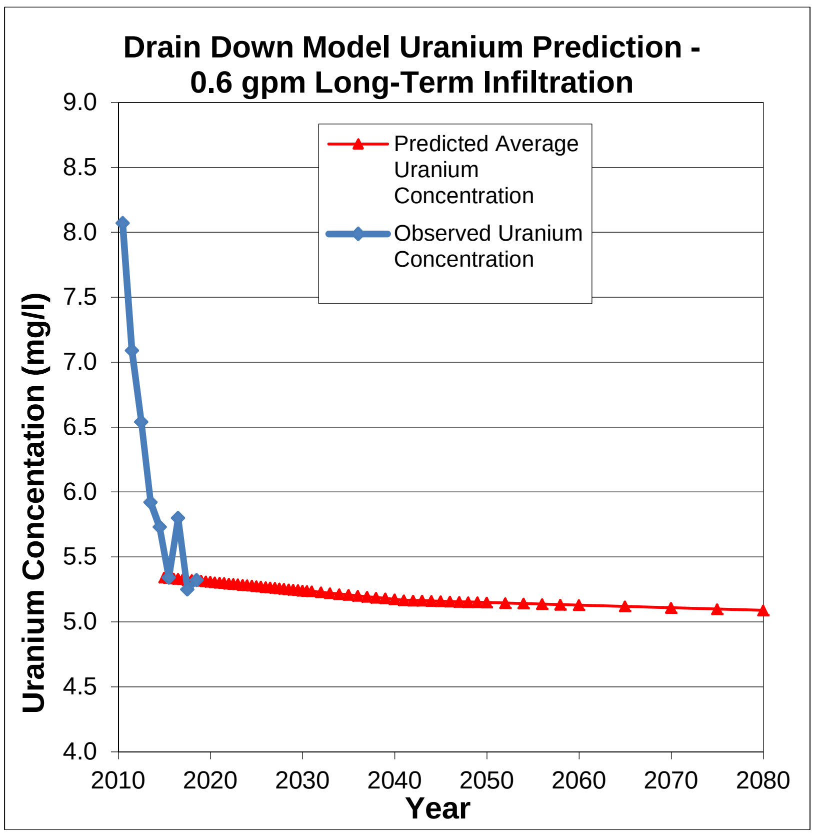
Figure 2

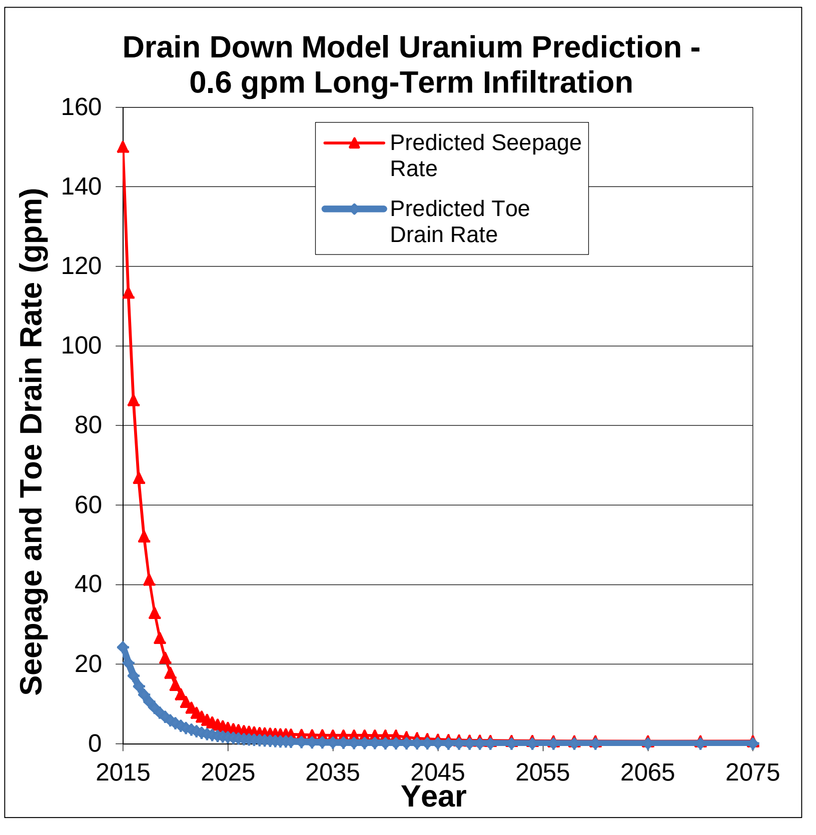
Drain Down Model Uranium Prediction with 0.6 gpm Long-Term Infiltration Rate and 0.11 mg/L Uranium Concentration in Infiltrate

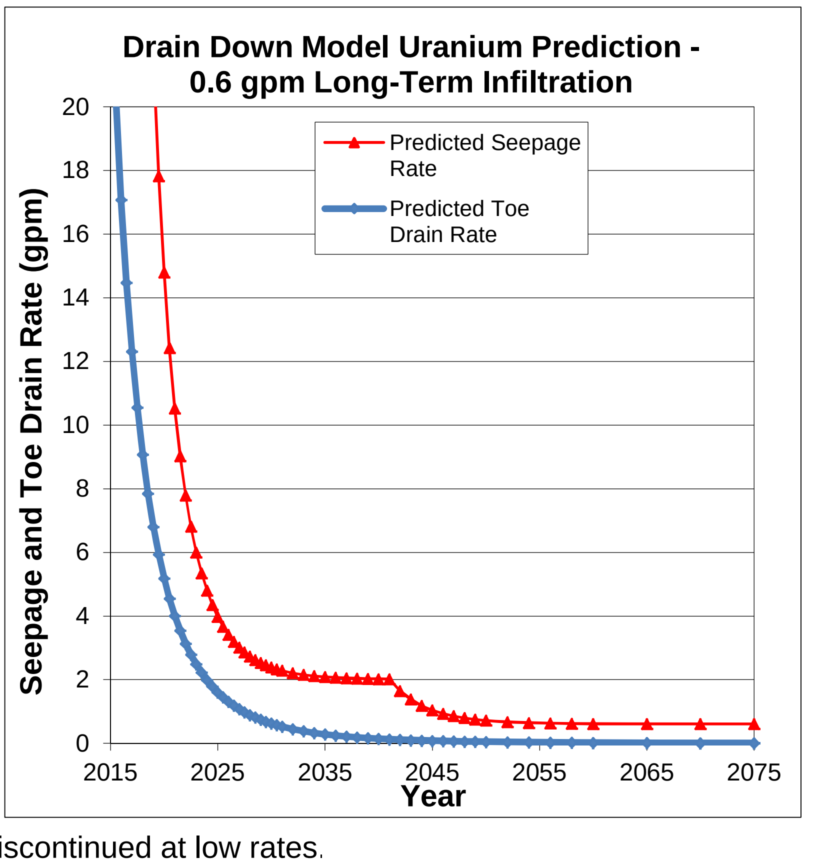
2015 Average U Concentration	5.34
Infiltration Water U Conc.	0.11
Humidity Cell Upper U Conc. (mg/L)	1.26
Humidity Cell Lower U Conc. (mg/L)	0.11

Estimated Drain Down and LTP Uranium Concentration

Year	Predicted Average Uranium Conc. (mg/l)	U Loading Seepage plus Toe Drain (kg/yr)	Infiltration Rate (gpm)	Seepage Rate (gpm)	Toe Drain Rate (gpm)
2012.5	6.54	2109.2	2.0	139.0	23.0
2013.5	5.92	2027.1	2.0	154.0	18.0
2014.5	5.73	2486.7	2.0	200.0	18.0
2015	5.34	1852.1	2.0	150.0	24.2
2015.5	5.34	1420.3	2.0	113.4	20.3
2016	5.33	1098.5	2.0	86.4	17.1
2016.5	5.33	862.4	2.0	66.8	14.5
2017	5.33	683.1	2.0	52.1	12.3
2017.5	5.32	549.0	2.0	41.2	10.6
2018	5.32	444.3	2.0	32.9	9.1
2018.5	5.32	364.3	2.0	26.6	7.8
2019	5.31	300.7	2.0	21.6	6.8
2019.5	5.31	251.2	2.0	17.8	5.9
2020	5.31	211.1	2.0	14.8	5.2
2020.5	5.30	179.3	2.0	12.4	4.6
2021	5.30	153.3	2.0	10.5	4.0
2021.5	5.30	132.5	2.0	9.0	3.5
2022	5.29	115.2	2.0	7.8	3.1
2022.5	5.29	101.1	2.0	6.8	2.8
2023	5.29	89.3	2.0	6.0	2.5
2023.5	5.28	79.6	2.0	5.3	2.2
2024	5.28	71.3	2.0	4.8	2.0
2024.5	5.28	64.5	2.0	4.3	1.8
2025	5.27	58.6	2.0	4.0	1.6
2025.5	5.27	53.7	2.0	3.7	1.5
2026	5.27	49.5	2.0	3.4	1.3
2026.5	5.26	45.9	2.0	3.2	1.2
2027	5.26	42.8	2.0	3.0	1.1
2027.5	5.26	40.2	2.0	2.9	1.0
2028	5.25	37.9	2.0	2.7	0.9
2028.5	5.25	35.9	2.0	2.6	0.8
2029	5.25	34.2	2.0	2.5	0.7
2029.5	5.24	32.7	2.0	2.5	0.7
2030	5.24	31.4	2.0	2.4	0.6
2030.5	5.24	30.3	2.0	2.3	0.6
2031	5.23	29.3	2.0	2.3	0.5
2032	5.23	27.6	2.0	2.2	0.4
2033	5.22	26.3	2.0	2.2	0.4
2034	5.21	25.3	2.0	2.1	0.3
2035	5.21	24.5	2.0	2.1	0.3
2036	5.20	23.9	2.0	2.1	0.2
2037	5.19	23.4	2.0	2.0	0.2
2038	5.19	22.9	2.0	2.0	0.2
2039	5.18	22.6	2.0	2.0	0.2
2040	5.17	22.3	2.0	2.0	0.1
2041	5.17	22.0	0.6	2.0	0.1
2042	5.16	18.1	0.6	1.6	0.1
2043	5.16	15.2	0.6	1.4	0.1
2044	5.16	13.1	0.6	1.2	0.1
2045	5.16	11.5	0.6	1.0	0.1
2046	5.16	10.3	0.6	0.9	0.1
2047	5.15	9.4	0.6	0.9	0.1
2048	5.15	8.7	0.6	0.8	0.1
2049	5.15	8.2	0.6	0.7	0.1
2050	5.15	7.8	0.6	0.7	0.0
2052	5.14	7.2	0.6	0.7	0.0
2054	5.14	6.9	0.6	0.6	0.0
2056	5.14	6.7	0.6	0.6	0.0
2058	5.13	6.5	0.6	0.6	0.0
2060	5.13	6.4	0.6	0.6	0.0
2065	5.12	6.3	0.6	0.6	0.0
2070	5.11	6.2	0.6	0.6	0.0
2075	5.10	6.2	0.6	0.6	0.0
2080	5.09	6.2	0.6	0.6	0.0
2085	5.08	6.1	0.6	0.6	0.0
2090	5.07	6.1	0.6	0.6	0.0
2095	5.06	6.1	0.6	0.6	0.0
2100	5.05	6.1	0.6	0.6	0.0
2110	5.03	6.0	0.6	0.6	0.0
2120	5.01	6.0	0.6	0.6	0.0







