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date: *November 6, 2023*

to: *WIPP Records Center*

from: *James Bethune* *Signature on file*

subject: *Screening Calculation for FEP W23 Subsidence*

This memorandum documents the impact of WIPP FEP W23 *Subsidence* on long-term repository performance. FEP W23 is currently screened out of Performance Assessment (PA) calculations on the basis of low consequence to repository performance. Calculations presented within the screening argument conservatively assess that repository excavations may locally produce an order of magnitude increase in Culebra transmissivity values through subsidence and strain induced fracture expansion (Appendix SCR-2024). The RPPCRW23 analysis documented in this memorandum calculates the impact this would have on radionuclide transport through the Culebra and on long-term repository performance in support of the AP-199 FEPs screening reassessment for the Compliance Recertification Application - 2024 (CRA-2024) (Kirkes 2022). Results are presented from WIPP PA codes DTRKMF, SECOTP2D, and CCDFGF and compared to those from the Replacement Panels Planned Change Request (RPPCR) PA (Brunell et al. 2023). Calculations were done for Replicate 1 only. Unless otherwise noted, input files, database parameters, calculations, hardware, and software are identical to those used in the RPPCR Culebra flow and transport (Bethune 2023) and CCDFGF (Brunell and Zeitler 2023) calculations. The RPPCRW23 is categorized as a Programmatic Decision analysis under NP 9-1 (Nielsen 2020).

Files are archived in the CVS module /data/cvs/CVSLIB/WIPP_EXTERNAL/RPPCRW23/

Procedure

The repository waste panels were grouped into three waste regions: 1) the original waste region with panels 1 through 10; 2) the replacement panels region with panels 11 and 12; and 3) the additional panels region with panels 13 through 19 (Figure 1). UTM coordinates of the waste region corners were obtained from the repository layout data in Bethune and Brunell (2022). The script *define_repository_footprint.py* uses the panel coordinates and the coordinates of the Culebra flow 100-m grid cells to write a matrix of indicator values to the file *repository_footprint.txt* with values for each grid cell of 1 if the cell is within the repository footprint or 0 if it is not (Appendix A).

The script *repository subsidence.py* multiplies Culebra transmissivity by the user input value in the repository footprint cells (Appendix B). The Culebra flow model run control script was modified to execute the script *repository_subsidence.py* on each realization of non-mining Culebra transmissivity using the subsidence transmissivity factor 10. After the repository subsidence script is executed, the Culebra PA model workflow is followed as for the RPPCR, including the mining modifications, Culebra transport, and CCDFGF probabilistic release calculations.

Results

DTRKMF particle tracks of conservative tracers released into the four Culebra mass release points (CRP1 through CRP4) above the WIPP waste regions are used to visualize Culebra flow fields and quantify the impact of subsidence on flow. The RPPCRW23 particle tracks are shown with travel times to the LWB summarized into exceedance plots and compared to the RPPCR results in Figure 2 for Partial Mining and Figure 3 for Full Mining conditions. Particles generally travel southward in both full and partial mining from CRP1, CRP2, and CRP3, and in partial mining from CRP4. The CRP4 full mining particles travel toward the western extent of the LWB before turning sharply to the south. In all release points and both mining scenarios, particle travel times to the LWB are shorter than in the RPPCR at all probability levels, indicating faster flow consistent with higher transmissivity values.

SECOTP2D simulates dual-domain mass transport of radionuclides through the Culebra from discrete locations above the WIPP repository to the LWB over 10,000 years. Consistent with the RPPCR, simulations consisted of release of 1.0 kg of isotopes Am-241, Pu-239, Th-230, and U-234 for each vector under each combination of release point and mining condition scenario. The cumulative mass discharged to the LWB is shown for isotopes Pu-239 (Figure 4) and U-234 (Figure 5) and compared to the RPPCR. The results show that larger fractions of mass are reaching the LWB in the RPPCRW23 analysis for all release points and mining scenarios, consistent with the DTRKMF results indicating faster flow to the LWB.

