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ENVIRONMENTAL CALCULATION COVER PAGE

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ENVIRONMENTAL CALCULATION COVER PAGE (CONTINUED)

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Environmental Calculation File

Hanford Site-wide Natural Recharge Boundary Condition for Groundwater Models

Contents

1 Purpose **1**

2 Background **1**

3 Methodology **2**

3.1 Extend the sitewide datasets for soils and vegetation 2

3.2 Enhance data on surface condition 2

3.3 Rank Data Sources for Use in Defining Surface Condition 3

3.4 Automate the Calculation of Recharge Sitewide 4

4 Assumptions and Inputs **4**

4.1 Spatial Data sources 4

4.1.1 The Geodatabase 7

4.1.2 NAIP Natural Color Digital Aerial Imagery 8

4.1.3 USGS Black and White Aerial Photography 8

4.1.4 Soils8

4.1.5 Vegetation Classification 11

4.1.6 Cleanup Verification Package (CVP) Boundaries 11

4.1.7 Waste Sites (*ehsit*) and Facilities (*bggenxs*, *bggensit*) 11

4.2 Non-spatial Data Sources 11

4.2.1 Hanford Disposition Baseline 11

4.2.2 Recharge Rates 12

4.2.3 Vegetation changes due to Secondary Succession 15

4.3 Data Interpretation: Surface Condition to Disposition 15

4.4 Data Interpretation: Surface Condition to Recharge 17

5 Software Applications **21**

5.1 Approved Software 21

6 Calculation **21**

6.1 Extend the 'sitewide' datasets for soils and vegetation 22

6.2 Enhance data on surface condition 23

6.2.1 Surface Condition from 2011 NAIP 24

6.2.2 Surface Condition from 1943 USGS 29

6.3 Rank Data Sources for Use in Defining Surface Condition 31
6.4 Automate the Calculation of Recharge Sitewide 33
7 Results/Conclusions 37
7.1 Results 37
7.2 Conclusions 41
7.3 Future Considerations 43
7.3.1 Expand the Data Sources 43
7.3.2 Refine the current automation process 44
8 References 45

Attachments

A. **Digital Content** 47

Figures

Figure 1 SSURGO soils data downloaded for use in filling data gaps within the model domain 9
Figure 2 Estimated Recharge Rates at the Hanford Site for Each Combination of Soil Type and Vegetation/Land Use (Table 4.1 in PNNL-10285-UC2010). 13
Figure 3 Estimated Recharge Rates by Soil Type/Sediment and Vegetation Condition in Each Hanford Area (Table 4.15 in PNNL-14072rev1). Significant secondary soil types and their associated recharge estimates are shown in parentheses but are not used in the current calculation 14
Figure 4 Irrigation Recharge Scenario Phases and Recharge Rates (Table 4 from ECF-Hanford-11-0063-Rev 06) . 15
Figure 5 Gaps in the vegetation and soils data within the model domain boundary. 22
Figure 6 Small, sliver-like areas (in red) of hte soils classification that remain to be updated to achieve full coverage within the model domain boundary. 22
Figure 7 Small, sliver-like areas (in red) of the vegetation classification that were updated to complete the vegetation coverage for the entire model domain 23
Figure 8 2011 NAIP Interpretation: disturbance that had been previously identified was not re-captured, even if shifted, as long as the total area appeared consistent. 26
Figure 9 2011 NAIP Interpretation: at a scale of 1:5,000, the land features identified with the arrows were not distinguished. 26
Figure 10 2011 NAIP Interpretation: no reclassification of existing vegetation polygons was made unless the change was directly related to a disturbance feature 27
Figure 11 2011 NAIP Interpretation: in this example, the gravel site is captured but the variability within the Sandberg's Cheatgrass is not. 27
Figure 12 2011 NAIP Interpretation: Cheatgrass is left as-is from the existing vegetation (BRMP), with no further distinction of previous development activities. 28
Figure 13 2011 NAIP Interpretation: evidence of the Hanford Construction Camp which apparently housed up to 50,000 workers in 1945 is not distinguished because the existing vegetation classification appears accurate. 28

Figure 14 Data sample demonstrating justification for removing 'agricultural' from the vegetation cover type 'Gravel/Industrial/Non-Vegetated/Agricultural/Exotic Weed'. 29

Figure 15 An area of the 1943 USGS imagery that demonstrates feature distortion that is likely the result of a variation in the camera angle on multiple passes over the same location. 30

Figure 16 Testing Results: An example of undisturbed habitat in the 1943 imagery that gets classified as gravel per 2011 data, because there is no vegetation map available for 1943. 35

Figure 17 Chart of Recharge Normalized by Area for sample Model Years pre-operations, operations, and post-operations. 38

Figure 18 Map of Estimated Recharge (mm/yr), 1943. 39

Figure 19 Map of Estimated Recharge (mm/yr), 1944. 39

Figure 20 Map of Estimated Recharge (mm/yr), 1987. 40

Figure 21 Map of Estimated Recharge (mm/yr), 2060. 40

Figure 22 Annual Recharge Volumes for Each Combination of Soil Type and Vegetation/Land Use Within the Boundaries of the Whole Site (from PNL-10285-UC2010) 42

Tables

Table 1 Index of Data Sources to be Considered for Development of this Calculation. 4

Table 2 Reference Index of Soil Types to Corresponding Recharge Type (based on literature published for Hanford Soils) as applied in this calculation. 9

Table 3 Reference Data Sources Considered Most Current for Groundwater Recharge by Soil Type. 12

Table 4 Surface Condition Changes as a Result of Secondary Succession. 15

Table 5 Dispositions from the Hanford Disposition Baseline (EMDT-BC-0008 Revision 0) with the corresponding cover and surface conditions for calculations of recharge. 16

Table 6 Recharge rates in mm/year as applied to each unique combination of cover, surface condition, and soil. 19

Table 7 Vegetative Cover Types and Surface Condition values as were assigned during the capture of new features. Only those values in gray-shaded rows were assigned by this calculation. 24

Table 8 Priority Ranking and Attribute Definitions for Data Sources Used in Calculations of Recharge[a] 32

Table 9 Testing Results: Attributes in Disposition and Related Lookup Tables must be consistent 35

Table 10 Testing Results: Recharge Rates in Model Year 2060 where soils data are absent (NULL): actual versus expected. 36

Table 11 Recharge Summary for the Calculation Area within the Model Domain Boundary. 37

Table 12 Unique features produced by the combination of Cover Type, Surface Condition, and Soil Type for each Model Year tested. 41

Table 13 Comparison of Annual Recharge Volumes for Quincy Sand in PNL-10285 versus the current calculation. 43

Table 14 Index to the Digital Content provided with ECF-HANFORD-15-0019, REV. 0. 48

Terms

ArcGIS™	Esri ArcGIS for Desktop (Basic and Advanced)
BRMP	Biological Resources Management Plan
CHPRC	CH2M HILL Plateau Remediation Company
DOE	Department of Energy
dpi	dots per inch
ECF	Environmental Calculation File
Esri	Environmental Systems Research Institute
GIS	Geographic Information System
GSD	ground sample distance
GUI	graphical user interface
HGIS	Hanford Geographic Information System
HLAN	Hanford Local Area Network
HSGW	Hanford Sitewide Ground Water
MSA	Mission Support Alliance
NAIP	National Agriculture Imagery Program
NRBC	natural recharge boundary condition
NRCS	Natural Resources Conservation Service
RGB	Red, Green, Blue color scale
SSURGO	Soil Survey Geographic Database
USGS	United States Geological Survey
WIDS	Waste Information Data System
*.mxd	Esri map document file
*.xls, *.xlsx	Excel spreadsheet

Environmental Calculation File

Hanford Site-wide Natural Recharge Boundary Condition for Groundwater Models

1 Purpose

The purpose of the task is to develop a temporally and spatially variable representation of natural recharge for the Hanford Site at relatively high resolution that applies sanctioned natural recharge rates that vary as a function of the condition of the ground surface (surface condition) and soil type at any point in time. This work will support all groundwater flow models for the Hanford Site, including the site-wide Hanford Site Groundwater Flow Model (HSGW Model) as well as multiple scale-appropriate fate-and-transport models.

Four main tasks were accomplished and are defined herein.

1) Extend the spatial coverage of the soils and vegetation data to provide full coverage of baseline information within the entire area of interest.
2) Enhance the available data on surface condition at different times in Hanford's history, using satellite and/or aerial photo image analysis to identify areas of surface activity not adequately represented in other data sources (waste sites, facilities, borrow pits, and vegetation classification).
3) Establish a method to rank spatial data sources that systematically prioritizes the use of available information to generate a single best reference for the desired model year.
4) Create an automation routine that ranks and queries the best available data sources at the time a model is run, to produce a best-estimate of recharge sitewide in a given model year.

The goal was to develop a data structure that allows increasingly detailed reference data to be incorporated into model grid values based on temporal query and prioritization of data sources of variable quantity and quality.

The product of the completed tasks demonstrates that the local variability in surface condition over time can account for the total recharge volumes during operational periods being almost twice that of pre- and post-operational periods, thus having the potential to better estimate actual effects over the previously used single average estimate.

2 Background

The spatial and temporal variability of the ground surface based on vegetative cover and soil conditions can influence recharge by as much as 130 mm/year, where disturbance can result in higher flux rates from the vadose zone while re-vegetation can subsequently reduce recharge (PNNL-14702 Revision 1). The vadose zone modeling in the past has aimed to present temporally variable recharge scenarios in the waste site areas, but the groundwater models continue to use a single value for recharge, representing a spatially averaged rate sitewide. The goal of this work is to demonstrate the value of additional information about surface condition on a local scale as well as to provide an information infrastructure for continuous improvement of recharge estimations.

The information infrastructure proposed standardizes and formalizes the ranking of data about surface condition so that the recharge boundary condition can be re-calculated systematically just before a new model year is extracted. The information used to establish the recharge boundary condition for a particular model run is then saved as a self-contained package representing the data source conditions used to feed the model. This will enable a spatio-temporal evaluation within a geographic information system (GIS) of the specific model inputs alongside other contextual information such as the model results.

New data collected were captured within the area defined by the HSGW Active Model Domain, which generally confines the area of interest based on the boundaries of natural features in the landscape. The current process automation is not limited to this boundary, but instead will calculate the recharge in any areas with a vegetative cover type, surface condition, and soils data.

Data created, both from image analysis and from the automation script, are stored in a file geodatabase which stores multiple data types in an easy to manage package that can be archived with the associated groundwater model. The geodatabase format also provides a single location for metadata related to the entire package as well as the individual component data sources, and ensures the integrity of geoprocessing functions across related feature classes through the use of data schema controls, domains, and coded value lists.

3 Methodology

3.1 Extend the sitewide datasets for soils and vegetation

Step 1. Review the extent of the existing data within the area of interest and identify gaps in the two primary data sources, soils and vegetation, required for establishing recharge.

Step 2. Acquire soils data from the Natural Resources Conservation Service (NRCS) web site to fill the gaps.

a. Prepare the data for use in the ArcGIS™ editing environment by updating the map projection and updating the schema as needed to match the existing soils schema.

b. Copy those features from the Soil Survey Geographic Database (SSURGO) to fill the gaps within the area of interest.

Step 3. Create new features to fill the gaps in the vegetation classification.

a. Create a new feature class from the schema for the existing vegetation (BRMP) feature class.

b. Review the vegetation (BRMP) in relation to the 2011 National Agriculture Imagery Program (NAIP) imagery, and digitize any missing vegetation features within the model domain boundary

c. Update the "Cover_Type" attribute in a manner consistent with the existing vegetation (BRMP).

3.2 Enhance data on surface condition

The current calculations only included the use of aerial imagery to create new surface condition values, but the methodology below includes the use of existing vector data sources that may simply need some extra formatting to be included in the calculations of recharge.