Note: Yellow shading indicates pumping from toe drain sumps will likely be discontinued at low rates.
Gray shading indicates values taken from measured/estimated water volume change and uranium concentration.

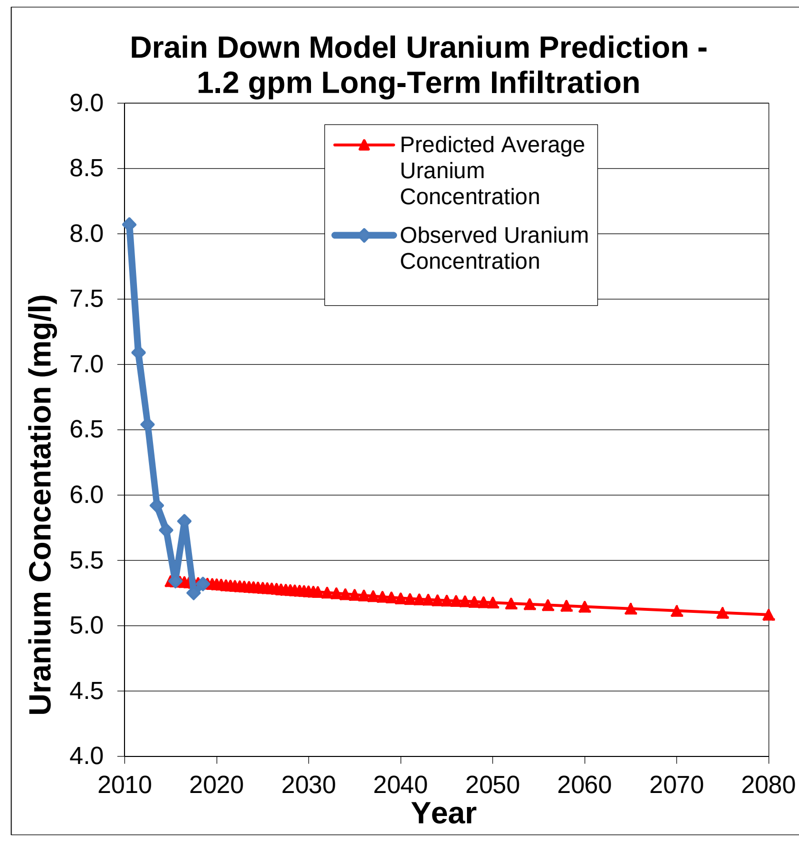
Figure 3

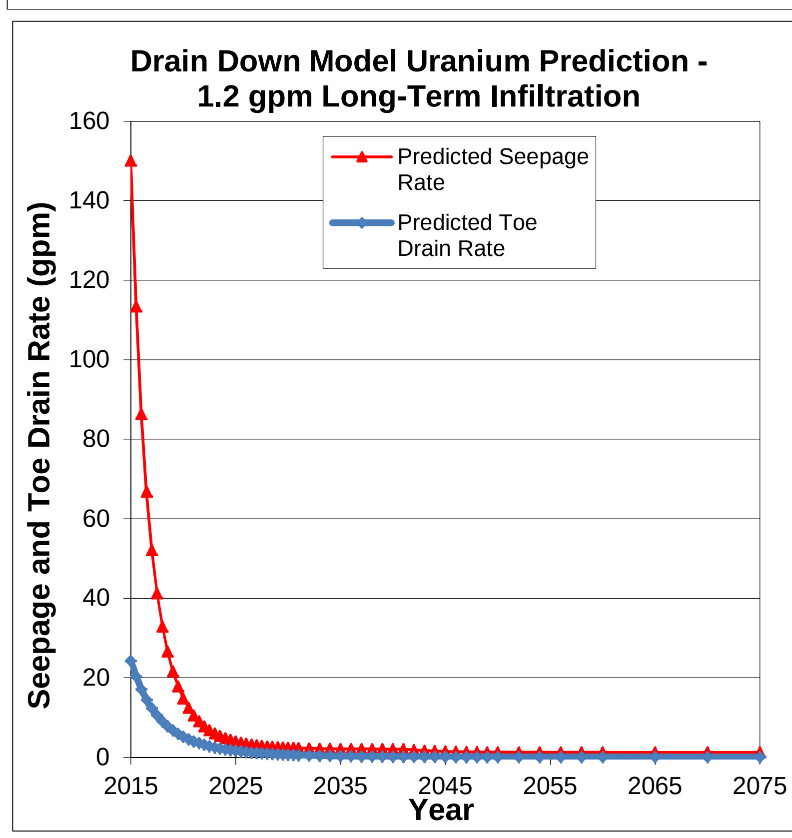
Drain Down Model Uranium Prediction with 1.2 gpm Long-Term Infiltration Rate and 1.26 mg/L Uranium Concentration in Infiltrate

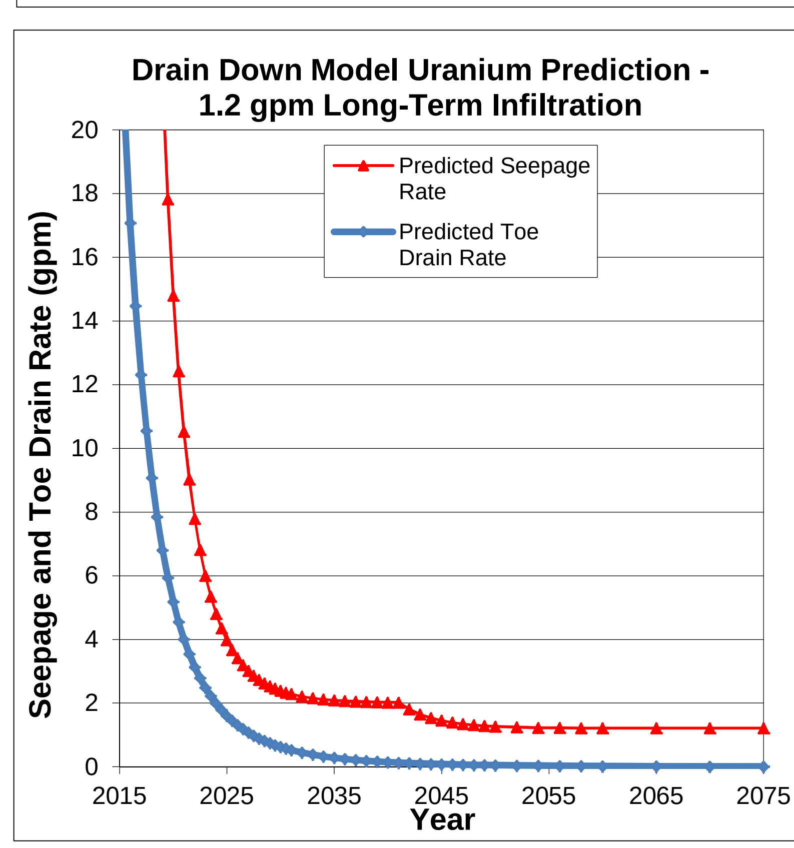
2015 Average U Concentration	5.34
Infiltration Water U Conc.	1.26
Humidity Cell Upper U Conc. (mg/L)	1.26
Humidity Cell Lower U Conc. (mg/L)	0.11