The WIPP code CCDFGF uses stochastic processes to simulate intrusion events by drilling and the occurrence of mining for natural resources. CCDFGF assembles the results from the deterministic models, including radionuclide transport to and through the Culebra, and selects the most appropriate scenario data provided by these models to use as the simulation of a 10,000-year future progresses. Ten thousand potential futures are simulated and used to create distributions of potential releases, and then compiled into a single CCDF of potential releases. The RPPCR CCDFGF results show that the RPPCRW23 releases through the Culebra are increased relative to the RPPCR by approximately an order of magnitude near the lower probability release limit (Figure 6). However, releases from the Culebra remain extremely low, such that when they are combined with results from the other release mechanisms into a total release curve, there is no discernable difference between the RPPCR and RPPCRW23 (Figure 7).

Summary

Subsidence within the Culebra induced by repository excavation has been conservatively assessed to potentially result in a local order of magnitude increase in Culebra transmissivity due to strain and fracture expansion above the excavations. The analysis RPPCRW23 indicates that if such an increase were to be implemented in the RPPCR PA calculations, this could potentially increase releases from the Culebra by an order of magnitude. However, because the releases from the Culebra remain an insignificant portion of total releases, screening out Culebra subsidence due to repository excavation has no impact on compliance determined with the RPPCR PA.

References

Bethune, J., and S. Brunell. 2022. Determination of Culebra Release Points Number and Locations in a Repository with New Panels. ERMS 576493. Carlsbad, NM: Sandia National Laboratories.

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Brunell, S., J. Bethune, P. Docherty, D. Kicker, S. Kim, S. King, J. Long, T. Zeilter. 2023. Summary Report for the 2023 Replacement Panels Planned Change Request Performance Assessment. ERMS 579729. Carlsbad, NM: Sandia National Laboratories.

Brunell, S., and T.R. Zeitler. 2023. Analysis Report for Normalized Releases in the Replacement Panels Planned Change Request (RPPCR). ERMS 579727. Carlsbad, NM: Sandia National Laboratories.

Kirkes, G.R., 2022. AP-199 Analysis Plan for the Reassessment of Features, Events, and Processes for the 2024 Compliance Recertification Application. ERMS 578587. Carlsbad, NM: Sandia National Laboratories.

Kirkes, G.R. 2023. Features, Events, and Processes Analysis for the Replacement Panels Planned Change Request Performance Assessment. ERMS 579720. Carlsbad, NM: Sandia National Laboratories.

Nielsen, S.R. 2020. Nuclear Waste Management Procedure NP 9-1 Analyses, Revision 11. Carlsbad, NM: Sandia National Laboratories.

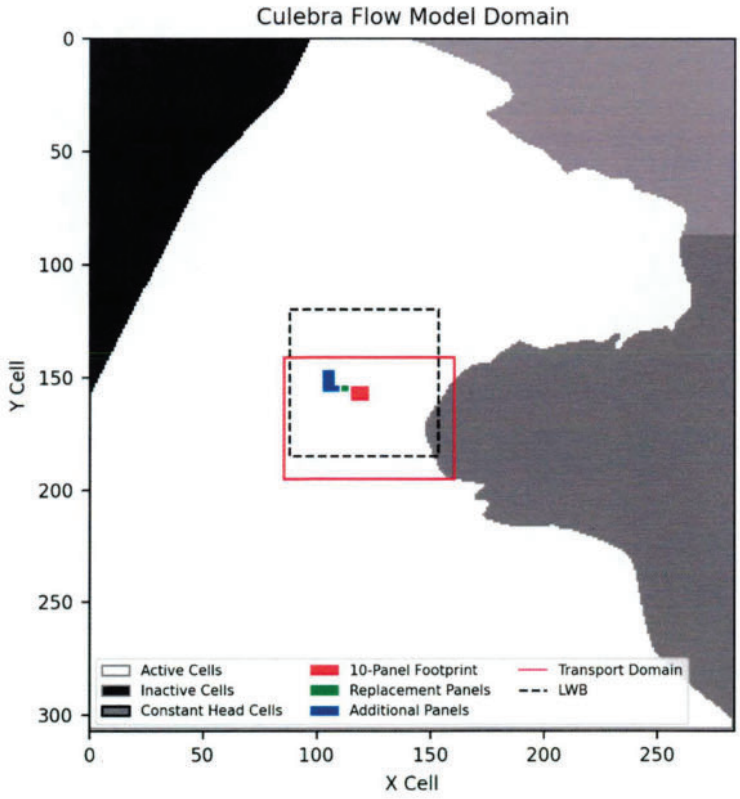


Figure 3 from Bethune (2023)