Step 1. Identify time periods (years) most likely to improve overall recharge estimate because of unique surface conditions. Evaluate potential time periods according to

a. relative importance to recharge estimations (as either a time period representing change, or as a time period containing valuable complementary information)

b. availability of imagery or other spatial feature data sources, either sitewide or at least in an area of particular value

c. usability of the data source, including spatial resolution and whether it is adequately available in digital, georeferenced, and orthorectified form

Step 2. Note the reasons for choosing this data source, including the reference data to which it will be compared if new features will be derived from it. This information will aid in decision-making during data capture in problem areas where interpretation is unclear, and will also be included in the metadata of the resulting dataset.

Step 3. For imagery that will be interpreted into new polygon features, identify a process to ensure a systematic and full-coverage review of the image, which may include use of the PLSS or other land grid to order the review. Other processing standards should include scheduling the review of each source by a single user for a consecutive number of days to minimize variability in data interpretation.

Step 4. Prepare and load the chosen data source into the same projection as related GIS content, load onto a local server, and create a map document in ArcMap containing related data sources as needed. Create attribute domains for cover type and surface condition with the valid coded values for this dataset.

Step 5. For features to be digitized from imagery, create a new feature class within the natural recharge boundary condition (NRBC) geodatabase by copying the schema of an existing one, or creating one from scratch, into which new features will be captured. Ensure the projection has been defined to match that of the image source, and that the attribute domains from the geodatabase have been applied to the appropriate data fields.

For features already in vector form, add new fields for "Cover_Type" and "SurfCond" to match those in the existing NRBC schema, applying the attribute domains as above.

It is important that the polygon feature schemas match before the data source can be used in the automated creation of recharge in the subsequent calculations. It is ideal to name the new or derived feature classes in a way that references the data source from which it is derived.

Step 6. Interpret the image source, using reference layers and/or comparable data sources whenever possible to maximize the similar use of new features across years and data sources. Capture (heads up digitize) new features to represent the full local extent of a particular class (such as disturbed ground) detected in the image, instead of digitizing only the part of the feature that has not been previously captured.

Document examples of each class of features with screenshots and notes as needed, paying particular attention to areas where interpretation is unclear and a judgement call has been made. Capture enough information to assist in consistent capture within the same data source, as well as for future captures from other data sources.

Step 7. Assign attributes for "Cover_Type" and "SurfCond", either as each feature is captured, or in an edit session after polygons have been digitized. Unless an additional effort is made to classify vegetation species assemblages on the ground (because comparable field control samples have been taken), "Cover_Type" should only be entered to help distinguish those types in bold in the interpretation Use a combination of attribute queries to double-check that all new feature attributes are consistent and as expected.

Step 8. Update the metadata for the feature class, paying special attention to note important process steps, interpretations, and the intended use.

Step 9. Validate the data collected by having someone other than the digitizer to review the output feature class relative to the methodology and capture notes.

3.3 Rank Data Sources for Use in Defining Surface Condition

Step 1. Identify the spatial features available that will provide the best information about variable surface conditions which impact estimates of recharge.

Step 2. Define the attributes for each feature type that are available and most relevant to the, and evaluate both the precision and accuracy of the content for representing on-the-ground conditions.

Step 3. Identify the time period for which each data source is valid. In some cases, the data will have strict constraints on applicability, while in other cases, the valid time period may be longer or shorter based on the presence or absence of other data.

Step 4. Using the information above, establish a formal ranking by feature and feature class (data source), documented in a format that can be easily updated as new information becomes available. This documentation will serve as a reference for subsequent processing within the GIS.

Step 5. Document the assumptions for each data source relative to the ranking that has been applied. This could include updating the metadata for the feature class to better reflect the purpose of use.

3.4 Automate the Calculation of Recharge Sitewide

Step 1. Review available data sources and identify the appropriate geoprocessing steps required to define the recharge rates for a given model year using the best-available sources of information.

Step 2. Implement the automation using Python script within ArcGIS™ to perform the geoprocessing identified in Step 1.

Step 3. Confirm the accuracy of the outputs by comparison against inputs and reference lookup values.

Step 4. Polish the code, to include error handling and warning messages for exception cases, remarks documenting the purpose of key functions and variables.

4 Assumptions and Inputs

4.1 Spatial Data sources

Most data used as inputs into these calculations originated from the Hanford GIS (HGIS) production data store. ***Table 1*** represents the name of the source data along with the relative file path for each file. While the metadata should indicate the unique version control for each source, these paths and filenames may help when the metadata are incomplete.

Table 1 Index of Data Sources to be Considered for Development of this Calculation.

Function	Usage for ECF-HANFORD-15-0019	Nickname	Data Custodian	Relative File System Location	Notes on Data Fields
Source Primary	used	Buildings	CMS (Hanford)	...\HGSC_Prod\buildings\buildings_general\structure_site\bggensit	
Source Primary	used	CVP (Cleanup Verification Package) Boundaries	CMS (Hanford)	...\Projects\PSC\Jeff\Project\Geology\Geology.gdb > WCH_RC_CleanupVerificationPackageBoundaries_2010Dec_RepairedGeometry	will supplant the waste site conditions only if not other information available from the Disposition Baseline
Source Primary	used	Facilities	CMS (Hanford)	...\Infrastructure\bggenexs_15Jan2014	
Source Primary	used	Soils - 1966 Soil Survey	CMS (Hanford)	...\HGIS_Share\geology\SOILSP.shp	
Source Primary	used	Waste Site Footprints	CMS (Hanford)	...\HGSC_Prod\environmental_hazards\env_haz_sites\environmental_restoration_site\ehsit	many other variations, but on 7/2/15 Jeff says only use ehsit
Source Primary	used	Hanford Disposition Baseline	INTERA - MC	...\Projects\SitewideDisposition	

Function	Usage for ECF-HANFORD-15-0019	Nickname	Data Custodian	Relative File System Location	Notes on Data Fields
Source Primary	used	Soils - SSURGO	USDA	http://www.nrcs.usda.gov/wps/portal/nrcs/surveylist/soils/survey/state/?stateId=WA	
Source Primary	used	Vegetation - Current (BRMP)		...\HGIS_Share\land_status\BRMP_Hanford_Cover_Post_2000_to_2011_Fires.shp	
Source Primary	used	NAIP - 2011	USDA	...\HGIS_Share\AerialImagery\	
Source Primary	used	Aerial Photo (Vert) - 1943	CMS (Hanford)	...\HGIS_Share\AerialImagery\1943_USGS_B&W	
Source New	created	Vegetation - Planned	INTERA - JBP	<within temporary outputs of tool, within geodatabase for a given model year>	derived from Hanford Disposition Baseline
Source New	created	Vegetation - Successional (temporal)	INTERA - JBP	<within temporary outputs of tool, within geodatabase for a given model year>	derived by applying standard rates for natural secondary succession from known cover types
Source New	created	Recharge Lookup Tables	INTERA - NMR	...\Deliverables\Data\Tables\NRBC_LookupTables*.xlsx	derived/developed with input from Hanford Disposition Baseline, PNNL-10285-UC2010, and PNNL-14072rev1
Basemap Primary	used	Model Boundary	INTERA - JM	...\Projects\PSC\Jeff\Project\HSGW_Active_Model_Domain.shp	
Basemap Primary	used	Operational Areas (fenced)		...\Boundaries\bdjurdsv_15Jan2014.shp	
Basemap Primary	used	Borrow Pits		...\HGSC_Prod\land_status\land_status_general\borrow_pit_site_poly.shp	
Basemap Primary	used	Monument Roads		...\HGSC_Prod\transportation\HRNM_Roads\Monument_Roads_wa83s.shp	
Basemap Primary	used	Road Centerlines		...\HGSC_Prod\transportation\transportation_vehicle\road_centerline\trvehrcl.shp	Hanford Routes and local roads
Basemap Primary	used	Road Sites		...\HGSC_Prod\transportation\transportation_vehicle\road_site\trvehrds.shp	
Basemap Primary	used	Trails		...\HGSC_Prod\transportation\transportation_vehicle\trails\trvehtrl.shp	
Basemap Secondary	used	River		...\Water Table 2013\River	
Basemap Secondary	used	100-BC Model Net Infiltration Estimate	INTERA - JM	..\20150324_100BC_Net_Infiltration\Data\EMDT\EMDT-BC-0007\Rev.0\Data	
Source Primary	<considered, not used>	Aerial Photo (Vert) - 1948	CMS (Hanford)	...\HGIS_Share\AerialImagery\1948_USGS_B&W	Data Incomplete, Not Mapped
Source Primary	<considered, not used>	Aerial Photo (Vert) - 1964	CMS (Hanford)	...\HGIS_Share\AerialImagery\1964_USGS_B&W	Data Complete, Not Mapped
Source Primary	<considered, not used>	Aerial Photo (Vert) - 1970	CMS (Hanford)	...\HGIS_Share\AerialImagery\1970_LMSI_B&W	no data or reference info found on HGIS_Share (just folders)
Source Primary	<considered, not used>	Aerial Photo (Vert) - 1973	CMS (Hanford)	...\HGIS_Share\AerialImagery\1973_USGS_B&W	Data Incomplete, Not Mapped; 1:24,000; "leaf on" 7/1/1973
Source Primary	<considered, not used>	Aerial Photo (Vert) - 1975	CMS (Hanford)	...\HGIS_Share\AerialImagery\1975_USDA_CIR	Data Complete, Not Mapped; small scale
Source Primary	<considered, not used>	Aerial Photo (Vert) - 1976	CMS (Hanford)	...\HGIS_Share\AerialImagery\1976_Hanford_Multispectral	color, b&w, and infrared at 3 different but similar times along river corridor areas (for riverine ecology)
Source Primary	<considered, not used>	Aerial Photo (Vert) - 1982	CMS (Hanford)	...\HGIS_Share\AerialImagery\1982_USDA_CIR	Data Complete, Not Mapped

Function	Usage for ECF-HANFORD-15-0019	Nickname	Data Custodian	Relative File System Location	Notes on Data Fields
Source Primary	<considered, not used>	Aerial Photo (Vert) - 1988	CMS (Hanford)	...\HGIS_Share\AerialImagery\1988_USGS_RGB	
Source Primary	<considered, not used>	Aerial Photo (Vert) - 1991	CMS (Hanford)	...\HGIS_Share\AerialImagery\1991_USGS_B&W	
Source Primary	<considered, not used>	Aerial Photo (Vert) - 1996	CMS (Hanford)	...\HGIS_Share\AerialImagery\1996_DOE_RemoteSensingLaboratory	Data Complete & Mapped; 1:32,000; "leaf on" 6/14/1996
Source Primary	<considered, not used>	Aerial Photo (Vert) - 1996	CMS (Hanford)	...\HGIS_Share\AerialImagery\1996_USGS_B&W_DOQQ	
Source Primary	<considered, not used>	Aerial Photo (Vert) - 1997	CMS (Hanford)	...\HGIS_Share\AerialImagery\1997_Hanford_RadarSat	
Source Primary	<considered, not used>	Aerial Photo (Vert) - 2000	CMS (Hanford)	...\HGIS_Share\AerialImagery\2000_ADAR_RGBI	
Source Primary	<considered, not used>	Imagery - Hanford Obliques (1987? - present)	CMS (Hanford)		Data Complete, Not Mapped; are these consistently present for all the disturbed areas?
Source Primary	<considered, not used>	Satellite Imagery - 2000	CMS (Hanford)	...\HGIS_Share\AerialImagery\2000_IKONOS_RGB	
Source Primary	<considered, not used>	NAIP - 2003	USDA		
Source Primary	<considered, not used>	NAIP - 2006	USDA		
Source Primary	<considered, not used>	NAIP - 2013	USDA		
Source Primary	<considered, not used>	NAIP - 2015	USDA		
Source Primary	<considered, not used>	Fires	USDOI	http://rmgsc.cr.usgs.gov/ArcGIS/rest/services/firehistory	fire scars not used individually but assumed accounted for on average with sitewide vegetation map
Source Primary	<not considered>	Aerial Photo (Vert) - 2002	CMS (Hanford)	...\HGIS_Share\AerialImagery\2002_YCGIS	
Source Primary	<not considered>	Aerial Photo (Vert) - 2003	CMS (Hanford)	...\HGIS_Share\AerialImagery\2003_NAIP_RGB	
Source Primary	<not considered>	Aerial Photo (Vert) - 2004	CMS (Hanford)	_	
Source Primary	<not considered>	Aerial Photo (Vert) - 2005	CMS (Hanford)	_	
Source Primary	<not considered>	Aerial Photo (Vert) - 2006	CMS (Hanford)	_	
Source Primary	<not considered>	Aerial Photo (Vert) - 2007	CMS (Hanford)	_	
Source Primary	<not considered>	Aerial Photo (Vert) - 2008	CMS (Hanford)	_	
Source Primary	<not considered>	Aerial Photo (Vert) - 2009	CMS (Hanford)	_	
Source Primary	<not considered>	Aerial Photo (Vert) - 2011	CMS (Hanford)	_	
Source Primary	<not considered>	Aerial Photo (Vert) - 2012	CMS (Hanford)	_	
Source Primary	<not considered>	Aerial Photo (Vert) - 2013	CMS (Hanford)	_	