Estimated Drain Down and LTP Uranium Concentration

Year	Predicted Average Uranium Conc. (mg/l)	U Loading Seepage plus Toe Drain (kg/yr)	Infiltration Rate (gpm)	Seepage Rate (gpm)	Toe Drain Rate (gpm)
2012.5	6.54	2109.2	2.0	139.0	23.0
2013.5	5.92	2027.1	2.0	154.0	18.0
2014.5	5.73	2486.7	2.0	200.0	18.0
2015	5.34	1852.1	2.0	150.0	24.2
2015.5	5.34	1420.5	2.0	113.4	20.3
2016	5.34	1098.8	2.0	86.4	17.1
2016.5	5.33	862.7	2.0	66.8	14.5
2017	5.33	683.4	2.0	52.1	12.3
2017.5	5.33	549.4	2.0	41.2	10.6
2018	5.33	444.6	2.0	32.9	9.1
2018.5	5.32	364.7	2.0	26.6	7.8
2019	5.32	301.0	2.0	21.6	6.8
2019.5	5.32	251.5	2.0	17.8	5.9
2020	5.32	211.4	2.0	14.8	5.2
2020.5	5.31	179.5	2.0	12.4	4.6
2021	5.31	153.5	2.0	10.5	4.0
2021.5	5.31	132.7	2.0	9.0	3.5
2022	5.30	115.4	2.0	7.8	3.1
2022.5	5.30	101.3	2.0	6.8	2.8
2023	5.30	89.5	2.0	6.0	2.5
2023.5	5.30	79.8	2.0	5.3	2.2
2024	5.29	71.5	2.0	4.8	2.0
2024.5	5.29	64.6	2.0	4.3	1.8
2025	5.29	58.8	2.0	4.0	1.6
2025.5	5.29	53.9	2.0	3.7	1.5
2026	5.28	49.6	2.0	3.4	1.3
2026.5	5.28	46.1	2.0	3.2	1.2
2027	5.28	43.0	2.0	3.0	1.1
2027.5	5.28	40.4	2.0	2.9	1.0
2028	5.27	38.0	2.0	2.7	0.9
2028.5	5.27	36.1	2.0	2.6	0.8
2029	5.27	34.3	2.0	2.5	0.7
2029.5	5.27	32.9	2.0	2.5	0.7
2030	5.26	31.6	2.0	2.4	0.6
2030.5	5.26	30.4	2.0	2.3	0.6
2031	5.26	29.4	2.0	2.3	0.5
2032	5.25	27.8	2.0	2.2	0.4
2033	5.25	26.5	2.0	2.2	0.4
2034	5.24	25.5	2.0	2.1	0.3
2035	5.24	24.7	2.0	2.1	0.3
2036	5.23	24.0	2.0	2.1	0.2
2037	5.23	23.5	2.0	2.0	0.2
2038	5.22	23.1	2.0	2.0	0.2
2039	5.21	22.7	2.0	2.0	0.2
2040	5.21	22.4	2.0	2.0	0.1
2041	5.20	22.2	1.2	2.0	0.1
2042	5.20	19.8	1.2	1.8	0.1
2043	5.20	18.1	1.2	1.6	0.1
2044	5.19	16.8	1.2	1.5	0.1
2045	5.19	15.8	1.2	1.4	0.1
2046	5.19	15.1	1.2	1.4	0.1
2047	5.19	14.5	1.2	1.3	0.1
2048	5.18	14.1	1.2	1.3	0.1
2049	5.18	13.7	1.2	1.3	0.1
2050	5.18	13.5	1.2	1.3	0.0
2052	5.17	13.1	1.2	1.2	0.0
2054	5.16	12.9	1.2	1.2	0.0
2056	5.16	12.8	1.2	1.2	0.0
2058	5.15	12.7	1.2	1.2	0.0
2060	5.14	12.6	1.2	1.2	0.0
2065	5.13	12.5	1.2	1.2	0.0
2070	5.11	12.4	1.2	1.2	0.0
2075	5.10	12.3	1.2	1.2	0.0
2080	5.08	12.3	1.2	1.2	0.0
2085	5.07	12.2	1.2	1.2	0.0
2090	5.05	12.2	1.2	1.2	0.0
2095	5.04	12.1	1.2	1.2	0.0
2100	5.02	12.1	1.2	1.2	0.0
2110	4.99	12.0	1.2	1.2	0.0
2120	4.96	11.9	1.2	1.2	0.0







Note: Yellow shading indicates pumping from toe drain sumps will likely be discontinued at low rates.
Gray shading indicates values taken from measured/estimated water volume change and uranium concentration.

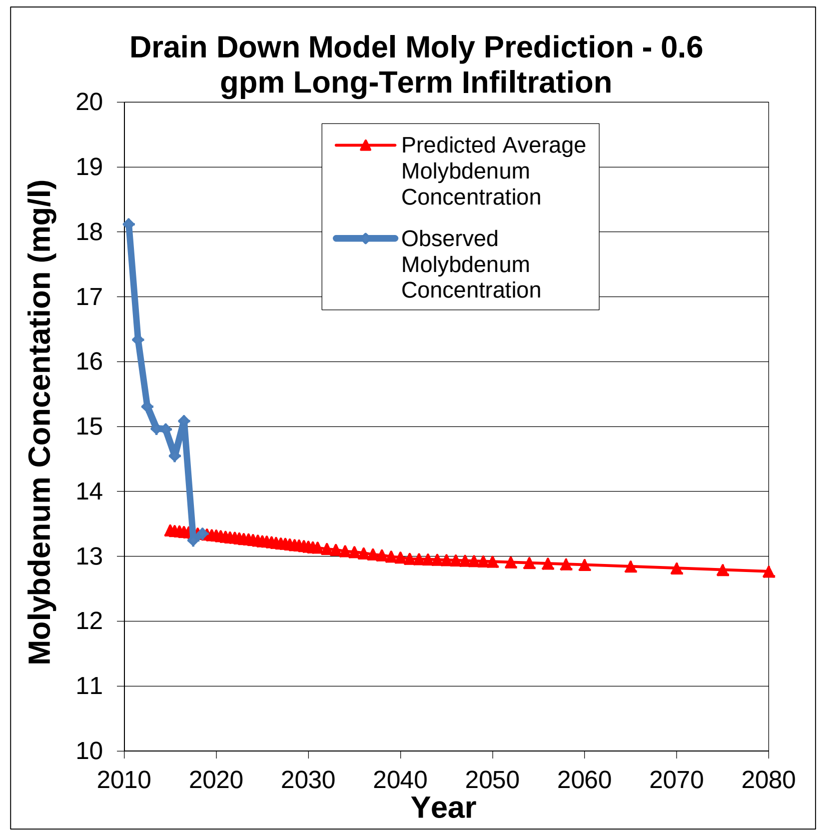
Figure 4

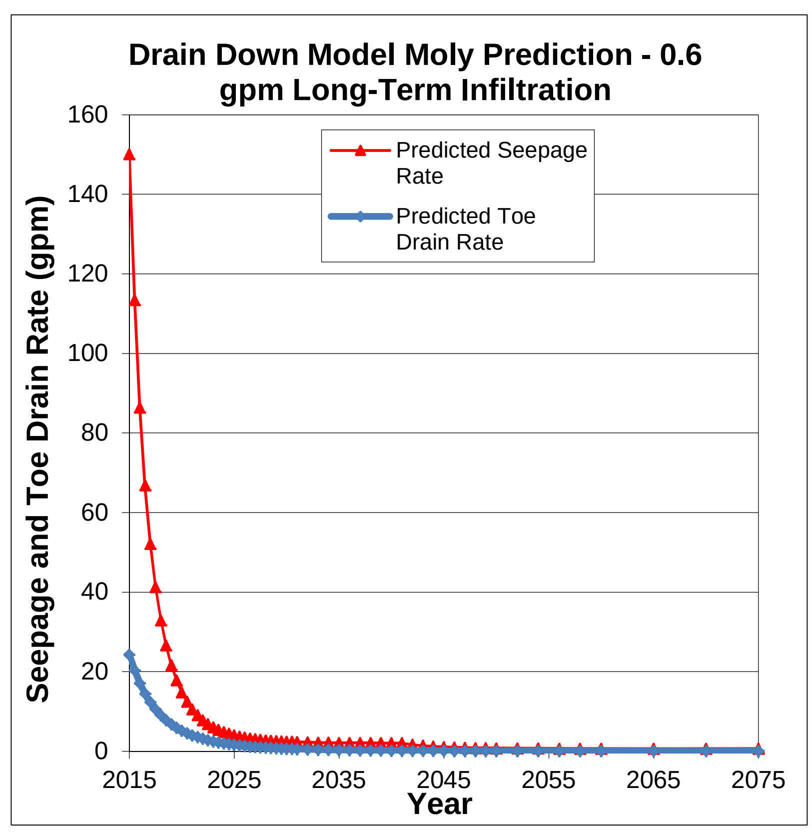
Drain Down Model Molybdenum Prediction with 0.6 gpm Long-Term Infiltration Rate and 0.28 mg/L Molybdenum Concentration in Infiltrate

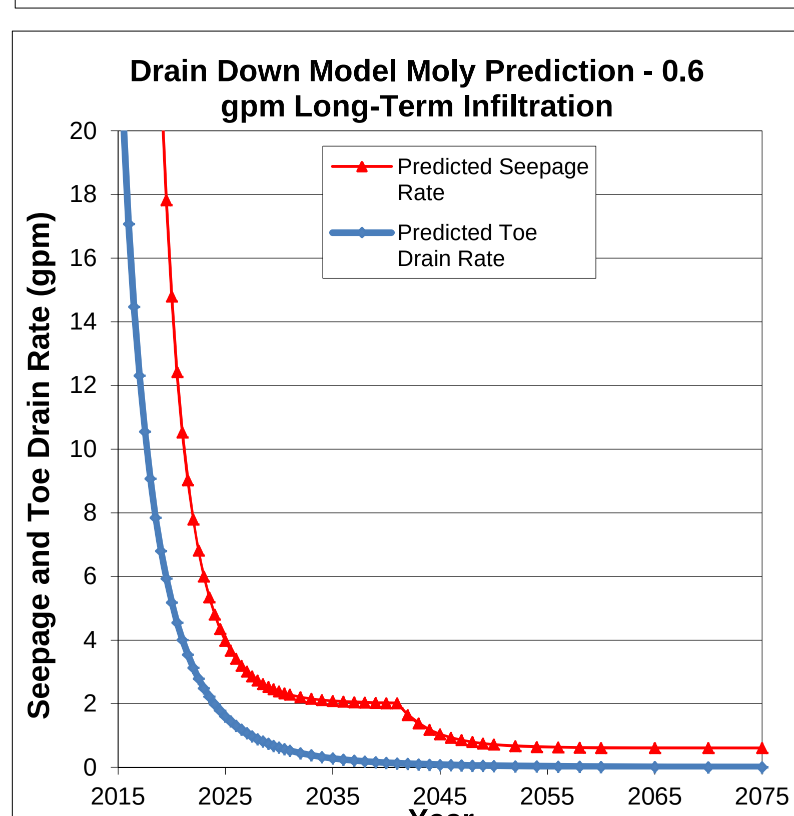
2015 Starting Mo Concentration	13.40
Infiltration Water Mo Conc.	0.28
Humidity Cell Upper Mo Conc. (mg/L)	0.28
Humidity Cell Lower Mo Conc. (mg/L)	0.087