Figure 1. 19-Panel WIPP Repository Footprint

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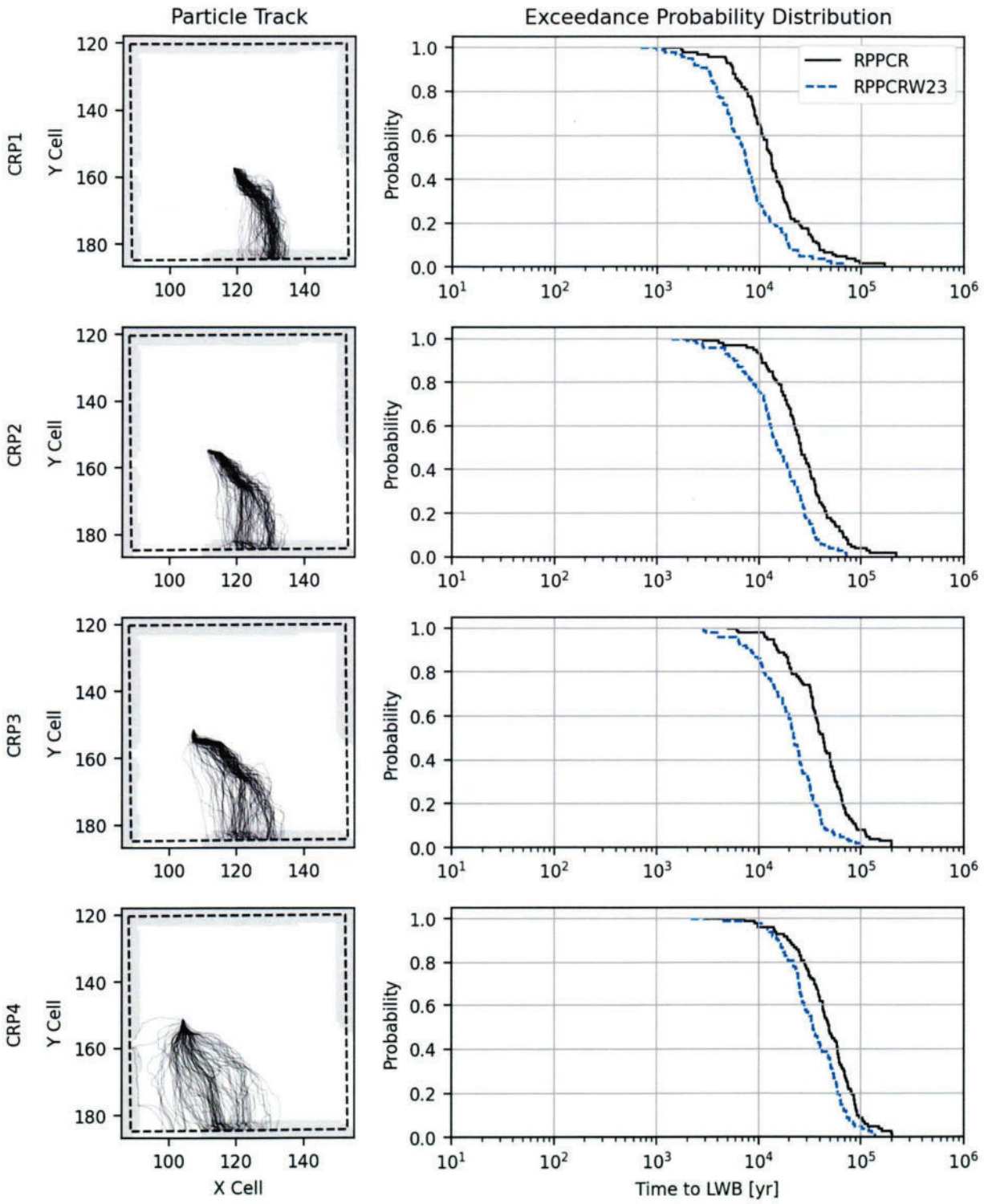