Function	Usage for ECF-HANFORD-15-0019	Nickname	Data Custodian	Relative File System Location	Notes on Data Fields
Source Primary	<not considered>	Satellite Imagery - 2000	CMS (Hanford)	...\HGIS_Share\AerialImagery\2000_SPOT_RGB	
Source Primary	<not considered>	Imagery Historical b/w	USDA		(APFO 55, 62, 71, 73, 78, 91, 96)
Source Primary	<not considered>	Imagery Historical CIR	USDA		(APFO 1982)
Source N/A	<considered, not used>	Clastic Dikes		-	Scale of model is 200m cells, so dikes not necessary
Basemap Primary	<considered, not used>	NLCD - 2011			this was a source for 100BC, but this calculation will collect actual features instead
Basemap Primary	<considered, not used>	Operational Areas (unfenced)			
Basemap Primary	<considered, not used>	Vernal Ponds			historic ponds/lentic sites that have been backfilled are covered elsewhere in the model
Basemap Secondary	<considered, not used>	Cadastral Federal Ownership		...\Basemap\Shape\Boundaries\cdfedown_15Jan2014	
Basemap Secondary	<considered, not used>	Completion Framework Areas		...\Boundaries\ehremgca_15Jan2014	(River Corridor, Central Plateau, etc)
Basemap Secondary	<considered, not used>	Groundwater contours		-	
Basemap Secondary	<considered, not used>	Groundwater Interest Areas		...\Boundaries\GWIA_2012.shp	
Basemap Secondary	<considered, not used>	Groundwater Monitoring Wells		...\HGSC_Prod\improvement\improvement_wells\water_well_point\imwelwel	
Basemap Secondary	<considered, not used>	Hillshade		...\Imagery\LiDAR\Mosaic.gdb > ground_hillsh	

4.1.1 The Geodatabase

A file geodatabase (NRBC_Final_V1.gdb) has been created to define certain default formats expected of the calculation files and to provide a single location for storing all the geospatial content related to the calculations.

All data have been loaded into the GIS in a single projection, **GCS_North_American_1983: NAD_1983_StatePlane_Washington_South_FIPS_4602**, which has the following specifications from ArcMap™:

NAD_1983_StatePlane_Washington_South_FIPS_4602
WKID: 32149 Authority: EPSG

Projection: Lambert_Conformal_Conic
False_Easting: 500000.0
False_Northing: 0.0
Central_Meridian: -120.5
Standard_Parallel_1: 45.83333333333334

Standard_Parallel_2: 47.33333333333334
Latitude_Of_Origin: 45.33333333333334
Linear Unit: Meter (1.0)

Geographic Coordinate System: GCS_North_American_1983
Angular Unit: Degree (0.0174532925199433)
Prime Meridian: Greenwich (0.0)
Datum: D_North_American_1983
Spheroid: GRS_1980
Semimajor Axis: 6378137.0
Semiminor Axis: 6356752.314140356
Inverse Flattening: 298.257222101

4.1.2 NAIP Natural Color Digital Aerial Imagery

The National Agriculture Imagery Program (NAIP) acquires aerial imagery with digital sensors during the agricultural growing seasons in the continental U.S. NAIP imagery is acquired at a one-meter ground sample distance (GSD) with a horizontal accuracy that matches within six meters of photo-identifiable ground control points, which are used during image inspection. The default spectral resolution is natural color (Red, Green and Blue, or RGB).

The NAIP imagery used was a compressed county mosaic, which was generated by compressing digital ortho quarter quadrangle image tiles into a single mosaic. The mosaic available from NAIP was originally rectified in the UTM coordinate system, NAD 83, and cast into a single predetermined UTM zone, which was then projected to the project coordinate system.

The NAIP images and county mosaics are available for free download through the USDA Geospatial Data Gateway, http://datagateway.nrcs.usda.gov/

4.1.3 USGS Black and White Aerial Photography

The HGIS contains digital image files of aerial photography collected by the United States Geological Survey (USGS) in 1943. The original images had been scanned previously at either 600 or 1200 dpi, and merged into a mosaic to cover most the Hanford site. The mosaic consists mostly of higher-resolution scans (1200 dpi), at least in the irrigated areas, while other parts of the mosaic were captured at 600 dpi. Though the 600 dpi data are too coarse to define vegetation cover per se, the images are considered legible enough to distinguish the particular surface condition classes of greatest interest to this calculation.

4.1.4 Soils

Most of the soils used in this calculation originate from the HGIS (soilsp.shp), which contains soil types for which recharge rates have been published previously. However, there are some areas of the model domain not covered by the current soils classification for Hanford, so in these areas the data gaps will be filled by the USDA NRCS SSURGO data available from http://www.nrcs.usda.gov/wps/portal/nrcs/surveylist/soils/survey/state/?stateId=WA.

www.nrcs.usda.gov/wps/portal/nrcs/surveylist/soils/survey/state/?stateId=WA

Soil survey name (Click links for online surveys.)	Date	Archived PDF online	Web Soil Survey (generated from official soil data)
Benton County Area	1971	Yes	No
Benton County Area	current	No	Yes
Benton County	1919	Yes	No

Figure 1 SSURGO soils data downloaded for use in filling data gaps within the model domain.

The SSURGO database contains information about soil as collected by the National Cooperative Soil Survey over the course of a century. The mapping is intended for natural resource planning and management by landowners, townships, and counties. The maps are linked in the database to information about the component soils and their properties for each map unit. Each map unit may contain one to three major components and some minor components. The map units are typically named for the major components.

SSURGO soil types were associated to the existing Hanford soils classification (see "Recharge Type" in ***Table 2***) in order to apply the recharge rates previously established for the Hanford soils.

Table 2 Reference Index of Soil Types to Corresponding Recharge Type (based on literature published for Hanford Soils) as applied in this calculation.

Abbreviation	Recharge Type	Description	Source[a]
BbA	Ba	Burbank loamy fine sand, 0 to 2 percent slopes	SSURGO
BbC	Ba	Burbank loamy fine sand, 0 to 15 percent slopes	SSURGO
BbD	Ba	Burbank loamy fine sand, 2 to 15 percent slopes	SSURGO
BlA	Ba	Burbank loamy fine sand, gravelly substratum, 0 to 2 percent slopes	SSURGO
BlD	Ba	Burbank loamy fine sand, gravelly substratum, 2 to 15 percent slopes	SSURGO
Ba	Ba	Burbank Loamy Sand: Coarse soil underlain by gravel. Gravel content: 20 to 80 vol %. Surface layer thickness: 40 cm.	SOILSP
D	D	Dune Sand: Represents miscellaneous materials of sand sized particles transported by wind. Can be both shifting and/or stabilized. No soil horizons have developed.	SOILSP
Eb	Eb	Ephrata Stony Loam: Medium textured soil underlain by gravel. Occurs on glacial hummocky ridges. Areas between hummocks contain 1 m size boulders.	SOILSP
FeA	El	Finley fine sandy loam, 0 to 2 percent slopes	SSURGO
FeB	El	Finley fine sandy loam, 2 to 5 percent slopes	SSURGO
FeD	El	Finley fine sandy loam, 5 to 15 percent slopes	SSURGO
FfE	El	Finley stony fine sandy loam, 0 to 30 percent slopes	SSURGO
FnA	El	Finley fine sandy loam, moderately deep, 0 to 2 percent slopes	SSURGO
FnB	El	Finley fine sandy loam, moderately deep, 2 to 5 percent slopes	SSURGO
UmB	El	Umapine silt loam, 0 to 5 percent slopes	SSURGO
El	El	Ephrata Sandy loam: Medium textured soil underlain by gravelly material. The topography is generally level.	SOILSP
HeA	He	Hezel loamy fine sand, 0 to 2 percent slopes	SSURGO

Abbreviation	Recharge Type	Description	Source[a]
He	He	Hezel Sand: Laminated and strongly calcareous, usually encountered within 60 cm of the surface. The surface soil was formed in eolian sands that covered lacustrine sediments.	SOILSP
Kf	Kf	Koehler Sand: Developed in an eolian mantle. Differs from the other sands in that it overlies a lime-silica cemented layer. The subsoil is calcareous and is at approx. 40 cm.	SOILSP
Ki	Ki	Kiona Silt Loam: Occupies steep slopes and ridges. The soil contains basalt fragments both in the surface and subsoil. Basalt rock outcrops are present.	SOILSP
Ls	Ls	Lickskillet Silt loam: Occupies ridge tops. Contains basalt fragments 30 cm in diameter and larger. Numerous basalt fragments are present throughout the profile. Many areas of stony silt loam and shallow lithosols may be mapped.	SOILSP
PaA	P	Pasco fine sandy loam, 0 to 2 percent slopes	SSURGO
PcA	P	Pasco silt loam, 0 to 2 percent slopes	SSURGO
P	P	Pasco Silt Loam: Very poorly drained soil formed in recent alluvial material. The subsoil is variable consisting of stratified layers. Limited in areal extent and located in low areas near the Columbia River.	SOILSP
EsA	Qu	Esquatzel fine sandy loam, 0 to 2 percent slopes	SSURGO
Qu	Qu	Esquatzel Silt Loam: Formed in recent alluvium derived from loess and lake sediments. The color and texture are stratified. Associated with the Ritzville and Warden soils.	SOILSP
QuA	Qy	Quincy loamy sand, 0 to 2 percent slopes	SSURGO
QuD	Qy	Quincy loamy sand, 2 to 15 percent slopes	SSURGO
QuE	Qy	Quincy loamy sand, 0 to 30 percent	SSURGO
Qy	Qy	Quincy Sand: Very extensive. Developed under grass, sagebrush and hopsage in coarse sandy alluvium mantled by eolian sands. Relief includes hummocky terraces and dune like ridges. Active dunes are present.	SOILSP
PITS	Qy	Pits	SSURGO
W	Qy	Water	SSURGO
XX	Qy	Not Coded (use Rupert Sand)	SOILSP
Rp	Rp	Quincy Sand (was Rupert Sand, Rp)	SOILSP
Ri	Ri	Ritzville Silt Loam: Developed on Rattlesnake Hills under bunch grass from eolian sands mixed with minor amounts of volcanic ash. Depth range: 50 cm-1 m.	SOILSP
Rh	Rv	Riverwash	SSURGO
Rv	Rv	Riverwash: Occur in wet, periodically flooded areas of sand gravel and boulders which make up islands in and adjacent to the Columbia River.	SOILSP
ScA	Sc	Scooteney silt loam, 0 to 2 percent slopes	SSURGO
SdA	Sc	Scooteney silt loam, gravelly subsoil, 0 to 2 percent slopes	SSURGO
Sc	Sc	Scootney Stony Silt Loam: Developed along the north slope of Rattlesnake Hills, confined to areas where draws and fan shaped areas open onto the plain. The soils are often severely eroded with exposed basalt boulders and other rocks.	SOILSP
WdAB	Wa	Warden silt loam, 0 to 5 percent slopes	SSURGO
WdB	Wa	Warden silt loam, 2 to 5 percent slopes	SSURGO
Wa	Wa	Warden Silt Loam: Characteristic of dry climate where evapotranspiration exceeds precipitation. The subsoil becomes strongly calcareous at 60 cm and calcium carbonate layers are common. Granitic boulders are common	SOILSP

Notes:

a The rows shaded in gray indicate those Hanford soils for which recharge rates have previously been published.