Estimated Drain Down and LTP Molybdenum Concentration

Year	Predicted Average Mo Conc. (mg/l)	Mo Loading Seepage plus Toe Drain (kg/yr)	Infiltration Rate (gpm)	Seepage Rate (gpm)	Toe Drain Rate (gpm)
2012.5	15.31	4937.5	2.0	139.0	23.0
2013.5	14.97	5125.9	2.0	154.0	18.0
2014.5	14.96	6492.4	2.0	200.0	18.0
2015	13.40	4647.7	2.0	150.0	24.2
2015.5	13.39	3564.2	2.0	113.4	20.3
2016	13.39	2756.5	2.0	86.4	17.1
2016.5	13.38	2164.0	2.0	66.8	14.5
2017	13.37	1714.1	2.0	52.1	12.3
2017.5	13.36	1377.7	2.0	41.2	10.6
2018	13.35	1114.9	2.0	32.9	9.1
2018.5	13.35	914.2	2.0	26.6	7.8
2019	13.34	754.5	2.0	21.6	6.8
2019.5	13.33	630.3	2.0	17.8	5.9
2020	13.32	529.7	2.0	14.8	5.2
2020.5	13.31	449.9	2.0	12.4	4.6
2021	13.30	384.7	2.0	10.5	4.0
2021.5	13.30	332.5	2.0	9.0	3.5
2022	13.29	289.0	2.0	7.8	3.1
2022.5	13.28	253.7	2.0	6.8	2.8
2023	13.27	224.0	2.0	6.0	2.5
2023.5	13.26	199.7	2.0	5.3	2.2
2024	13.25	179.0	2.0	4.8	2.0
2024.5	13.24	161.8	2.0	4.3	1.8
2025	13.24	147.1	2.0	4.0	1.6
2025.5	13.23	134.8	2.0	3.7	1.5
2026	13.22	124.2	2.0	3.4	1.3
2026.5	13.21	115.3	2.0	3.2	1.2
2027	13.20	107.5	2.0	3.0	1.1
2027.5	13.19	100.9	2.0	2.9	1.0
2028	13.18	95.1	2.0	2.7	0.9
2028.5	13.18	90.2	2.0	2.6	0.8
2029	13.17	85.9	2.0	2.5	0.7
2029.5	13.16	82.1	2.0	2.5	0.7
2030	13.15	78.9	2.0	2.4	0.6
2030.5	13.14	76.0	2.0	2.3	0.6
2031	13.13	73.5	2.0	2.3	0.5
2032	13.12	69.4	2.0	2.2	0.4
2033	13.10	66.1	2.0	2.2	0.4
2034	13.08	63.6	2.0	2.1	0.3
2035	13.07	61.6	2.0	2.1	0.3
2036	13.05	59.9	2.0	2.1	0.2
2037	13.03	58.6	2.0	2.0	0.2
2038	13.01	57.5	2.0	2.0	0.2
2039	13.00	56.7	2.0	2.0	0.2
2040	12.98	55.9	2.0	2.0	0.1
2041	12.96	55.3	0.6	2.0	0.1
2042	12.96	45.3	0.6	1.6	0.1
2043	12.95	38.1	0.6	1.4	0.1
2044	12.95	32.8	0.6	1.2	0.1
2045	12.94	28.8	0.6	1.0	0.1
2046	12.94	25.9	0.6	0.9	0.1
2047	12.93	23.6	0.6	0.9	0.1
2048	12.93	21.9	0.6	0.8	0.1
2049	12.92	20.6	0.6	0.7	0.1
2050	12.92	19.6	0.6	0.7	0.0
2052	12.91	18.2	0.6	0.7	0.0
2054	12.90	17.3	0.6	0.6	0.0
2056	12.89	16.7	0.6	0.6	0.0
2058	12.88	16.4	0.6	0.6	0.0
2060	12.87	16.1	0.6	0.6	0.0
2065	12.84	15.8	0.6	0.6	0.0
2070	12.82	15.6	0.6	0.6	0.0
2075	12.79	15.5	0.6	0.6	0.0
2080	12.77	15.4	0.6	0.6	0.0
2085	12.74	15.4	0.6	0.6	0.0
2090	12.72	15.3	0.6	0.6	0.0
2095	12.69	15.3	0.6	0.6	0.0
2100	12.67	15.2	0.6	0.6	0.0
2110	12.62	15.2	0.6	0.6	0.0
2120	12.57	15.1	0.6	0.6	0.0







Note: Yellow shading indicates pumping from toe drain sumps will likely be discontinued at low rates.
Gray shading indicates values taken from measured/estimated water volume change and molybdenum concentration.

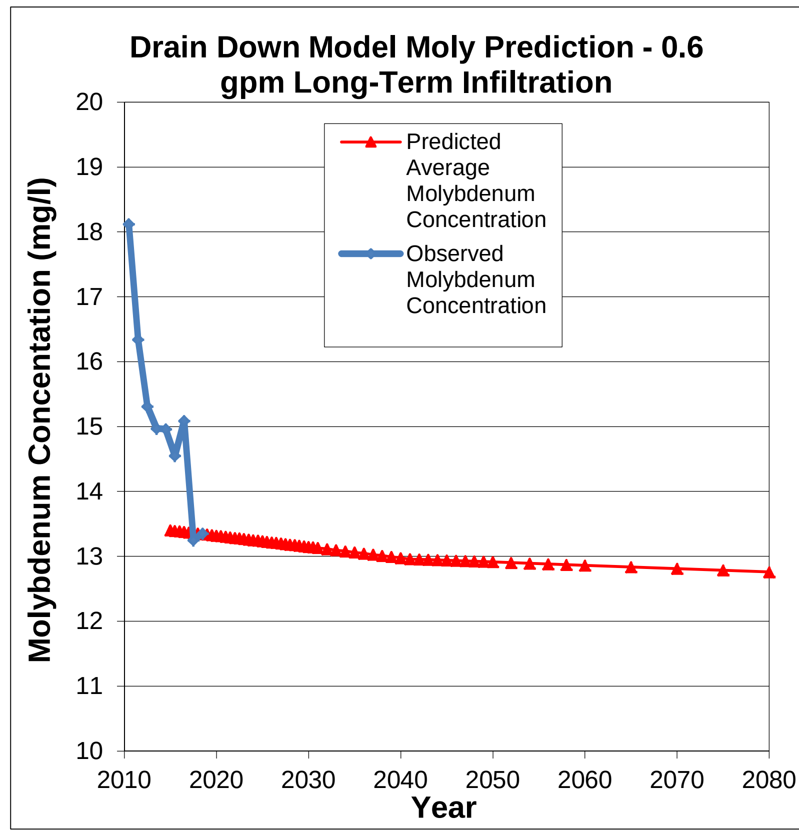
Figure 5

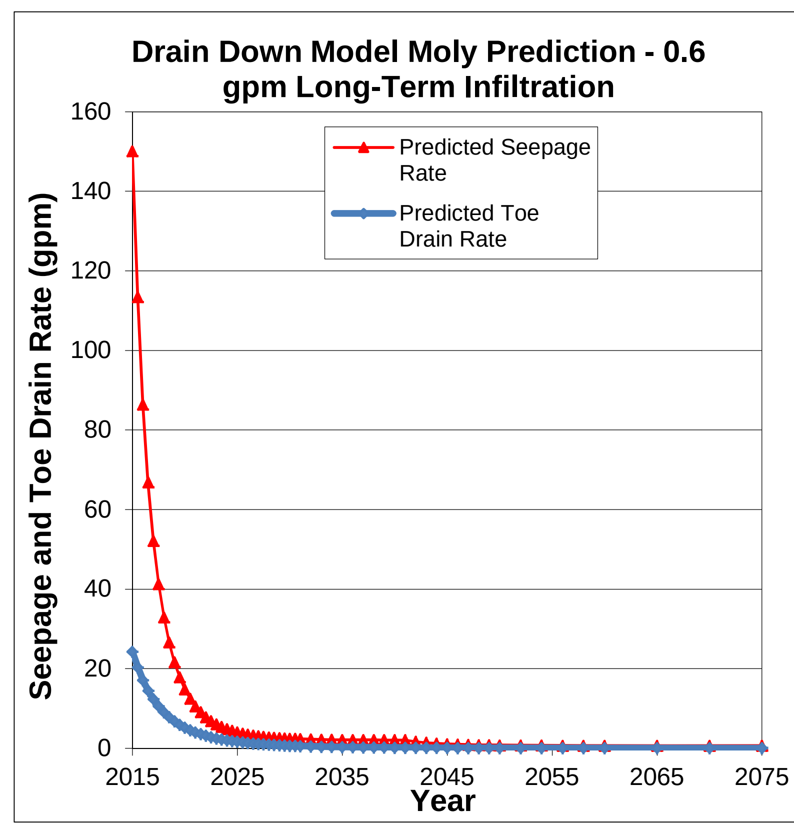
Drain Down Model Molybdenum Prediction with 0.6 gpm Long-Term Infiltration Rate and 0.087 mg/L Molybdenum Concentration in Infiltrate