Figure 2. Partial mining particle tracks and travel times

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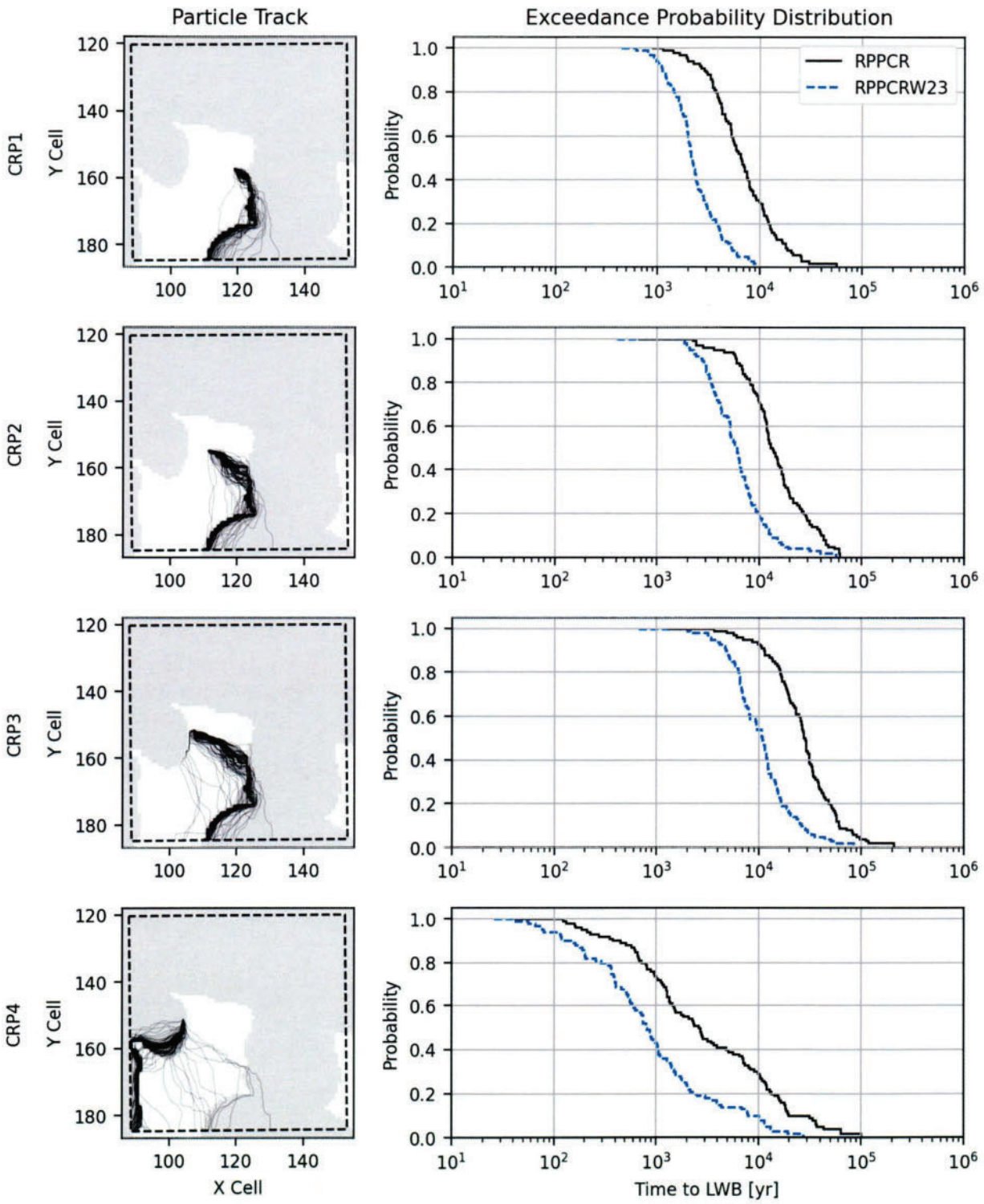