4.1.5 Vegetation Classification

The surface condition for the majority of the site will be the natural vegetative cover, which is defined in a GIS polygon feature class referenced by the Biological Resources Management Plan (DOE_RL-96-32_Rev_1). This data set includes areas throughout the site that have evidence of fire scarring.

In the absence of data on the natural vegetation condition in times prior to 2011, data from this feature class are also applied to other time periods, presuming that the surface variability across different natural disturbance events and soil types is adequately represented in the mosaic of conditions present in 2011. For those features classified as 'Disturbed' in vegetation (BRMP) and which have been retained for a model year prior to 1944, the 'Mature-Vegetated' cover type will be substituted.

The existing vegetation classification is missing data along the perimeter and in the southernmost tail of the model domain. These gaps will need to be filled through additional photo interpretation.

4.1.6 Cleanup Verification Package (CVP) Boundaries

CVP data was collected as part of an environmental restoration contract in the late 1990's, and is considered to represent the best available information on disposition for those sites that do not have related records in the Disposition Baseline.

4.1.7 Waste Sites (*ehsit*) and Facilities (*bggenxs*, *bggensit*)

These data sources represent all of the known point, line and polygon features that make up mapped waste sites, facilities, and buildings at the Department of Energy's Hanford Site. These features can include both known and suspected features, which means that there may be features in these datasets that do not correspond to features in the Disposition Baseline (described below). The mapped locations provide a starting point for remediation planning and field activities, and are also used during excavation and drilling activities to identify potential conditions at the work site.

As more information is acquired through the declassification of documents and photos, newly identified drawings, and field work associated with remediation planning, the mapped location is modified to account for the newly identified information. The automation script provided by this calculation is designed to incorporate new information from these datasets as it becomes available.

4.2 Non-spatial Data Sources

4.2.1 Hanford Disposition Baseline

The Disposition Baseline (EMDT-BC-0008 Revision 0, Hanford Disposition Baseline) is the source of information regarding changes in the surface condition for waste sites and facilities within the Hanford Site boundaries from the date of initial disturbance to the expected final condition, or "disposition" of the site. This disposition focuses on determining the changes in the surface conditions of the sites resulting from changes in operations; specifically, the years in which a site began accepting wastes, no longer accepted wastes, was remediated, and the type of remediation. This disposition does not include changes in the surface conditions of roads, gravel pits, and other types of infrastructure which are not listed in Waste Information Data System (WIDS), the Mission Support Alliance (MSA) Structures List, or the Department of Energy (DOE) Dashboards.

Each site in the Disposition Baseline has both a disposition and a related disposition date, upon which recharge calculations are based. For example, a site that was cleaned up and revegetated in 2005 will generate a different recharge than one that continues to be active or that has a future disposition date.

The current calculation is designed to incorporate new information from the Disposition Baseline as it becomes available, by re-running the automation script using a new Excel file as the data source. Before the calculation of

recharge rates, the attributes on disposition are joined to the spatial features for waste site (*ehsit*) and facilities (*bggenexs*, *bggensit*) via a site identification number.

4.2.2 Recharge Rates

Three references are used to establish the recharge rate for the unique combinations of surface condition and soil type. Recharge for the majority of the site will be defined using the values in Table 4.1 of PNNL-10285-UC2010 (***Figure 2***). Recharge in the operational areas, containing the majority of human disturbance, is defined when available using the values in table 4.15 of PNNL-14072rev1 (***Figure 3***); and these values supplant any that were previously defined. Finally, for locations where irrigation is a factor, rates have been derived based on WDOH guidance (WDOH/320-015, Hanford Guidance for Radiological Cleanup), as cited in ECF-Hanford_11-0063, Rev 6 (***Figure 4***).

The table below indicates for each soil type, which reference is considered the most recent, primary source for defining the recharge rate. The "Reference Source" listed here will be the actual source in the event that different rates are defined in more than one report.

Table 3 Reference Data Sources Considered Most Current for Groundwater Recharge by Soil Type.

GRID_CODE	TEXT_SYM	SOIL_NAME	Reference Source
8	Eb	Ephrata Stoney Loam	PNNL14072rev1
5	Ba	Burbank Loamy Sand	PNNL14072rev1
6	El	Ephrata Sandy Loam	PNNL14072rev1
14	Rv	Riverwash	PNL-10285-UC-2010
2	Qy	Quincy Sand (was Rupert Sand, Rp)	PNL-10285-UC-2010
12	P	Pasco Silt Loam	PNL-10285-UC-2010
9	Ki	Kiona Silt Loam	PNL-10285-UC-2010
10	Wa	Warden Silt Loam	PNL-10285-UC-2010
1	Ri	Ritzville Silt Loam	PNL-10285-UC-2010
13	Qu	Esquatzel Silt Loam	PNL-10285-UC-2010
3	He	Hezel Sand	PNL-10285-UC-2010
15	D	Dunesand	PNL-10285-UC-2010
4	Kf	Koehler Sand	PNL-10285-UC-2010
11	Sc	Scooteney Stoney Silt Loam	PNL-10285-UC-2010
7	Ls	Lickskillet Silt Loam	PNL-10285-UC-2010
0	XX	Not Coded	

Notes:

Table 4.1. Estimated Recharge Rates at the Hanford Site for Each Combination of Soil Type and Vegetation/Land Use. The recharge estimate for each combination is based on either measurements, modeling, or inferences from other combinations, as explained in Section 3.0.

Vegetation/Land Use		Recharge Rates (mm/yr)							
		Soil Types							
Index	Description	Ri	Rp	He	Kf	Ba	El	Ls	Eb
1	Shrub-steppe on slopes	3.4	8.6	2.6	2.6	2.6	2.6	3.4	2.6
2	Shrub-steppe on plain/uplands	3.4	8.6	2.6	2.6	2.6	2.6	3.4	2.6
3	Recovering shrub-steppe on plain/uplands	3.4	11.3	2.6	2.6	2.6	2.6	3.4	2.6
4	Bunchgrass on slopes	3.4	11.3	2.6	2.6	2.6	2.6	3.4	2.6
5	Hopsage/greasewood	3.4	8.6	2.6	2.6	2.6	2.6	3.4	2.6
6	Cheatgrass	4.8	25.4	3.4	3.4	2.6	4.9	4.8	4.9
7	Abandoned fields	4.8	25.4	3.4	3.4	2.6	4.9	4.8	4.9
8	Riparian	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	Agricultural areas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	Sand dunes	55.4	55.4	55.4	55.4	55.4	55.4	55.4	55.4
11	Disturbed/Facilities	6.8	55.4	6.4	6.4	4.4	17.3	6.8	17.3
12	Water	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	Basalt outcrops	86.7	86.7	86.7	86.7	86.7	86.7	127.1	86.7

Vegetation/Land Use		Recharge Rates (mm/yr)						
		Soil Types						
Index	Description	Ki	Wa	So	P	Qu	Rv	D
1	Shrub-steppe on slopes	3.4	3.4	3.4	3.4	3.4	8.6	8.6
2	Shrub-steppe on plain/uplands	3.4	3.4	3.4	3.4	3.4	8.6	8.6
3	Recovering shrub-steppe on plain/uplands	3.4	3.4	3.4	3.4	3.4	11.3	11.3
4	Bunchgrass on slopes	3.4	3.4	3.4	3.4	3.4	11.3	11.3
5	Hopsage/greasewood	3.4	3.4	3.4	3.4	3.4	8.6	8.6
6	Cheatgrass	4.8	4.8	4.8	4.8	4.8	25.4	25.4
7	Abandoned fields	4.8	4.8	4.8	4.8	4.8	25.4	25.4
8	Riparian	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	Agricultural areas	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	Sand dunes	55.4	55.4	55.4	55.4	55.4	55.4	55.4
11	Disturbed/Facilities	6.8	6.8	6.8	6.8	6.8	55.4	55.4
12	Water	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	Basalt outcrops	86.7	86.7	86.7	86.7	86.7	86.7	86.7

Figure 2 Estimated Recharge Rates at the Hanford Site for Each Combination of Soil Type and Vegetation/Land Use (Table 4.1 in PNNL-10285-UC2010).

Area Label	Brief Description	Major (Secondary)[a] Soil Type(s) and Sediments	Estimated Recharge Rate (mm/yr)[b]			
			No Vegetation	Cheatgrass	Young Shrub-Steppe	Shrub-Steppe
C	Reactor along river	E_b (B_a)	17 (52)	8.5 (26.5)	3.0 (6.0)	1.5 (3.0)
K	Reactor along river	E_b (E_l)	17 (17)	8.5 (8.5)	3.0 (3.0)	1.5 (1.5)
N	Reactor along river	E_b	17	8.5	3.0	1.5
D	Reactor along river	E_l	17	8.5	3.0	1.5
H	Reactor along river	B_a	52	26	6.0	3.0
F	Reactor along river	R_p (E_l)	44 (17)	22 (8.5)	8.0 (3.0)	4.0 (1.5)
R	300 Area	R_p (E_l)	44 (17)	22 (8.5)	8.0 (3.0)	4.0 (1.5)
Q	400 Area	R_p (B_a)	44 (52)	22 (26)	8.0 (3.0)	4.0 (3.0)
P	618-10 Area	R_p (B_a)	44 (52)	22 (26)	8.0 (3.0)	4.0 (3.0)
M	618-11 Area	R_p (B_a)	44 (52)	22 (26)	8.0 (3.0)	4.0 (3.0)
G	Gable Mtn. Pond Area	E_l (B_a)	17 (52)	8.5 (26)	3.0 (6.0)	1.5 (3.0)
I	200N Area	E_l (B_a)	17 (52)	8.5 (26)	3.0 (6.0)	1.5 (3.0)
T	Northern 200W Area	R_p (B_a)	44 (52)	22 (26)	8.0 (3.0)	4.0 (3.0)
S	Southern 200W Area and ERDF	R_p	44	22	8.0	4.0
A	Southern 200E Area	R_p (B_a, R_{pi}, R_{pu})	44 (52, 44, 30)	22 (26, 22, na)	8.0 (6.0, 1.8, na)	4.0 (3.0, 0.9, na)
B	Northwestern 200E Area	E_l	17	8.5	3.0	1.5
E	Eastern 200E Area	B_a (R_p)	52 (44)	26 (22)	6.0 (1.8)	3.0 (0.9)
--	All Areas with soils disturbed by excavations	Hanford sand	63	31.5	8.0	4.0
--	All Areas with an Evapotranspiration (ET) surface barrier after design life	Warden silt loam (Wa)	na	na	0.08	0.04
--	All Areas with gravel surface and no plants	gravel	92	46	na	na

B_a = Burbank loamy sand
E_b = Ephrata stony loam
E_l = Ephrata sandy loam
R_p = Rupert sand
R_{pi} = Rupert sand in the IDF in the 200 East Area.
R_{pu} = Rupert sand at the US Ecology Site, southwest of the 200 East Area.
na = not applicable
(a) Only the major soil types were used to represent each aggregate area.
(b) Alternate/reference case values shown in Table 4.14 are not provided here.
(c) Value to be used in reference case analyses (DOE. October 21, 2005. *Technical Guidance Document for Composite Analysis of Low-Level Waste Disposal at the Hanford Site*. DOE/RL-2005-66, U.S. Department of Energy, Richland, Washington [unsigned]).