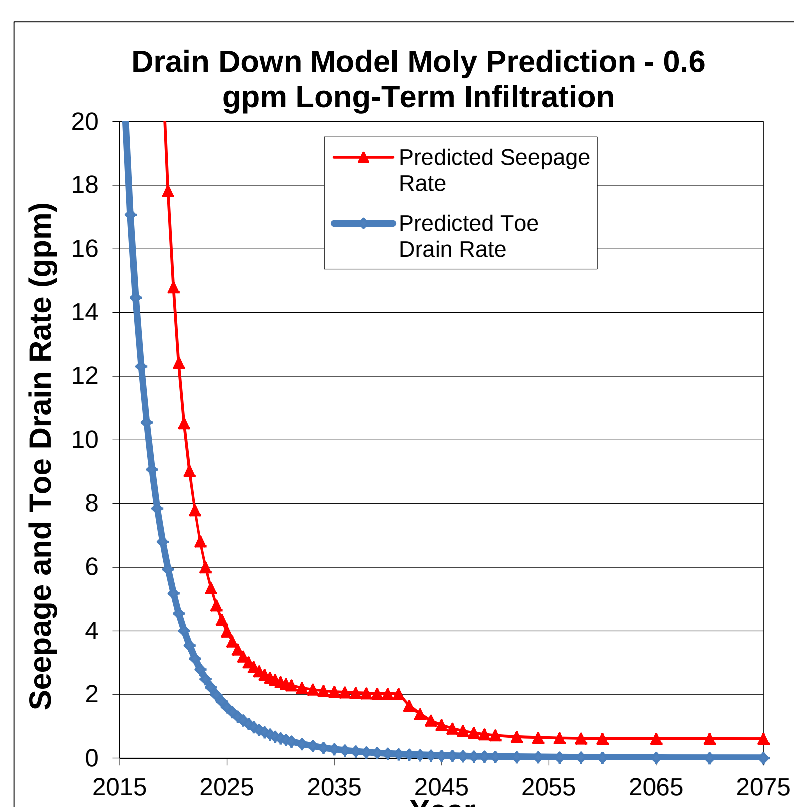
2015 Starting Mo Concentration	13.40
Infiltration Water Mo Conc.	0.087
Humidity Cell Upper Mo Conc. (mg/L)	0.28
Humidity Cell Lower Mo Conc. (mg/L)	0.087

Estimated Drain Down and LTP Molybdenum Concentration

Year	Predicted Average Mo Conc. (mg/l)	Mo Loading Seepage plus Toe Drain (kg/yr)	Infiltration Rate (gpm)	Seepage Rate (gpm)	Toe Drain Rate (gpm)
2012.5	15.31	4937.5	2.0	139.0	23.0
2013.5	14.97	5125.9	2.0	154.0	18.0
2014.5	14.96	6492.4	2.0	200.0	18.0
2015	13.40	4647.7	2.0	150.0	24.2
2015.5	13.39	3564.1	2.0	113.4	20.3
2016	13.39	2756.5	2.0	86.4	17.1
2016.5	13.38	2163.9	2.0	66.8	14.5
2017	13.37	1714.1	2.0	52.1	12.3
2017.5	13.36	1377.6	2.0	41.2	10.6
2018	13.35	1114.8	2.0	32.9	9.1
2018.5	13.34	914.2	2.0	26.6	7.8
2019	13.34	754.4	2.0	21.6	6.8
2019.5	13.33	630.2	2.0	17.8	5.9
2020	13.32	529.6	2.0	14.8	5.2
2020.5	13.31	449.8	2.0	12.4	4.6
2021	13.30	384.6	2.0	10.5	4.0
2021.5	13.29	332.4	2.0	9.0	3.5
2022	13.29	288.9	2.0	7.8	3.1
2022.5	13.28	253.7	2.0	6.8	2.8
2023	13.27	224.0	2.0	6.0	2.5
2023.5	13.26	199.7	2.0	5.3	2.2
2024	13.25	179.0	2.0	4.8	2.0
2024.5	13.24	161.8	2.0	4.3	1.8
2025	13.23	147.1	2.0	4.0	1.6
2025.5	13.22	134.8	2.0	3.7	1.5
2026	13.22	124.2	2.0	3.4	1.3
2026.5	13.21	115.3	2.0	3.2	1.2
2027	13.20	107.5	2.0	3.0	1.1
2027.5	13.19	100.9	2.0	2.9	1.0
2028	13.18	95.1	2.0	2.7	0.9
2028.5	13.17	90.2	2.0	2.6	0.8
2029	13.16	85.8	2.0	2.5	0.7
2029.5	13.16	82.1	2.0	2.5	0.7
2030	13.15	78.8	2.0	2.4	0.6
2030.5	13.14	76.0	2.0	2.3	0.6
2031	13.13	73.5	2.0	2.3	0.5
2032	13.11	69.3	2.0	2.2	0.4
2033	13.09	66.1	2.0	2.2	0.4
2034	13.08	63.6	2.0	2.1	0.3
2035	13.06	61.5	2.0	2.1	0.3
2036	13.04	59.9	2.0	2.1	0.2
2037	13.03	58.6	2.0	2.0	0.2
2038	13.01	57.5	2.0	2.0	0.2
2039	12.99	56.6	2.0	2.0	0.2
2040	12.97	55.9	2.0	2.0	0.1
2041	12.96	55.3	0.6	2.0	0.1
2042	12.95	45.3	0.6	1.6	0.1
2043	12.95	38.1	0.6	1.4	0.1
2044	12.94	32.8	0.6	1.2	0.1
2045	12.94	28.8	0.6	1.0	0.1
2046	12.93	25.9	0.6	0.9	0.1
2047	12.93	23.6	0.6	0.9	0.1
2048	12.92	21.9	0.6	0.8	0.1
2049	12.92	20.6	0.6	0.7	0.1
2050	12.91	19.6	0.6	0.7	0.0
2052	12.90	18.2	0.6	0.7	0.0
2054	12.89	17.3	0.6	0.6	0.0
2056	12.88	16.7	0.6	0.6	0.0
2058	12.87	16.4	0.6	0.6	0.0
2060	12.86	16.1	0.6	0.6	0.0
2065	12.83	15.8	0.6	0.6	0.0
2070	12.81	15.6	0.6	0.6	0.0
2075	12.78	15.5	0.6	0.6	0.0
2080	12.76	15.4	0.6	0.6	0.0
2085	12.73	15.4	0.6	0.6	0.0
2090	12.71	15.3	0.6	0.6	0.0
2095	12.68	15.3	0.6	0.6	0.0
2100	12.66	15.2	0.6	0.6	0.0
2110	12.61	15.2	0.6	0.6	0.0
2120	12.56	15.1	0.6	0.6	0.0







Note: Yellow shading indicates pumping from toe drain sumps will likely be discontinued at low rates.
Gray shading indicates values taken from measured/estimated water volume change and molybdenum concentration.

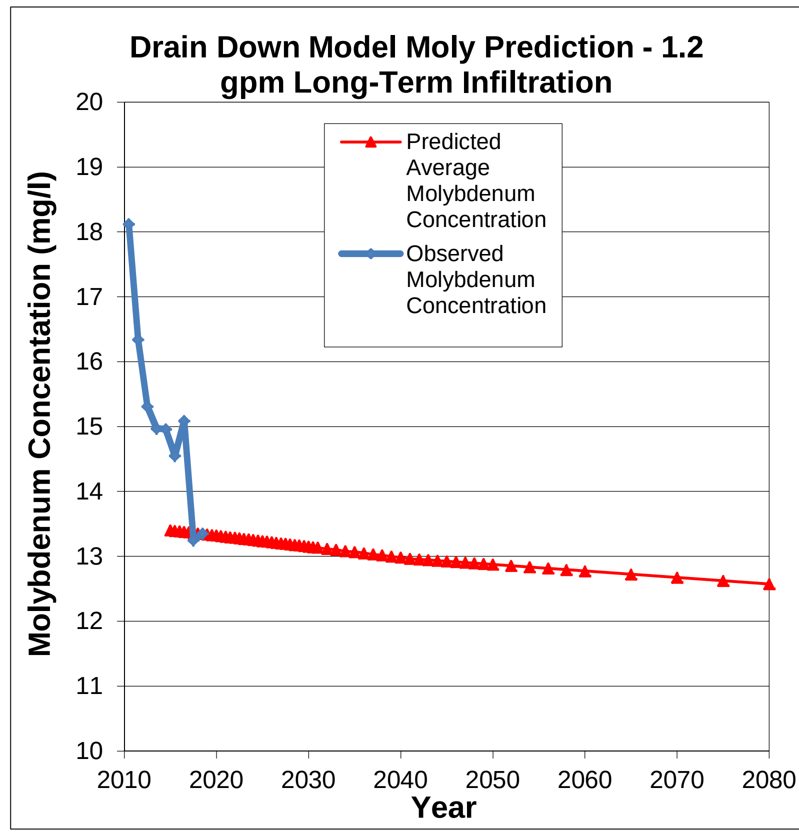
Figure 6

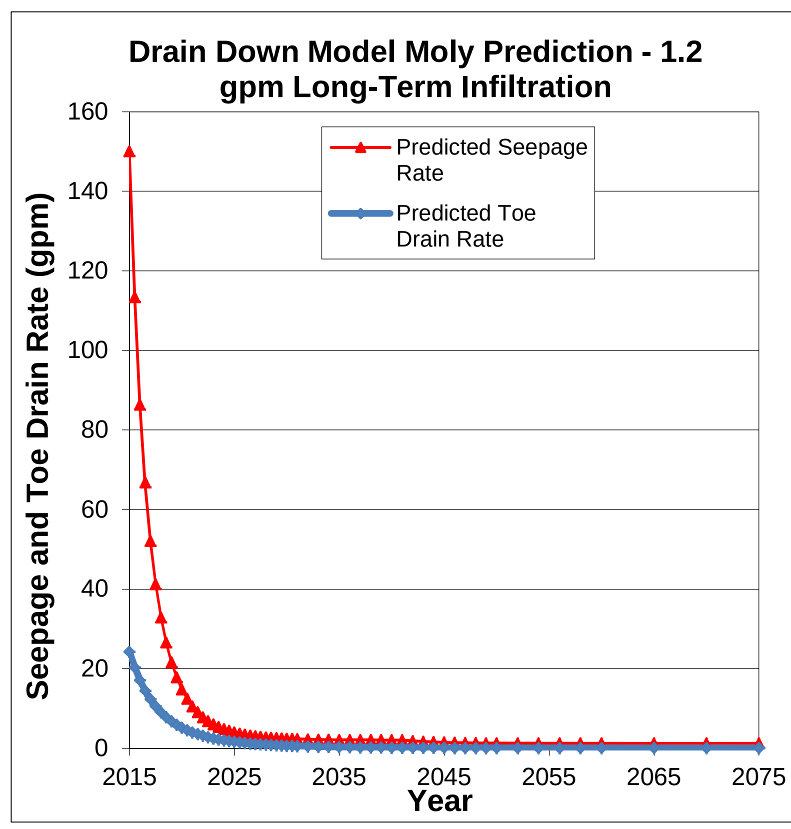
Drain Down Model Molybdenum Prediction with 1.2 gpm Long-Term Infiltration Rate and 0.28 mg/L Molybdenum Concentration in Infiltrate