Figure 3. Full mining particle tracks and travel times

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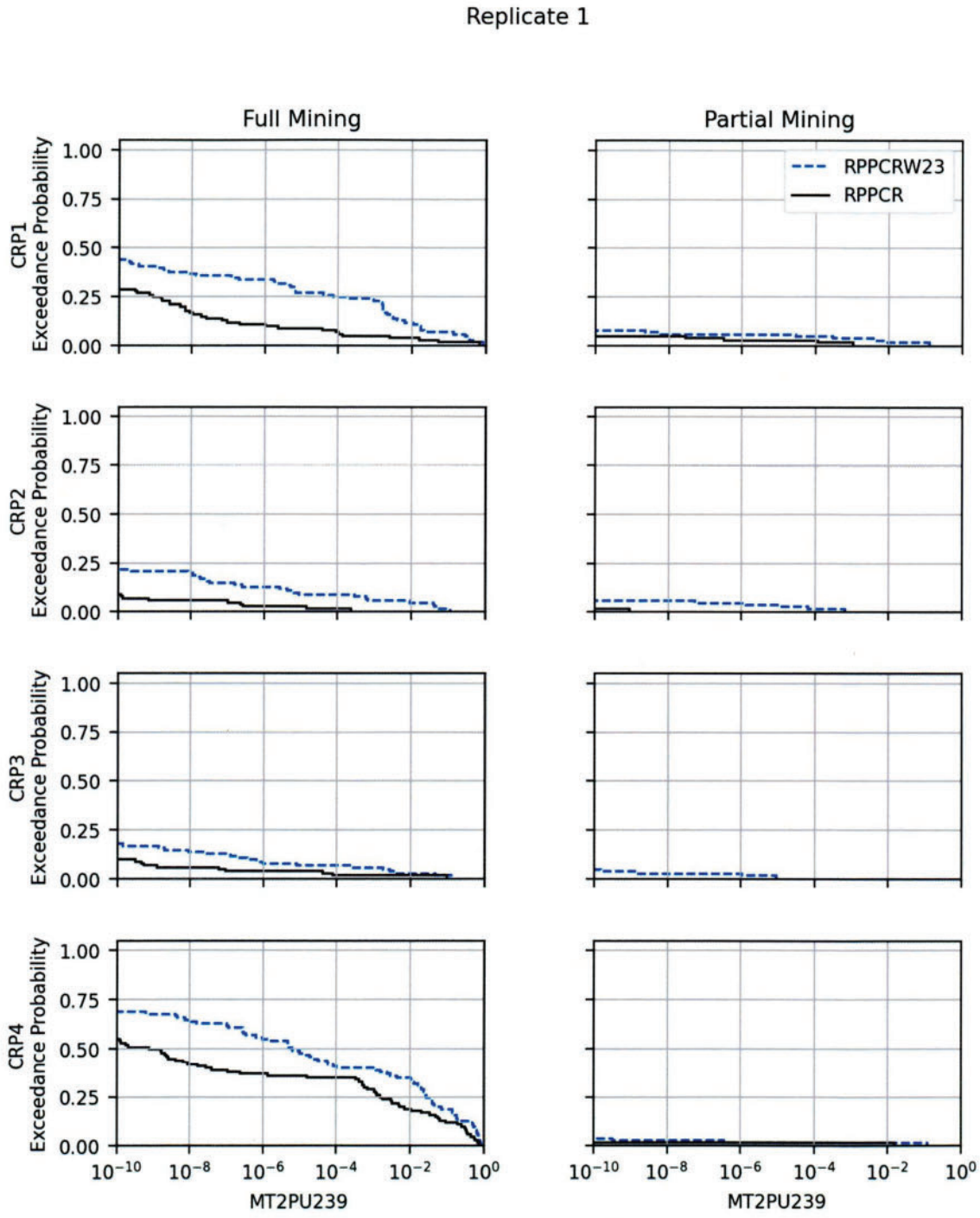