Figure 3 Estimated Recharge Rates by Soil Type/Sediment and Vegetation Condition in Each Hanford Area (Table 4.15 in PNNL-14072rev1). Significant secondary soil types and their associated recharge estimates are shown in parentheses but are not used in the current calculation.

Table 4. Irrigation Recharge Scenario Phases and Recharge Rates (mm/yr)

Surface Soil Type	Historic Simulation (pre-2010) (calculation of initial hydraulic conditions)			Predictive Simulation (post-2010) (calculation of peak groundwater concentration)		
	Pre-Settlement (< 1880)	Historic Irrigation [a] (1880-1944)	Hanford Operations (1944-2010)	Bare Soil (2010-2015)	Irrigation I (2015-2045)	Irrigation II (2045 >)
Hanford sand, disturbed	4.0 [b]	72.4 [c]	63.0 [d]	63.0 [d]	76.4 [e]	72.4 [e]

a. Irrigated agriculture was prevalent in the100-D/H Area prior to Hanford Site construction; irrigation therefore was conservatively assumed applicable to all 100-D/H sites from calendar years 1880 through 1944.

b. Source: PNNL-14702 Rev. 1, Table 4-15, all areas with soils disturbed by excavations; shrub steppe.

c. Recharge rates for historic irrigation phase is that from the long-term irrigation rate (irrigation II phase).

d. Source: PNNL-14702 Rev. 1, Table 4-15, all areas with soils disturbed by excavations; no vegetation.

e. Recharge rates for future irrigation phases represent incremental increases over corresponding undisturbed native vegetation recharge rates, based on WDOH guidance (WDOH/320-015, *Hanford Guidance for Radiological Cleanup*). The recharge increment attributable to irrigation alone is 68.4 mm/yr. This increment is added to the corresponding rate for immature shrub steppe (8.0 mm/yr) and mature shrub steppe (4.0 mm/yr) phases of the native vegetation recharge scenario (Table 3) to obtain the total recharge rate.

Figure 4 Irrigation Recharge Scenario Phases and Recharge Rates (Table 4 from ECF-Hanford-11-0063-Rev 06)

4.2.3 Vegetation changes due to Secondary Succession

In order to account for natural changes in vegetation over time, a standard rate of succession will be applied to each transition in surface condition values. For example, per the prior river corridor RI/FS documents (e.g. ECF-Hanford-11-0063 Rev. 6), after 5 years, surface conditions of 'Bare' will change to 'Cheatgrass', and surface conditions of 'Cheatgrass' will change to 'Developing'. Similarly, per DOE/RL-2011-50 Rev. 1, surface condition 'Developing' will change to 'Mature' after 30 years. Further, 'Mature' will remain the surface condition until a new disturbance feature is identified for the same location.

Table 4 Surface Condition Changes as a Result of Secondary Succession.

Surface Condition	Duration (years)
Bare	5
Cheatgrass	5
Developing	30
Mature	ongoing until disturbed

Notes:

4.3 Data Interpretation: Surface Condition to Disposition

The Hanford Disposition Baseline provides a single, most accurate estimation of the current or planned disposition for the waste sites and facilities that contain some element of contamination. In support of the recharge calculations, a cover type and surface condition was defined for each disposition type that is currently in the Disposition Baseline. This list is stored in the lookup tables

(NRBC_LookupTables_V*.xlsx) as it is referenced by the automation script in order to assign recharge values to sites according to their disposition. Thus, this list should be maintained or at least confirmed to be up-to-date before a new model year is run.

Table 5 Dispositions from the Hanford Disposition Baseline (*EMDT-BC-0008 Revision 0*) with the corresponding cover and surface conditions for calculations of recharge.

Disposition[a]	Cover_Type	SurfCond
D4 (complete removal)	Disturbed	Bare
D4 (demolish in place; backfill)	Disturbed	Bare
D4 (sanitary holding tanks removed)	Disturbed	Bare
D4 (tank removed)	Disturbed	Bare
D4; bury in place	Disturbed	Bare
Demolish in place	Disturbed	Bare
Ex situ bioremediation	Disturbed	Bare
pipeline capping	Disturbed	Bare
Remove, stabilize	Disturbed	Bare
RTD	Disturbed	Bare
<blanks>	Gravel/Industrial/Non-Vegetated/Exotic Weed	Cheatgrass
Complete	Gravel/Industrial/Non-Vegetated/Exotic Weed	Cheatgrass
CSNA	Gravel/Industrial/Non-Vegetated/Exotic Weed	Cheatgrass
D4	Gravel/Industrial/Non-Vegetated/Exotic Weed	Cheatgrass
D4 (septic tank left in place)	Gravel/Industrial/Non-Vegetated/Exotic Weed	Cheatgrass
D4S	Gravel/Industrial/Non-Vegetated/Exotic Weed	Cheatgrass
default	Gravel/Industrial/Non-Vegetated/Exotic Weed	Cheatgrass
Demolished	Gravel/Industrial/Non-Vegetated/Exotic Weed	Cheatgrass
Disposition	Gravel/Industrial/Non-Vegetated/Exotic Weed	Cheatgrass
MESC	Gravel/Industrial/Non-Vegetated/Exotic Weed	Cheatgrass
MESC/MNA/IC	Gravel/Industrial/Non-Vegetated/Exotic Weed	Cheatgrass
NFRAN (no further remedial action necessary)	Gravel/Industrial/Non-Vegetated/Exotic Weed	Cheatgrass
No action	Gravel/Industrial/Non-Vegetated/Exotic Weed	Cheatgrass
Post closure	Gravel/Industrial/Non-Vegetated/Exotic Weed	Cheatgrass
Soil cover	Gravel/Industrial/Non-Vegetated/Exotic Weed	Cheatgrass
undefined	Gravel/Industrial/Non-Vegetated/Exotic Weed	Cheatgrass
unk	Gravel/Industrial/Non-Vegetated/Exotic Weed	Cheatgrass
Deleted from NPL	Artificial regeneration	Developing
IC	Artificial regeneration	Developing
<blanks>	Bldg	Barrier/MinRchrg
ABAR	Bldg	Barrier/MinRchrg
Cocoon	Bldg	Barrier/MinRchrg
Cocoon/RTD	Bldg	Barrier/MinRchrg
D&D	Bldg	Barrier/MinRchrg
D4 (tank removed, foundation remains)	Bldg	Barrier/MinRchrg
D4; grout	Bldg	Barrier/MinRchrg

Disposition[a]	Cover Type	SurfCond
D4 (structure backfilled)	Bldg	Barrier/MinRchrg
Deactivation	Bldg	Barrier/MinRchrg
Grout in place below ground (entombment); demolish aboveground	Bldg	Barrier/MinRchrg
In situ vitrification	Bldg	Barrier/MinRchrg
Museum	Bldg	Barrier/MinRchrg
O&M	Bldg	Barrier/MinRchrg
Operating	Bldg	Barrier/MinRchrg
Planned	Bldg	Barrier/MinRchrg
remove sludge; stabilize tank	Bldg	Barrier/MinRchrg
RTD; grout	Bldg	Barrier/MinRchrg
Shutdown Pending	Bldg	Barrier/MinRchrg
Standby	Bldg	Barrier/MinRchrg
To Go	Bldg	Barrier/MinRchrg
Transition	Bldg	Barrier/MinRchrg
Void fill grouting	Bldg	Barrier/MinRchrg
Barrier	ET Barrier	Barrier/MinRchrg
ET Barrier	ET Barrier	Barrier/MinRchrg
ET barrier (+MNA for short-lived radioisotopes)	ET Barrier	Barrier/MinRchrg
ET Cap	ET Barrier	Barrier/MinRchrg
Hanford or ET barrier	ET Barrier	Barrier/MinRchrg
partial RTD with unspecified barrier	ET Barrier	Barrier/MinRchrg

Notes:

a Two disposition values are included here which are not part of the Hanford Disposition Baseline. The rows colored in gray are those that are used as default values when a waste site or facility has no disposition defined.

4.4 Data Interpretation: Surface Condition to Recharge

An Excel worksheet of lookup values was created to standardize and track the assignment of published recharge rates to the various detailed descriptions available on surface condition. Based on the available data on recharge, defined in ***4.2.2*** above, all vegetative cover types and disposition values were assigned to the following six surface conditions, listed in order of decreasing recharge rates:

1. Irrigated
2. Bare
3. Cheatgrass
4. Developing
5. Mature
6. Barrier-MinRchrg

Table *6* represents the values used in the current calculation. The recharge values are assigned for each soil type and are colored to indicate the reference publication from which the value was taken.

In most cases there is a clear relationship between the surface conditions and soils defined in this calculation with the references in ***4.2.2*** above. There were a few exceptions.

PNNL-14072 Rev1 provides a long-term recharge rate expected from the eventual degradation of ET Barriers within the Warden silt loam soil type. In the absence of rates for other soil types, this one value was used for all soil types.

Per the ECF-Hanford_11-0063 Rev 6, the recharge increment attributable to irrigation alone is 68.4 mm/yr. Within that publication, that increment was added to the corresponding rate for mature shrub steppe (4.0 mm/yr) phases of the native vegetation recharge scenario in Hanford Sands/Disturbed soils to obtain the total recharge rate for long-term irrigation conditions. For this calculation then, the increment for irrigation was added to the corresponding rates for the mature shrub steppe phase of each of the other soil types. For example, recharge in active irrigation in the Ephrata Stony Loam were set at 69.9 mm/yr (68.4 + 1.5) and at 72.4 mm/yr (68.4 + 4) in the Quincy (Rupert) Sand.

For locations where a soil type remains undefined ('XX') in the GIS data source, the values for Rupert Sand are applied.

Artificial regeneration was presumed to begin in the immature shrub steppe 'developing' phase and thus assumed the same values as other undisturbed vegetation cover types.

Table 6 Recharge rates in mm/year as applied to each unique combination of cover, surface condition, and soil.