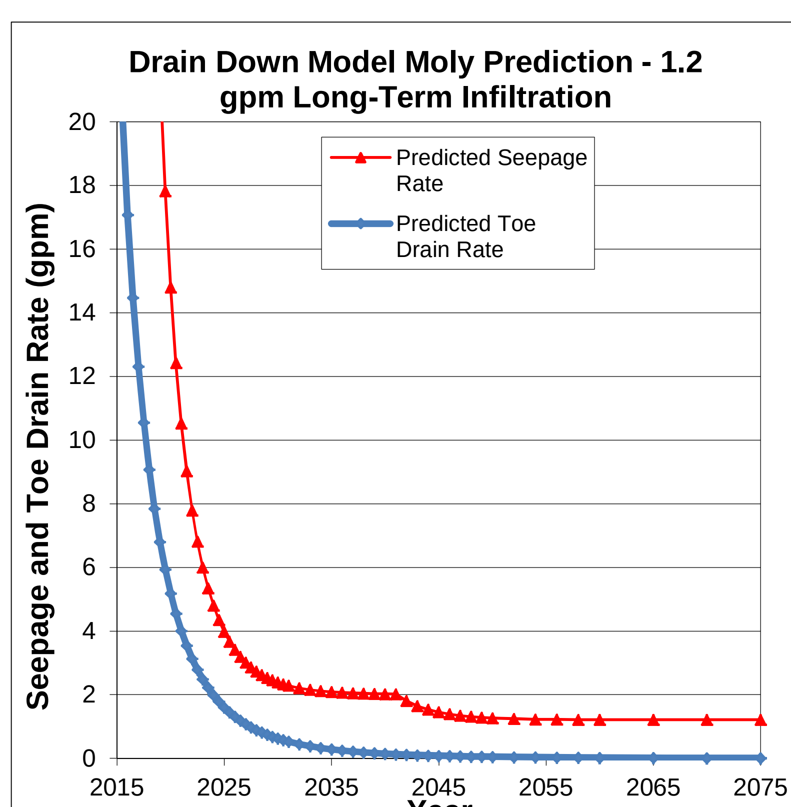
2015 Starting Mo Concentration	13.40
Infiltration Water Mo Conc.	0.28
Humidity Cell Upper Mo Conc. (mg/L)	0.28
Humidity Cell Lower Mo Conc. (mg/L)	0.087

Estimated Drain Down and LTP Molybdenum Concentration

Year	Predicted Average Mo Conc. (mg/l)	Mo Loading Seepage plus Toe Drain (kg/yr)	Infiltration Rate (gpm)	Seepage Rate (gpm)	Toe Drain Rate (gpm)
2012.5	15.31	4937.5	2.0	139.0	23.0
2013.5	14.97	5125.9	2.0	154.0	18.0
2014.5	14.96	6492.4	2.0	200.0	18.0
2015	13.40	4647.7	2.0	150.0	24.2
2015.5	13.39	3564.2	2.0	113.4	20.3
2016	13.39	2756.5	2.0	86.4	17.1
2016.5	13.38	2164.0	2.0	66.8	14.5
2017	13.37	1714.1	2.0	52.1	12.3
2017.5	13.36	1377.7	2.0	41.2	10.6
2018	13.35	1114.9	2.0	32.9	9.1
2018.5	13.35	914.2	2.0	26.6	7.8
2019	13.34	754.5	2.0	21.6	6.8
2019.5	13.33	630.3	2.0	17.8	5.9
2020	13.32	529.7	2.0	14.8	5.2
2020.5	13.31	449.9	2.0	12.4	4.6
2021	13.30	384.7	2.0	10.5	4.0
2021.5	13.30	332.5	2.0	9.0	3.5
2022	13.29	289.0	2.0	7.8	3.1
2022.5	13.28	253.7	2.0	6.8	2.8
2023	13.27	224.0	2.0	6.0	2.5
2023.5	13.26	199.7	2.0	5.3	2.2
2024	13.25	179.0	2.0	4.8	2.0
2024.5	13.24	161.8	2.0	4.3	1.8
2025	13.24	147.1	2.0	4.0	1.6
2025.5	13.23	134.8	2.0	3.7	1.5
2026	13.22	124.2	2.0	3.4	1.3
2026.5	13.21	115.3	2.0	3.2	1.2
2027	13.20	107.5	2.0	3.0	1.1
2027.5	13.19	100.9	2.0	2.9	1.0
2028	13.18	95.1	2.0	2.7	0.9
2028.5	13.18	90.2	2.0	2.6	0.8
2029	13.17	85.9	2.0	2.5	0.7
2029.5	13.16	82.1	2.0	2.5	0.7
2030	13.15	78.9	2.0	2.4	0.6
2030.5	13.14	76.0	2.0	2.3	0.6
2031	13.13	73.5	2.0	2.3	0.5
2032	13.12	69.4	2.0	2.2	0.4
2033	13.10	66.1	2.0	2.2	0.4
2034	13.08	63.6	2.0	2.1	0.3
2035	13.07	61.6	2.0	2.1	0.3
2036	13.05	59.9	2.0	2.1	0.2
2037	13.03	58.6	2.0	2.0	0.2
2038	13.01	57.5	2.0	2.0	0.2
2039	13.00	56.7	2.0	2.0	0.2
2040	12.98	55.9	2.0	2.0	0.1
2041	12.96	55.3	1.2	2.0	0.1
2042	12.95	49.4	1.2	1.8	0.1
2043	12.94	45.0	1.2	1.6	0.1
2044	12.93	41.7	1.2	1.5	0.1
2045	12.92	39.3	1.2	1.4	0.1
2046	12.91	37.5	1.2	1.4	0.1
2047	12.90	36.1	1.2	1.3	0.1
2048	12.89	35.0	1.2	1.3	0.1
2049	12.88	34.2	1.2	1.3	0.1
2050	12.87	33.6	1.2	1.3	0.0
2052	12.85	32.7	1.2	1.2	0.0
2054	12.83	32.1	1.2	1.2	0.0
2056	12.81	31.7	1.2	1.2	0.0
2058	12.79	31.4	1.2	1.2	0.0
2060	12.77	31.2	1.2	1.2	0.0
2065	12.72	30.9	1.2	1.2	0.0
2070	12.67	30.7	1.2	1.2	0.0
2075	12.62	30.5	1.2	1.2	0.0
2080	12.57	30.3	1.2	1.2	0.0
2085	12.52	30.2	1.2	1.2	0.0
2090	12.47	30.0	1.2	1.2	0.0
2095	12.43	29.9	1.2	1.2	0.0
2100	12.38	29.8	1.2	1.2	0.0
2110	12.28	29.5	1.2	1.2	0.0
2120	12.18	29.3	1.2	1.2	0.0







Note: Yellow shading indicates pumping from toe drain sumps will likely be discontinued at low rates.
Gray shading indicates values taken from measured/estimated water volume change and molybdenum concentration.