Figure 4. Cumulative Pu-239 mass [kg] discharge to LWB by year 10,000

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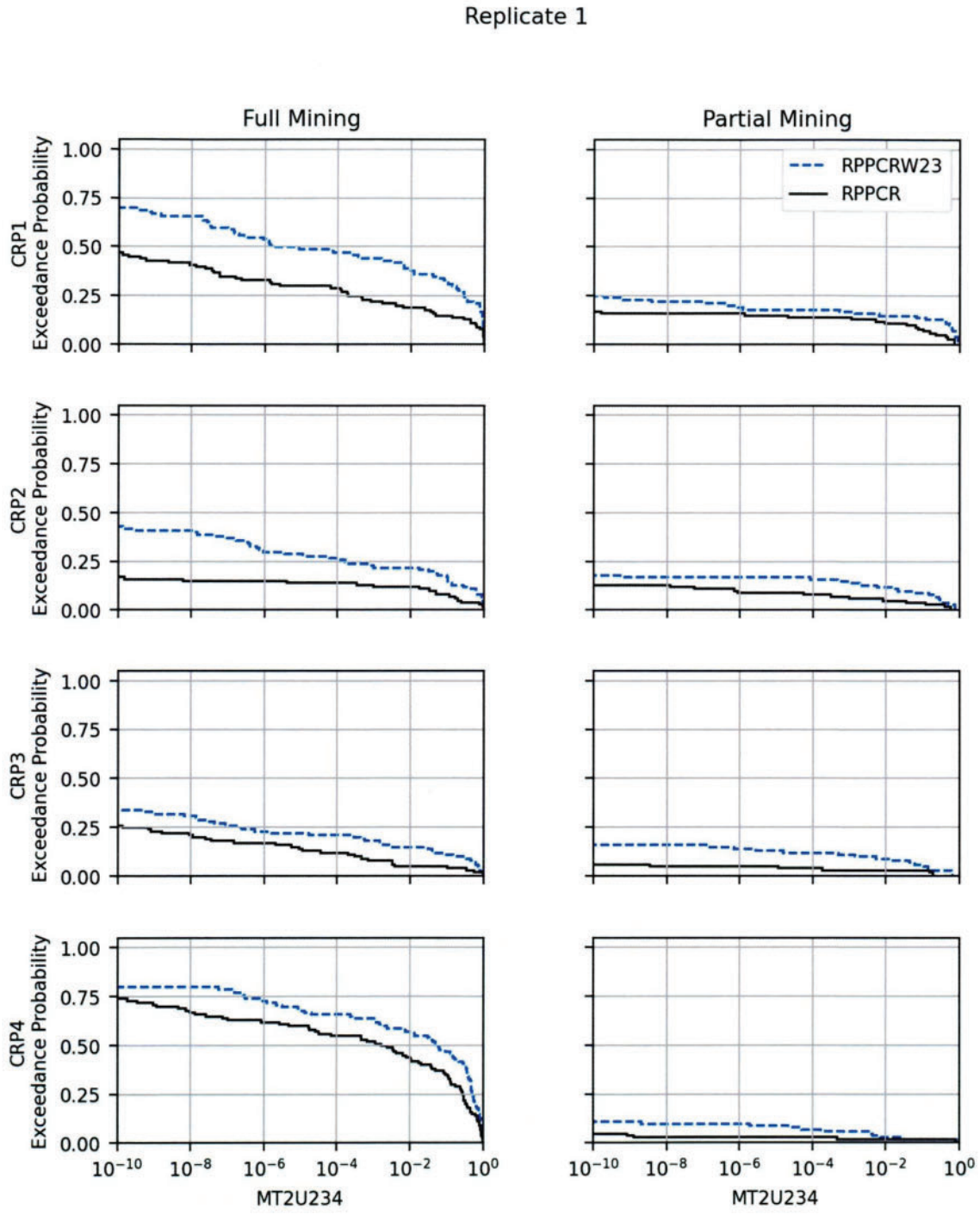