Cover_Type[a]	SurfCond	Reference Source[b]	Ri	Qy	Rp	He	Kf	Ba	El	Ls	Eb	Ki	Wa	Sc	P	Qu	Rv	D	XX
Agricultural / Orchard	Irrigated	ECF-Hanford-11-0063-Rev 06	71.8	72.4	72.4	71	71	71.4	69.9	71.8	69.9	71.8	71.8	71.8	71.8	71.8	77	77	72.4
Urban	Irrigated		71.8	72.4	72.4	71	71	71.4	69.9	71.8	69.9	71.8	71.8	71.8	71.8	71.8	77	77	72.4
Basalt	Bare	PNNL-10285-UC2010	86.7	86.7	86.7	86.7	86.7	86.7	86.7	127.1	86.7	86.7	86.7	86.7	86.7	86.7	86.7	86.7	86.7
Disturbed	Bare	PNNL-14072rev1	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63
Non-Vegetated Sand - Bluffs - Talus	Bare	PNNL-10285-UC2010	55.4	55.4	55.4	55.4	55.4	55.4	55.4	55.4	55.4	55.4	55.4	55.4	55.4	55.4	55.4	55.4	55.4
Gravel/Industrial/Non-Vegetated/Exotic Weed	Cheatgrass	PNNL-14072rev1	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46
Disturbed	Cheatgrass	PNNL-14072rev1	31.5	31.5	31.5	31.5	31.5	31.5	31.5	31.5	31.5	31.5	31.5	31.5	31.5	31.5	31.5	31.5	31.5
Abandoned Fields	Cheatgrass	PNNL-14072rev1, PNNL-10285-UC2010	4.8	22	22	3.4	3.4	26	8.5	4.8	8.5	4.8	4.8	4.8	4.8	4.8	25.4	25.4	22
Bluebunch Wheatgrass - Sandberg's Bluegrass	Cheatgrass	PNNL-14072rev1, PNNL-10285-UC2010	4.8	22	22	3.4	3.4	26	8.5	4.8	8.5	4.8	4.8	4.8	4.8	4.8	25.4	25.4	22
Bunchgrass Mosaic	Cheatgrass	PNNL-14072rev1, PNNL-10285-UC2010	4.8	22	22	3.4	3.4	26	8.5	4.8	8.5	4.8	4.8	4.8	4.8	4.8	25.4	25.4	22
Crested Wheatgrass - Bluegrass - Cheatgrass	Cheatgrass	PNNL-14072rev1, PNNL-10285-UC2010	4.8	22	22	3.4	3.4	26	8.5	4.8	8.5	4.8	4.8	4.8	4.8	4.8	25.4	25.4	22
Sand Dropseed - Sandberg's Bluegrass - Cheatgrass	Cheatgrass	PNNL-14072rev1, PNNL-10285-UC2010	4.8	22	22	3.4	3.4	26	8.5	4.8	8.5	4.8	4.8	4.8	4.8	4.8	25.4	25.4	22
Sandberg's Bluegrass	Cheatgrass	PNNL-14072rev1, PNNL-10285-UC2010	4.8	22	22	3.4	3.4	26	8.5	4.8	8.5	4.8	4.8	4.8	4.8	4.8	25.4	25.4	22
Sandberg's Bluegrass - Cheatgrass	Cheatgrass	PNNL-14072rev1, PNNL-10285-UC2010	4.8	22	22	3.4	3.4	26	8.5	4.8	8.5	4.8	4.8	4.8	4.8	4.8	25.4	25.4	22
Cheatgrass - Vegetated	Cheatgrass		4.8	22	22	3.4	3.4	26	8.5	4.8	8.5	4.8	4.8	4.8	4.8	4.8	25.4	25.4	22
Gravel/Industrial/Non-Vegetated/Exotic Weed	Developing	PNNL-14072rev1	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46
Rabbitbrush/Bunchgrass Mosaic	Developing	PNNL-14072rev1, PNNL-10285-UC2010	3.4	8	8	2.6	2.6	6	3	3.4	3	3.4	3.4	3.4	3.4	3.4	11.3	11.3	8
Rabbitbrush/Sandberg's Bluegrass - Cheatgrass	Developing	PNNL-14072rev1, PNNL-10285-UC2010	3.4	8	8	2.6	2.6	6	3	3.4	3	3.4	3.4	3.4	3.4	3.4	11.3	11.3	8
Snow Buckwheat/Bunchgrass Mosaic	Developing	PNNL-14072rev1, PNNL-10285-UC2010	3.4	8	8	2.6	2.6	6	3	3.4	3	3.4	3.4	3.4	3.4	3.4	11.3	11.3	8
Snow Buckwheat/Sandberg's Bluegrass - Cheatgrass	Developing	PNNL-14072rev1, PNNL-10285-UC2010	3.4	8	8	2.6	2.6	6	3	3.4	3	3.4	3.4	3.4	3.4	3.4	11.3	11.3	8
Spiny Hopsage/Sandberg's Bluegrass - Cheatgrass	Developing	PNNL-14072rev1, PNNL-10285-UC2010	3.4	8	8	2.6	2.6	6	3	3.4	3	3.4	3.4	3.4	3.4	3.4	11.3	11.3	8
Thymeleaf Buckwheat/Sandberg's Bluegrass	Developing	PNNL-14072rev1, PNNL-10285-UC2010	3.4	8	8	2.6	2.6	6	3	3.4	3	3.4	3.4	3.4	3.4	3.4	11.3	11.3	8
Winterfat/Bunchgrass Mosaic	Developing	PNNL-14072rev1, PNNL-10285-UC2010	3.4	8	8	2.6	2.6	6	3	3.4	3	3.4	3.4	3.4	3.4	3.4	11.3	11.3	8
Developing - Vegetated	Developing		3.4	8	8	2.6	2.6	6	3	3.4	3	3.4	3.4	3.4	3.4	3.4	11.3	11.3	8
Artificial Regeneration	Developing		3.4	8	8	2.6	2.6	6	3	3.4	3	3.4	3.4	3.4	3.4	3.4	11.3	11.3	8
Disturbed	Developing	PNNL-14072rev1	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8

Cover_Type[a]	SurfCond	Reference Source[b]	Rl	Qy	Rp	He	Kf	Ba	El	Ls	Eb	Kl	Wa	Sc	P	Qu	Rv	D	XX
ET Barrier	Developing	PNNL-14072rev1	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Gravel/Industrial/Non-Vegetated/Exotic Weed	Mature	PNNL-14072rev1	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46
Big Sagebrush - Bitterbrush/Bunchgrass Mosaic	Mature	PNNL-14072rev1, PNNL-10285-UC2010	3.4	4	4	2.6	2.6	3	1.5	3.4	1.5	3.4	3.4	3.4	3.4	3.4	8.6	8.6	4
Big Sagebrush - Bitterbrush/Sandberg's Bluegrass	Mature	PNNL-14072rev1, PNNL-10285-UC2010	3.4	4	4	2.6	2.6	3	1.5	3.4	1.5	3.4	3.4	3.4	3.4	3.4	8.6	8.6	4
Big Sagebrush - Rigid Sagebrush/Bunchgrass Mosaic	Mature	PNNL-14072rev1, PNNL-10285-UC2010	3.4	4	4	2.6	2.6	3	1.5	3.4	1.5	3.4	3.4	3.4	3.4	3.4	8.6	8.6	4
Big Sagebrush - Spiny Hopsage/Bunchgrass Mosaic	Mature	PNNL-14072rev1, PNNL-10285-UC2010	3.4	4	4	2.6	2.6	3	1.5	3.4	1.5	3.4	3.4	3.4	3.4	3.4	8.6	8.6	4
Big Sagebrush - Spiny Hopsage/Sandberg's Bluegrass - Cheatgrass	Mature	PNNL-14072rev1, PNNL-10285-UC2010	3.4	4	4	2.6	2.6	3	1.5	3.4	1.5	3.4	3.4	3.4	3.4	3.4	8.6	8.6	4
Big Sagebrush/Bluebunch Wheatgrass - Sandberg's Bluegrass	Mature	PNNL-14072rev1, PNNL-10285-UC2010	3.4	4	4	2.6	2.6	3	1.5	3.4	1.5	3.4	3.4	3.4	3.4	3.4	8.6	8.6	4
Big Sagebrush/Bunchgrass Mosaic	Mature	PNNL-14072rev1, PNNL-10285-UC2010	3.4	4	4	2.6	2.6	3	1.5	3.4	1.5	3.4	3.4	3.4	3.4	3.4	8.6	8.6	4
Big Sagebrush/Sandberg's Bluegrass - Cheatgrass	Mature	PNNL-14072rev1, PNNL-10285-UC2010	3.4	4	4	2.6	2.6	3	1.5	3.4	1.5	3.4	3.4	3.4	3.4	3.4	8.6	8.6	4
Bitterbrush/Bunchgrass Mosaic	Mature	PNNL-14072rev1, PNNL-10285-UC2010	3.4	4	4	2.6	2.6	3	1.5	3.4	1.5	3.4	3.4	3.4	3.4	3.4	8.6	8.6	4
Bitterbrush/Sandberg's Bluegrass - Cheatgrass	Mature	PNNL-14072rev1, PNNL-10285-UC2010	3.4	4	4	2.6	2.6	3	1.5	3.4	1.5	3.4	3.4	3.4	3.4	3.4	8.6	8.6	4
Black Greasewood/Alkali Saltgrass	Mature	PNNL-14072rev1, PNNL-10285-UC2010	3.4	4	4	2.6	2.6	3	1.5	3.4	1.5	3.4	3.4	3.4	3.4	3.4	8.6	8.6	4
Purple Sage/Sandberg's Bluegrass - Cheatgrass	Mature	PNNL-14072rev1, PNNL-10285-UC2010	3.4	4	4	2.6	2.6	3	1.5	3.4	1.5	3.4	3.4	3.4	3.4	3.4	8.6	8.6	4
Rigid Sagebrush/Sandberg's Bluegrass	Mature	PNNL-14072rev1, PNNL-10285-UC2010	3.4	4	4	2.6	2.6	3	1.5	3.4	1.5	3.4	3.4	3.4	3.4	3.4	8.6	8.6	4
Threetip Sagebrush/Bunchgrass Mosaic	Mature	PNNL-14072rev1, PNNL-10285-UC2010	3.4	4	4	2.6	2.6	3	1.5	3.4	1.5	3.4	3.4	3.4	3.4	3.4	8.6	8.6	4
Mature - Vegetated	Mature	PNNL-14072rev1, PNNL-10285-UC2010	3.4	4	4	2.6	2.6	3	1.5	3.4	1.5	3.4	3.4	3.4	3.4	3.4	8.6	8.6	4
Disturbed	Mature	PNNL-14072rev1	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
ET Barrier	Mature	PNNL-14072rev1	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Bldg	Barrier/MinRchrg		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ET Barrier	Barrier/MinRchrg	PNNL-14072rev1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Open Reservoir	Barrier/MinRchrg	PNNL-10285-UC2010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Riparian/Wetlands/Aquatic Habitats	Barrier/MinRchrg		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Notes:

a Certain combinations of cover and surface condition have not yet been incorporated into the automation script. These data rows are shaded gray.

b Recharge values for each soil are colored in black or gray font to match the color of the corresponding Reference Source.

5 Software Applications

Esri® ArcGIS™ Version 10.2.2 (both ArcGIS™ for Desktop Basic and ArcGIS™ for Desktop Advanced; including ArcMap™, ArcCatalog™, ArcToolbox™, and ArcPy™) was the primary software used for this calculation and data were ingested as shapefiles and output to feature classes within a geodatabase. Capture of new features from aerial imagery was done within the desktop application directly, while the automation of the data ranking and calculation of recharge output features was done with Python script built into a custom ArcGIS™ tool in ArcToolbox™.

These calculations were performed using a commercial software license that is maintained by INTERA Inc., a pre-selected subcontractor to CHPRC. Calculations were performed on a desktop with ID INTERA-00575. The hardware is a Dell® Optiplex 790 with a 3.40-GHz Intel® Core™ i7-2600 processor and 8.0 GB of RAM loaded with the Windows® 7 Professional 64-bit operating system.

Microsoft Excel® spreadsheets were used for data storage, of both waste site attributes and of calculation parameters such as valid values lists, and were queried from within the GIS for attributes being joined to spatial features and for processing parameters within the geoprocessing tool.

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5.1 Approved Software

Because the geoprocessing tool developed within ArcMap is used in the same manner as the desktop software, and only serves to automate desktop functions, it is not considered a new software application and thus is not further described.

6 Calculation

All the reference source data to be used in the calculations were loaded as shapefiles onto a local INTERA server and then loaded into a single geodatabase used as the source for all subsequent calculations.

A default map document (MXD) was created containing the data sources, and organized into logical groups based on their relevance to the calculations. This MXD served as the starting point for new map documents developed for interim processing steps.

Specific ArcGIS™ commands are referenced in the ECF text in a bold font with all capital letters (**CLIP**), while parameters specified within a command are indicated in bold font with initial capitals only (**Clip_Features**). Attribute field names within a feature class are enclosed in double quotes ("Cover_Type"), attribute values in single quotes ('Developing'), and variables are indicated with pointy brackets (<YYYY>, enter the year using 4 characters).

Most the commands used for this ECF can be issued with an ArcGIS™ for Desktop Basic license, except for the **UPDATE** command, which requires an ArcGIS™ for Desktop Advanced license. If the Advanced license is unavailable for future processing, then a workaround will need to be substituted anywhere the **UPDATE** function is applied.

All digital content developed for and used in these calculations are being provided with this ECF and are listed and named in Attachment A. References in the ECF to these digital files, feature classes, feature datasets, and worksheets within an Excel® workbook are in bold font ('**SurfCondDisposition**').

6.1 Extend the 'sitewide' datasets for soils and vegetation

Step 1. Gaps in the soils and vegetation data within the model area domain were identified in the far northwest and southernmost extents of the model domain, as highlighted in **Figure 5**.