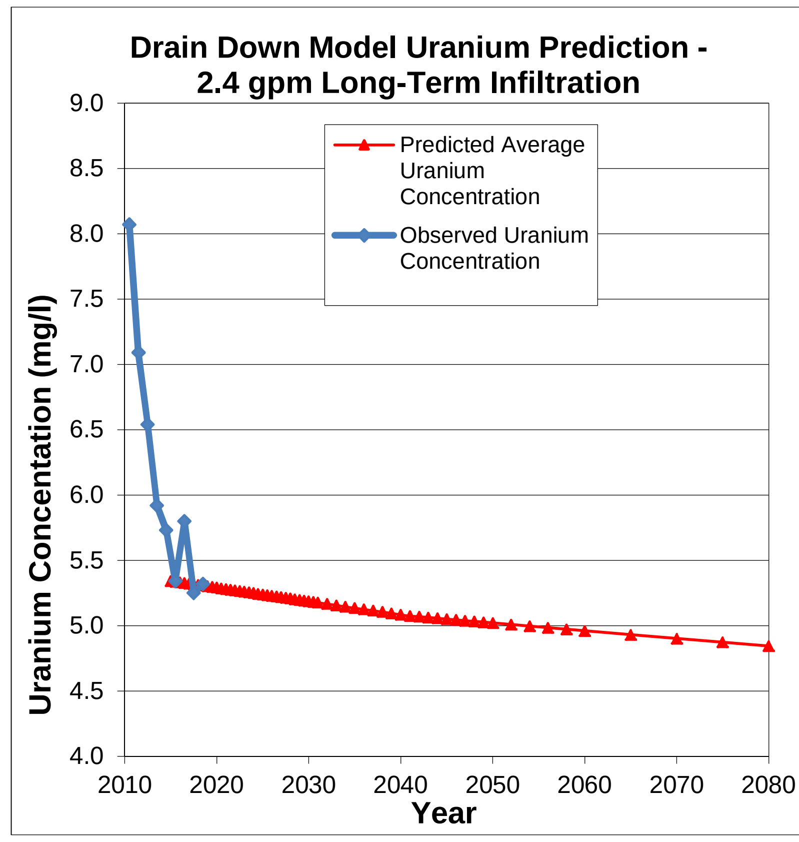
Figure 7

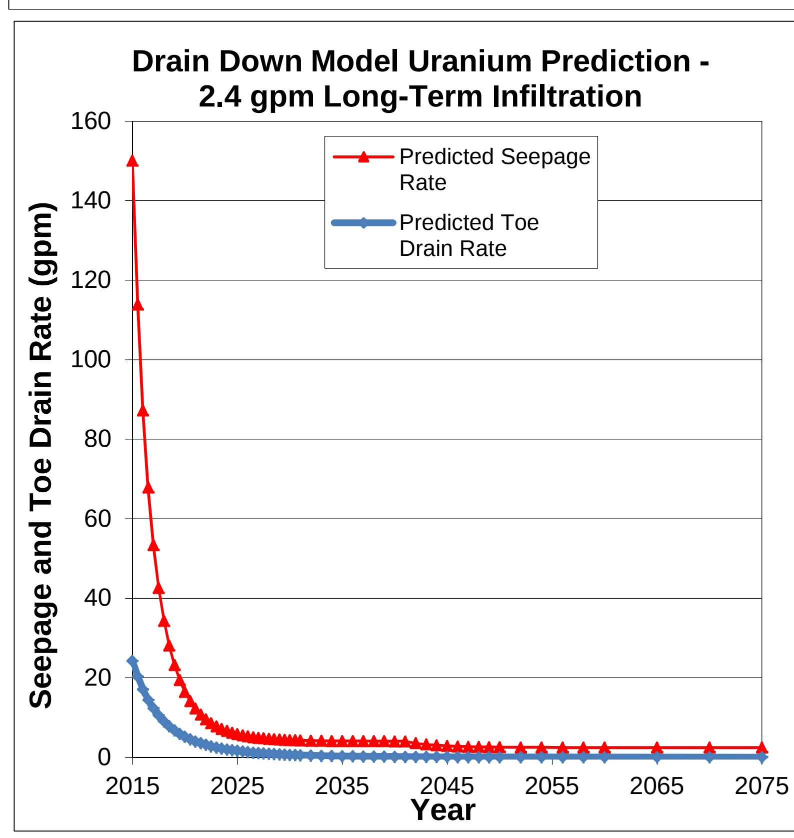
Drain Down Model Uranium Prediction with 4.0 gpm Short-Term Infiltration Rate, 2.4 gpm Long-Term Infiltration Rate and 1.26 mg/L Uranium Concentration in Infiltrate

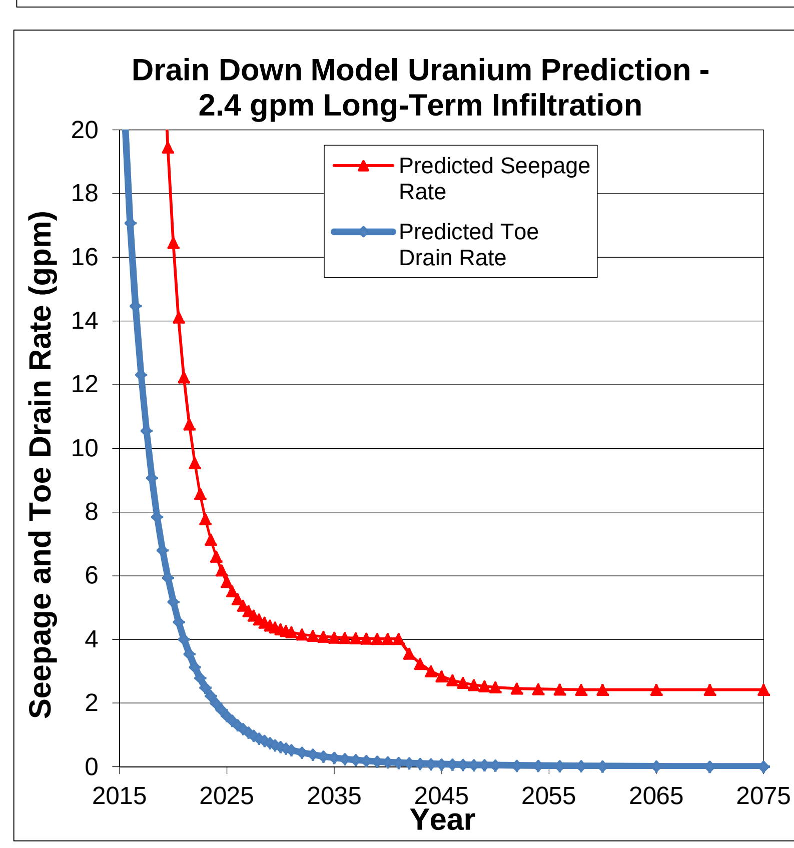
2015 Average U Concentration	5.34
Infiltration Water U Conc.	1.26
Humidity Cell Upper U Conc. (mg/L)	1.26
Humidity Cell Lower U Conc. (mg/L)	0.11

Estimated Drain Down and LTP Uranium Concentration

Year	Average Uranium Conc. (mg/l)	U Loading Seepage plus Toe Drain (kg/yr)	Infiltration Rate (gpm)	Seepage Rate (gpm)	Toe Drain Rate (gpm)
2012.5	6.54	2109.2	4.0	139.0	23.0
2013.5	5.92	2027.1	4.0	154.0	18.0
2014.5	5.73	2486.7	4.0	200.0	18.0
2015	5.34	1852.1	4.0	150.0	24.2
2015.5	5.34	1425.1	4.0	113.9	20.3
2016	5.33	1106.6	4.0	87.2	17.1
2016.5	5.33	872.9	4.0	67.9	14.5
2017	5.32	695.4	4.0	53.3	12.3
2017.5	5.32	562.6	4.0	42.6	10.6
2018	5.31	458.9	4.0	34.3	9.1
2018.5	5.31	379.7	4.0	28.1	7.8
2019	5.30	316.6	4.0	23.2	6.8
2019.5	5.30	267.6	4.0	19.4	5.9
2020	5.29	227.9	4.0	16.5	5.2
2020.5	5.29	196.4	4.0	14.1	4.6
2021	5.28	170.7	4.0	12.2	4.0
2021.5	5.28	150.1	4.0	10.8	3.5
2022	5.27	133.0	4.0	9.5	3.1
2022.5	5.26	119.1	4.0	8.6	2.8
2023	5.26	107.4	4.0	7.8	2.5
2023.5	5.25	97.9	4.0	7.1	2.2
2024	5.25	89.8	4.0	6.6	2.0
2024.5	5.24	83.0	4.0	6.2	1.8
2025	5.24	77.3	4.0	5.8	1.6
2025.5	5.23	72.5	4.0	5.5	1.5
2026	5.23	68.4	4.0	5.3	1.3
2026.5	5.22	65.0	4.0	5.1	1.2
2027	5.22	62.0	4.0	4.9	1.1
2027.5	5.21	59.4	4.0	4.7	1.0
2028	5.21	57.2	4.0	4.6	0.9
2028.5	5.20	55.3	4.0	4.5	0.8
2029	5.20	53.7	4.0	4.4	0.7
2029.5	5.19	52.3	4.0	4.4	0.7
2030	5.19	51.0	4.0	4.3	0.6
2030.5	5.18	49.9	4.0	4.3	0.6
2031	5.18	49.0	4.0	4.2	0.5
2032	5.17	47.4	4.0	4.2	0.4
2033	5.16	46.2	4.0	4.1	0.4
2034	5.15	45.2	4.0	4.1	0.3
2035	5.14	44.4	4.0	4.1	0.3
2036	5.12	43.8	4.0	4.0	0.2
2037	5.11	43.2	4.0	4.0	0.2
2038	5.10	42.8	4.0	4.0	0.2
2039	5.09	42.4	4.0	4.0	0.2
2040	5.08	42.1	4.0	4.0	0.1
2041	5.07	41.8	2.4	4.0	0.1
2042	5.07	37.0	2.4	3.6	0.1
2043	5.06	33.5	2.4	3.2	0.1
2044	5.06	31.1	2.4	3.0	0.1
2045	5.05	29.3	2.4	2.8	0.1
2046	5.04	28.0	2.4	2.7	0.1
2047	5.04	27.1	2.4	2.6	0.1
2048	5.03	26.3	2.4	2.6	0.1
2049	5.03	25.8	2.4	2.5	0.1
2050	5.02	25.4	2.4	2.5	0.0
2052	5.01	24.9	2.4	2.5	0.0
2054	5.00	24.5	2.4	2.4	0.0
2056	4.98	24.3	2.4	2.4	0.0
2058	4.97	24.2	2.4	2.4	0.0
2060	4.96	24.0	2.4	2.4	0.0
2065	4.93	23.8	2.4	2.4	0.0
2070	4.90	23.6	2.4	2.4	0.0
2075	4.87	23.5	2.4	2.4	0.0
2080	4.84	23.3	2.4	2.4	0.0
2085	4.81	23.2	2.4	2.4	0.0
2090	4.79	23.0	2.4	2.4	0.0
2095	4.76	22.9	2.4	2.4	0.0
2100	4.73	22.7	2.4	2.4	0.0
2110	4.67	22.5	2.4	2.4	0.0
2120	4.62	22.2	2.4	2.4	0.0







Note: Yellow shading indicates pumping from toe drain sumps will likely be discontinued at low rates.
Gray shading indicates values taken from measured/estimated water volume change and uranium concentration.