Figure 5. Cumulative U-234 mass [kg] discharge to LWB by year 10,000

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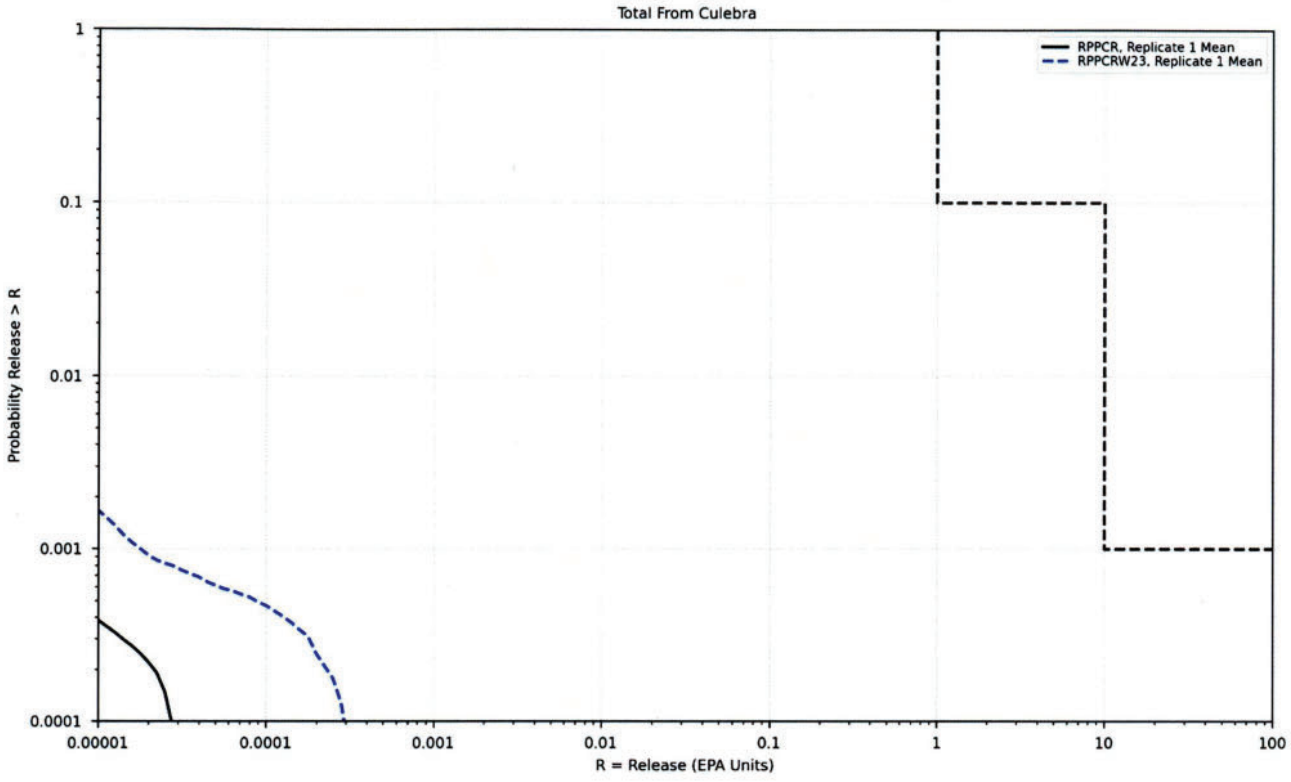