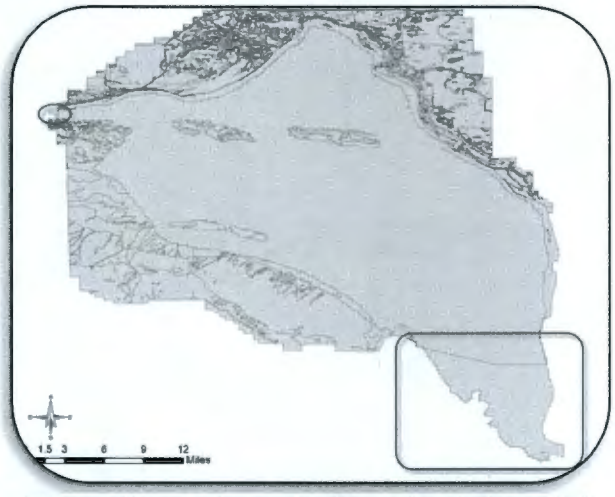

Figure 5 Gaps in the vegetation and soils data within the model domain boundary.

Step 2. The most current SSURGO dataset for Benton County was downloaded from the NRCS Web Soil Survey.

a) The soil descriptions contained in a related MS Access database were joined to the geographic features following instructions provided on the Web Soil Survey.

b) The resulting geographic shapefile (*SSURGO_soil_a_wa605.shp*) was projected to match the current calculation requirements, and then clipped by the model domain boundary and the existing Hanford soils data extent.

c) The clipped shapefile was modified to add a new attributes for "TEXT_SYM" and then updating the values according to the corresponding Hanford soil type specified in ***Table 2***.

d) The existing *SOILSP* feature class was renamed to NRBC_Soils and a new attribute "HAN_SYM" was added and values from "TEXT_SYM" were copied into "HAN_SYM".

e) The modified SSURGO shapefile was then loaded into the geodatabase as a temporary feature class, and then loaded into *NRBC_Soils*, assigning "MUSY" to "HAN_SYM" and "MUName" to "Comments".

f) Basic metadata for the new feature class was created.

g) There are small, sliver-type areas along the model domain boundary that are missing a soil type (see **Figure 6**). These should be resolved in a future calculation.

Figure 6 Small, sliver-like areas (in red) of the soils classification that remain to be updated to achieve full coverage within the model domain boundary.

Step 3. New vegetation features were added to the outputs from the 2011 image analysis described below in ECF section 6.2 Enhance data on surface condition.

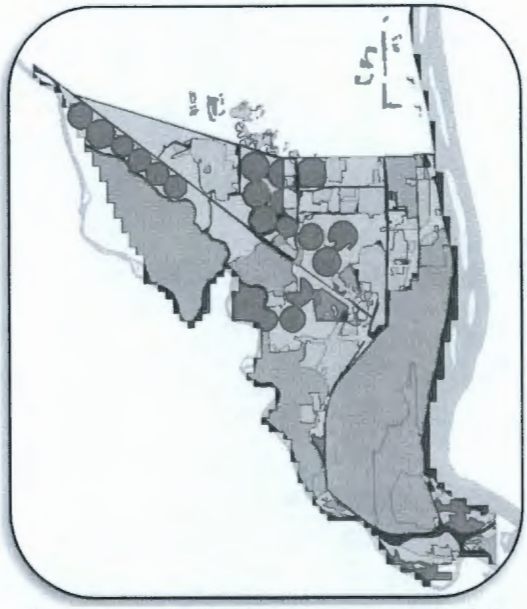

Figure 7 Small, sliver-like areas (in red) of the vegetation classification that were updated to complete the vegetation coverage for the entire model domain.

a) A copy of the new surface condition polygons that were identified using the 2011 NAIP imagery was made, and vegetation polygons were digitized in areas not previously captured within the model domain boundary. For small, sliver-type areas along the model domain boundary and along roadways (see the red areas in **Figure 7**), a copy of the model domain boundary was unioned with the existing vegetation polygons, and the resulting small, sliver areas were bisected and attributed as necessary to distinguish unique cover/surface conditions.

b) Attributes were assigned to "SurfCon" and "Cover" using the same methodology for assigning values in the original feature class, where "Cover" was only updated to the general category (e.g. 'Developing – Vegetated' instead of indicating individual species composition).

c) Basic metadata for the new feature class was created.

d) Features were checked by a person who did not do the initial feature capture and updated when inconsistent with other data collection efforts.

6.2 Enhance data on surface condition

Step 1. Two time periods were captured with aerial photo image analysis. Our biggest priority was to capture features with largest impact on potential recharge, so the capture focus was on treatment ponds, scarified lands such as dirt pits, irrigated fields,

a) An image analysis was conducted for the year 2011 because 1) NAIP for 2011 was the same data source used for the existing sitewide vegetation (BRMP) map; 2) the resolution and natural color bands provide ample information for vegetation classification; 3) the data source was readily available and usable, 3) because the existing vegetation classification (BRMP) exists for much of the site, the area to be captured was relatively small.

b) The year 1943 was chosen for image analysis because of 1) the significant impact the recently irrigated lands would potential have on recharge leading into the operational period; 2) the imagery had been captured at a reasonably large scale, had already been scanned into digital files, had almost full coverage sitewide, and was already available on local servers; 3) a mosaic of the individual images sitewide had already been created, and consists mostly of higher-resolution scans (1200 dpi), at least in the irrigated areas. And, arguably the parts of the mosaic that are captured at 600 dpi are still legible enough to distinguish the particular surface condition classes we are most interested in: Irrigated, Disturbed, Bare, and Mature.

There are gaps in the digital imagery, in the 200 Area in particular, which are also reflected in the polygons that were captured in this calculation.

A more automated classification was considered, but can't really do a supervised or unsupervised classification because the shadows and water are black, and because dunes and road shoulders are white.

c) The year 1982 was considered as the preferred time period to most closely represent the operational period, as this is the closest year of color imagery at high resolution, sitewide, that is also already in digital format. This is a time period recommended for future review but was not chosen for this calculation.

6.2.1 Surface Condition from 2011 NAIP

Step 2. Information on the surface condition in 2011 is considered well represented sitewide by the BRMP. However, because the BRMP was more focused on natural vegetation condition, areas of human development and disturbance were less represented. As such, the priority for new feature capture focused on refining the surface condition in those areas (listed below) most likely to impact recharge and the downstream impacts of recharge.

- Operational Areas (disturbance)
- Buffers around OU's
- 'upgradient' of OU's
- All other areas

In the interest of time, roads were not captured because the existing transportation feature classes were considered an adequate representation of that disturbance; however, wide swaths of disturbance around the standard road feature may have been captured.

Step 3. The imagery was evaluated in a serpentine pattern along the PLSS Section grid, starting in the top right of the model domain and moving right to left. Three passes were made: the first to capture all of the most obvious features, a second to capture smaller features, and a final to assign attributes to the features. All initial data capture was made over consecutive days by the same analyst, and daily logs were maintained of progress.

Step 4. Working files were stored in the NRBC_Default_v*.gdb geodatabase, and edited from a derivation of the NRBC_Basemap_v*.mxd map document that was used as the starting point for every step in the calculations. The new feature class was created in the appropriate Washington State Plane projection to match both the map document data frame and the related data sources.

Step 5. Domains and coded value lists were created (according to the highlighted values in ***Table 7***) to control the attribute values being assigned to 'Cover' and 'SurfCon'. For example, while polygons from the existing vegetation classification (BRMP) assigned individual species names, the cover types assigned by this calculation were generalized into a functional group, instead of presuming to know the exact species composition.

Table 7 Vegetative Cover Types and Surface Condition values as were assigned during the capture of new features. Only those values in gray-shaded rows were assigned by this calculation.

VegCover_Type	SurfCond
Agricultural / Orchard	Irrigated
Urban	Irrigated
Disturbed	Bare
Non-Vegetated Sand - Bluffs - Talus	Bare
Riparian/Wetlands/Aquatic Habitats	Bare

VegCover_Type	SurfCond
Abandoned Fields	Cheatgrass
Bluebunch Wheatgrass - Sandberg's Bluegrass	Cheatgrass
Bunchgrass Mosaic	Cheatgrass
Crested Wheatgrass - Bluegrass - Cheatgrass	Cheatgrass
Cheatgrass - Vegetated	Cheatgrass
Gravel/Industrial/Non-Vegetated/Exotic Weed	Cheatgrass
Sand Dropseed - Sandberg's Bluegrass - Cheatgrass	Cheatgrass
Sandberg's Bluegrass	Cheatgrass
Sandberg's Bluegrass - Cheatgrass	Cheatgrass
Rabbitbrush/Bunchgrass Mosaic	Developing
Rabbitbrush/Sandberg's Bluegrass - Cheatgrass	Developing
Snow Buckwheat/Bunchgrass Mosaic	Developing
Snow Buckwheat/Sandberg's Bluegrass - Cheatgrass	Developing
Spiny Hopsage/Sandberg's Bluegrass - Cheatgrass	Developing
Thymeleaf Buckwheat/Sandberg's Bluegrass	Developing
Winterfat/Bunchgrass Mosaic	Developing
Developing - Vegetated	Developing
Artificial Regeneration	Developing
Big Sagebrush - Bitterbrush/Bunchgrass Mosaic	Mature
Big Sagebrush - Bitterbrush/Sandberg's Bluegrass	Mature
Big Sagebrush - Rigid Sagebrush/Bunchgrass Mosaic	Mature
Big Sagebrush - Spiny Hopsage/Bunchgrass Mosaic	Mature
Big Sagebrush - Spiny Hopsage/Sandberg's Bluegrass - Cheatgrass	Mature
Big Sagebrush/Bluebunch Wheatgrass - Sandberg's Bluegrass	Mature
Big Sagebrush/Bunchgrass Mosaic	Mature
Big Sagebrush/Sandberg's Bluegrass - Cheatgrass	Mature
Bitterbrush/Bunchgrass Mosaic	Mature
Bitterbrush/Sandberg's Bluegrass - Cheatgrass	Mature
Black Greasewood/Alkali Saltgrass	Mature
Purple Sage/Sandberg's Bluegrass - Cheatgrass	Mature
Rigid Sagebrush/Sandberg's Bluegrass	Mature
Threetip Sagebrush/Bunchgrass Mosaic	Mature
Mature - Vegetated	Mature
Bldg	Barrier-MinRchrg
ET Barrier	Barrier-MinRchrg
Open Reservoir	Barrier-MinRchrg

Step 6. Polygons were created after visual inspection of imagery for any surface condition that appeared significantly different from the existing classifications. Surface condition polygons were generally not defined for areas smaller than ¼ square kilometer because the impact to recharge at that scale is considered negligible.

All attributes of the polygons were assigned solely through visual interpretation of the imagery in a GIS, and were not verified in the field. Accordingly, except in areas where no prior mapping of vegetation existed, no assumptions were made about species composition or other native vegetation classification.

There were significant areas of disturbance that were not captured within this feature class because they are already well represented by other spatial datasets for cleanup verification packages, buildings and facilities, and environmental waste sites. Similarly, road features were not captured because the existing transportation features were considered adequate.

Examples of specific image interpretation decisions are provided in ***Figures 8*** through ***14***.