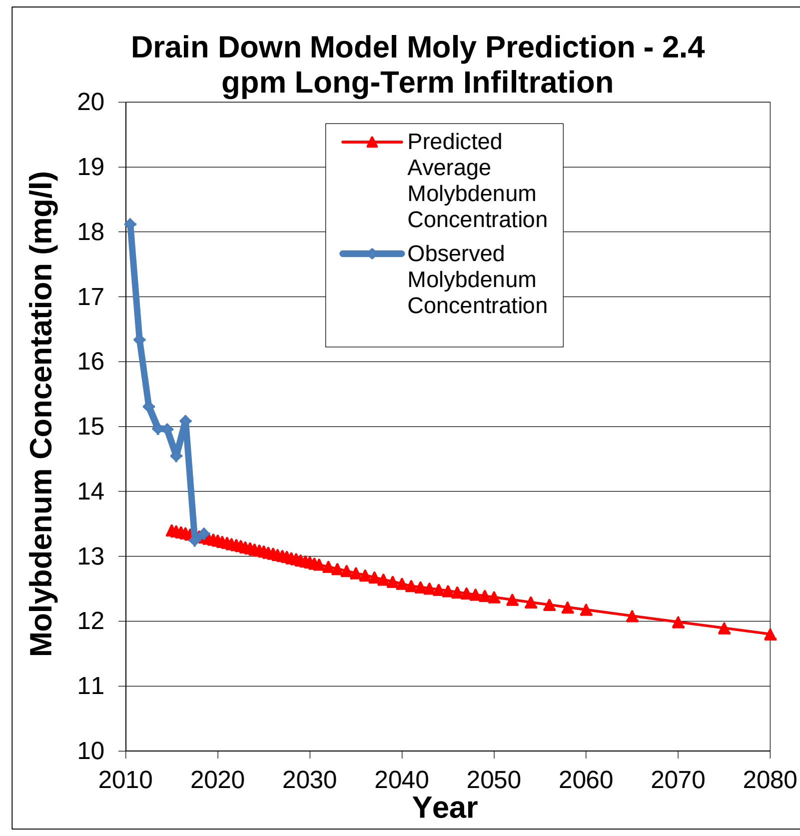
Figure 8

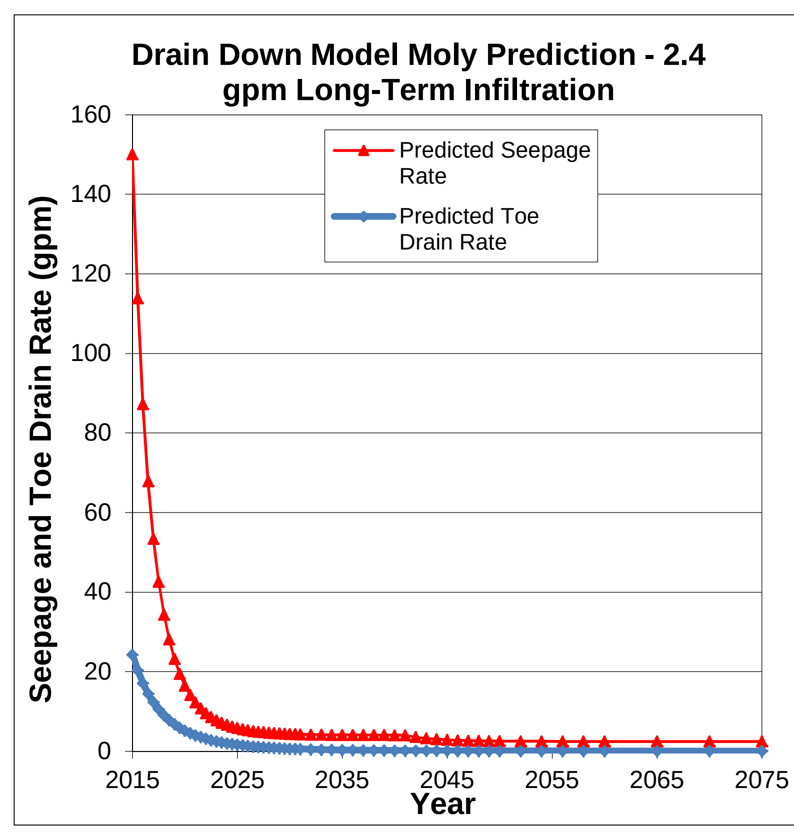
Drain Down Model Molybdenum Prediction with 4.0 gpm Short-Term Infiltration Rate, 2.4 gpm Long-Term Infiltration Rate and 0.28 mg/L Molybdenum Concentration in Infiltrate

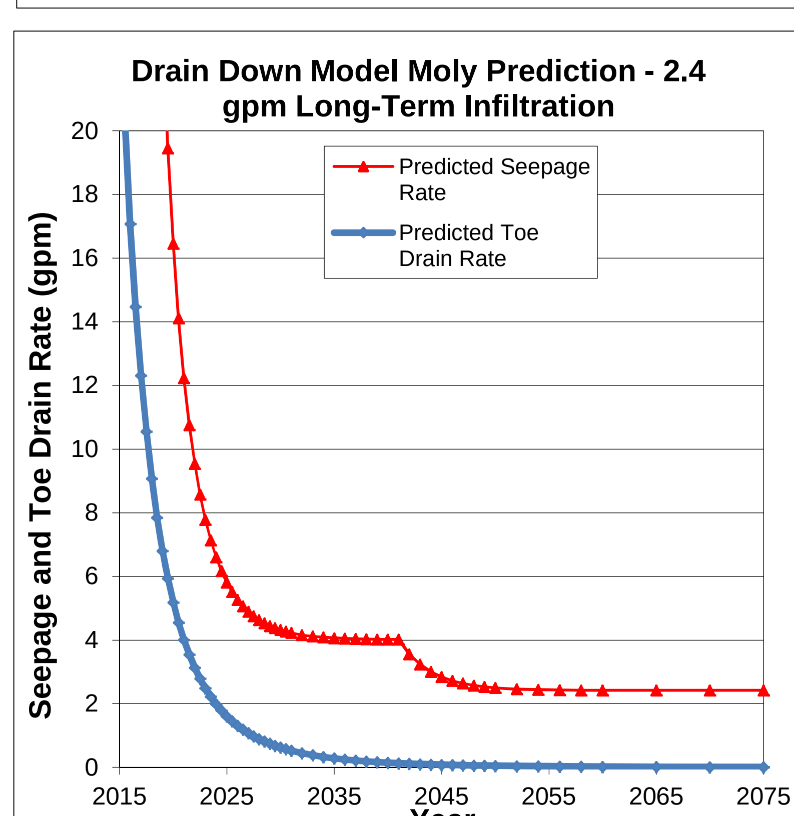
2015 Starting Mo Concentration	13.40
Infiltration Water Mo Conc.	0.28
Humidity Cell Upper Mo Conc. (mg/L)	0.28
Humidity Cell Lower Mo Conc. (mg/L)	0.087

Estimated Drain Down and LTP Molybdenum Concentration

Year	Average Moly Conc. (mg/l)	Mo Loading Seepage plus Toe Drain (kg/yr)	Infiltration Rate (gpm)	Seepage Rate (gpm)	Toe Drain Rate (gpm)
2012.5	15.31	4937.5	4.0	139.0	23.0
2013.5	14.97	5125.9	4.0	154.0	18.0
2014.5	14.96	6492.4	4.0	200.0	18.0
2015	13.40	4647.7	4.0	150.0	24.2
2015.5	13.39	3575.2	4.0	113.9	20.3
2016	13.37	2775.6	4.0	87.2	17.1
2016.5	13.36	2188.9	4.0	67.9	14.5
2017	13.34	1743.3	4.0	53.3	12.3
2017.5	13.32	1410.1	4.0	42.6	10.6
2018	13.31	1149.8	4.0	34.3	9.1
2018.5	13.29	951.1	4.0	28.1	7.8
2019	13.27	792.9	4.0	23.2	6.8
2019.5	13.26	669.9	4.0	19.4	5.9
2020	13.24	570.4	4.0	16.5	5.2
2020.5	13.23	491.4	4.0	14.1	4.6
2021	13.21	426.9	4.0	12.2	4.0
2021.5	13.19	375.3	4.0	10.8	3.5
2022	13.18	332.4	4.0	9.5	3.1
2022.5	13.16	297.6	4.0	8.6	2.8
2023	13.14	268.4	4.0	7.8	2.5
2023.5	13.12	244.5	4.0	7.1	2.2
2024	13.11	224.1	4.0	6.6	2.0
2024.5	13.09	207.3	4.0	6.2	1.8
2025	13.07	192.9	4.0	5.8	1.6
2025.5	13.06	181.0	4.0	5.5	1.5
2026	13.04	170.6	4.0	5.3	1.3
2026.5	13.02	162.0	4.0	5.1	1.2
2027	13.01	154.5	4.0	4.9	1.1
2027.5	12.99	148.1	4.0	4.7	1.0
2028	12.97	142.5	4.0	4.6	0.9
2028.5	12.96	137.8	4.0	4.5	0.8
2029	12.94	133.6	4.0	4.4	0.7
2029.5	12.92	130.1	4.0	4.4	0.7
2030	12.91	126.9	4.0	4.3	0.6
2030.5	12.89	124.2	4.0	4.3	0.6
2031	12.87	121.8	4.0	4.2	0.5
2032	12.84	117.8	4.0	4.2	0.4
2033	12.81	114.7	4.0	4.1	0.4
2034	12.77	112.2	4.0	4.1	0.3
2035	12.74	110.2	4.0	4.1	0.3
2036	12.71	108.5	4.0	4.0	0.2
2037	12.68	107.2	4.0	4.0	0.2
2038	12.64	106.0	4.0	4.0	0.2
2039	12.61	105.0	4.0	4.0	0.2
2040	12.58	104.1	4.0	4.0	0.1
2041	12.54	103.4	2.4	4.0	0.1
2042	12.53	91.4	2.4	3.6	0.1
2043	12.51	82.9	2.4	3.2	0.1
2044	12.49	76.8	2.4	3.0	0.1
2045	12.47	72.3	2.4	2.8	0.1
2046	12.45	69.1	2.4	2.7	0.1
2047	12.43	66.7	2.4	2.6	0.1
2048	12.41	65.0	2.4	2.6	0.1
2049	12.39	63.7	2.4	2.5	0.1
2050	12.37	62.6	2.4	2.5	0.0
2052	12.33	61.3	2.4	2.5	0.0
2054	12.29	60.4	2.4	2.4	0.0
2056	12.25	59.8	2.4	2.4	0.0
2058	12.22	59.4	2.4	2.4	0.0
2060	12.18	59.0	2.4	2.4	0.0
2065	12.08	58.4	2.4	2.4	0.0
2070	11.99	57.8	2.4	2.4	0.0
2075	11.89	57.3	2.4	2.4	0.0
2080	11.80	56.8	2.4	2.4	0.0
2085	11.71	56.3	2.4	2.4	0.0
2090	11.62	55.9	2.4	2.4	0.0
2095	11.53	55.4	2.4	2.4	0.0
2100	11.44	55.0	2.4	2.4	0.0
2110	11.26	54.1	2.4	2.4	0.0
2120	11.08	53.3	2.4	2.4	0.0







Note: Yellow shading indicates pumping from toe drain sumps will likely be discontinued at low rates.
Gray shading indicates values taken from measured/estimated water volume change and molybdenum concentration.