Figure 6. Releases from the Culebra

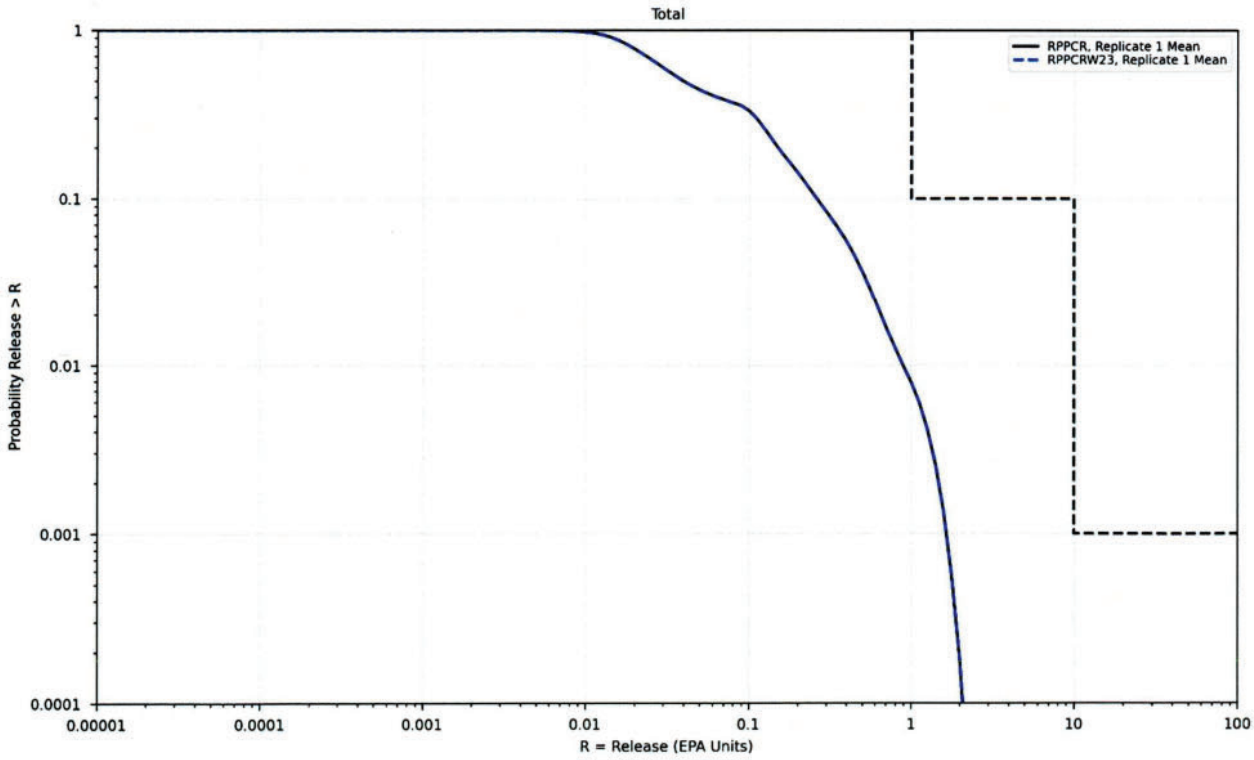


Figure 7. Total Releases

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Appendix A. define_repository_footprint.py

```
# -*- coding: utf-8 -*-
"""
Created on Tue Oct 10 16:44:31 2023

Create repository footprint for subsidence FEP testing

Using expansion area

1 : repository
0 : no repository

@author: jbethu
"""

from shapely.geometry import Point
from shapely.geometry.polygon import Polygon
import matplotlib.pyplot as plt
import numpy as np


# model is 284x307 with 100m spacing
# cell center will be 50m off-edge
dl = 100
nx = 284
ny = 307
cx = np.linspace(dl/2, (nx)*dl-50, num=nx) + 601700 # shift origin
cy = 3597100 - np.linspace(dl/2, (ny)*dl-50, num=ny)


# original
# Panel 8 -> Panel 1 -> Panel 4 ->
#    Panel 5 -> Panel 8
orig = [
    (613211.21, 3581698.42), (613984.12, 3581706.58), (613991.63, 3581075.68),
    (613218.11, 3581068.4), (613211.21, 3581698.42)
]
orig_p = Polygon(orig)


# replacement panels
# panel 11 TR, panel 11 BR, panel 12 BL,
# panel 12 TL, panel 11 TR,
rep = [
    (613082.86, 3581755.58), (613086.39, 3581499.59), (612772.82, 3581496.25),
    (612769.36, 3581750.25), (613082.86, 3581755.58)
]
rep_p = Polygon(rep)

    # additional panels
    # Panel 17 TL ->  Panel 19 TR -> Panel 14 TR
    # -> Panel 13 TR -> Panel 13 BR -> Panel 16 BL
    # -> Panel 17 TL
add = [
    (611952.01, 3582425.44), (612468.16, 3582431.6), (612477.11, 3581746.47),
    (612680.18, 3581749.02), (612681.3, 3581495.44), (611963.33, 3581487.65),
```

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```
    (611952.01, 3582425.44)
]
add_p = Polygon(add)

matout = np.zeros((nx, ny))
for i,x in enumerate(cx):
    for j,y in enumerate(cy):
        p = Point(x,y)
        if orig_p.contains(p):
            matout[i,j] = 1
            continue
        if rep_p.contains(p):
            matout[i,j] = 1
            continue
        if add_p.contains(p):
            matout[i,j] = 1

np.savetxt("repository_footprint.txt", matout)

#plt.imshow(matout)
```

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Appendix B. repository_subsidence.py

```
# Multiply t-field by repository subsidence
# impact factor

import os
import numpy as np
from sys import argv

# subsidence impact on t-field
impact_factor = float(argv[1])

# t-field
tfn = os.path.join("mf6_head.npf_k.txt")
t = np.loadtxt(tfn)


# 1- repo; 0- no repo
footprintfn = os.path.join("repository_footprint.txt")
footprint = np.loadtxt(footprintfn).T

# multiply by user input factor
impact_footprint = impact_factor*footprint
impact_footprint[impact_footprint==0] = 1

# t-field
tout = impact_footprint*t

# write output
np.savetxt(
    fname=tfn,
    X=tout,
    fmt="%.11e"
)
```

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