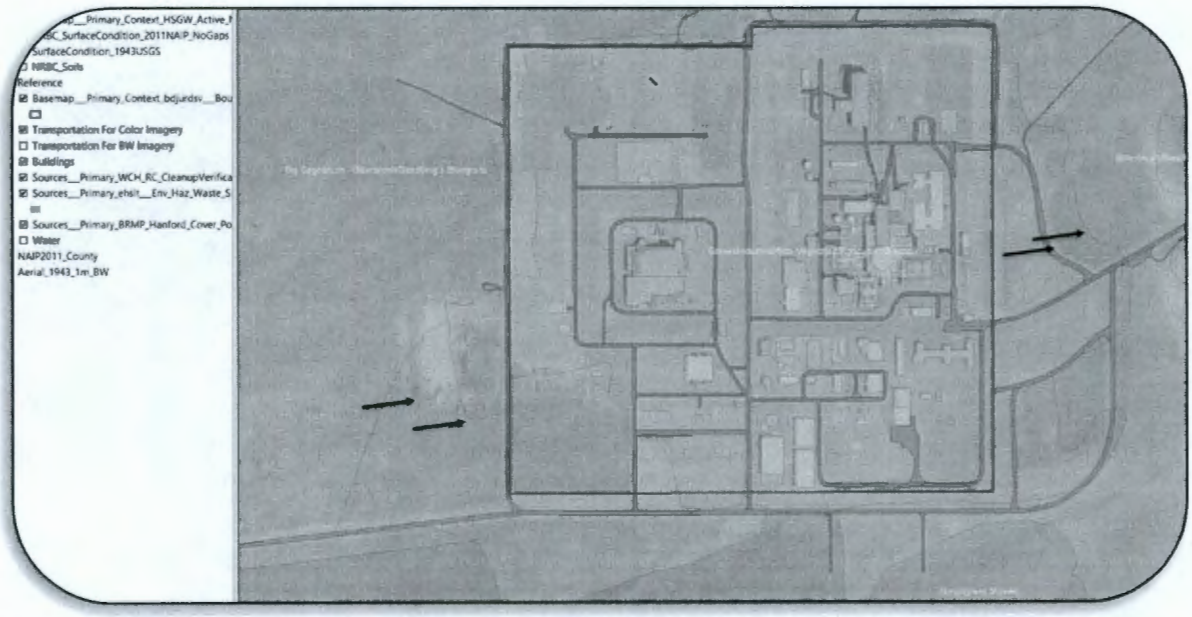

Figure 8 2011 NAIP Interpretation: disturbance that had been previously identified was not re-captured, even if shifted, as long as the total area appeared consistent.

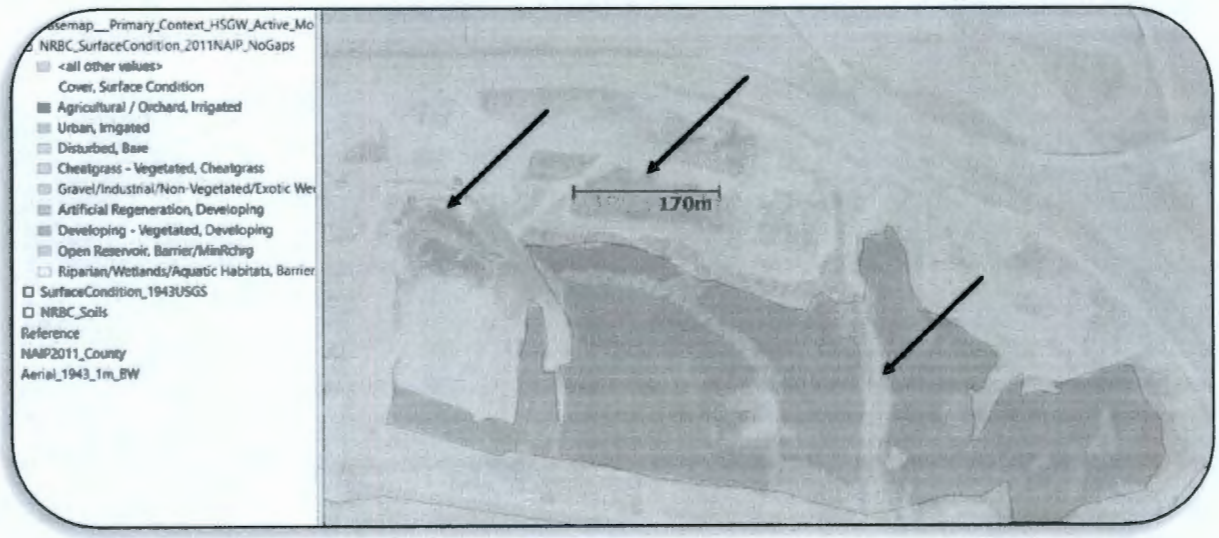

Figure 9 2011 NAIP Interpretation: at a scale of 1:5,000, the land features identified with the arrows were not distinguished.

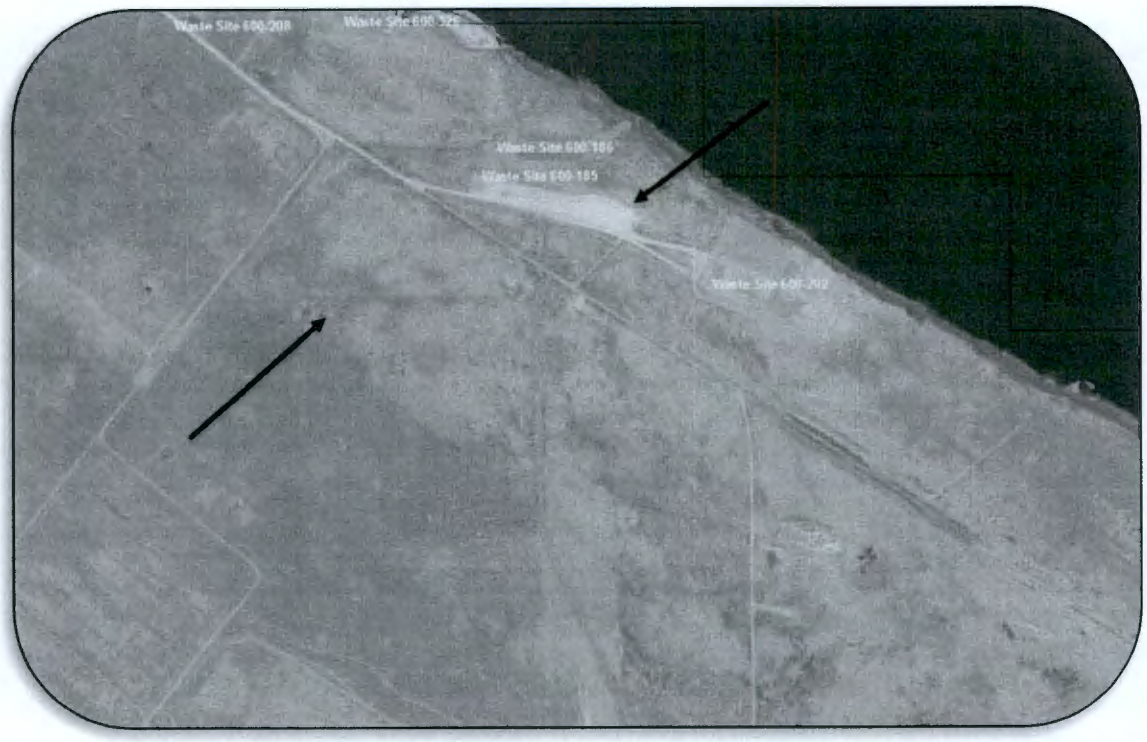

Figure 10 2011 NAIP Interpretation: no reclassification of existing vegetation polygons was made unless the change was directly related to a disturbance feature.

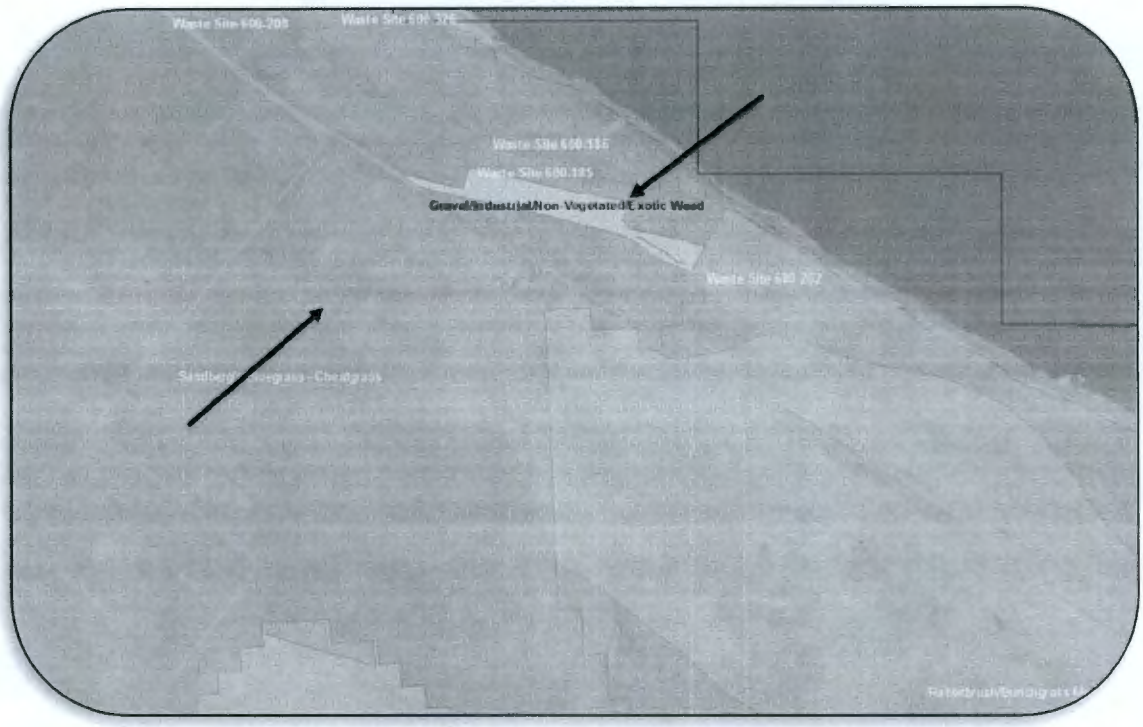

Figure 11 2011 NAIP Interpretation: in this example, the gravel site is captured but the variability within the Sandberg's Cheatgrass is not.

Figure 12 2011 NAIP Interpretation: Cheatgrass is left as-is from the existing vegetation (BRMP), with no further distinction of previous development activities.

Figure 13 2011 NAIP Interpretation: evidence of the Hanford Construction Camp which apparently housed up to 50,000 workers in 1945 is not distinguished because the existing vegetation classification appears accurate.

Step 7. One of the cover types in the BRMP was updated during this calculation because the original value included 'agriculture' but for this analysis we are capturing agriculture as a separate cover type. ***Figure 12*** provides a visual example of the data review that was made to confirm that it is reasonable to remove the 'agricultural' portion of the 'Gravel' cover type in the vegetation datasets. In the image, the purple outlines surround those features in the vegetation (BRMP) feature class with cover type set to "Gravel/Industrial/Non-Vegetated/Agricultural/Exotic Weed". Sitewide, there was only one feature with agricultural cover type, in the NE corner of the image, which is across the river and outside the model area boundary.

Figure 14 Data sample demonstrating justification for removing 'agricultural' from the vegetation cover type 'Gravel/Industrial/Non-Vegetated/Agricultural/Exotic Weed'.

Step 8. Basic metadata were created and maintained within the feature class as it was updated throughout the calculation.

Step 9. Data were checked by a person other than the one digitizing the features, which included checks against the new feature attribute lookup values that were defined as the automation script for this ECF was refined.

6.2.2 Surface Condition from 1943 USGS

Step 2. Data on surface condition is desirable from 1943 to specifically highlight any areas that are irrigated (with row furrows, indications of water, etc), bare ground (very light gray in the image), or disturbed (whitest areas of image). Defining the locations of these features will affect the recharge rates being

applied during the operational period as these sites will have greater recharge until the effects of secondary succession are seen.

Step 3. The image analysis was conducted in three passes, first along the river corridor where irrigation features were most likely, then again across the entire site more systematically according to the PLSS section grid, and finally again to assign attributes to the mapped features. All initial data capture was made over consecutive days by the same analyst, and daily logs were maintained of progress.

Step 4. Working files were stored in the NRBC_Default_v*.gdb geodatabase, and edited from a derivation of the NRBC_Basemap_v*.mxd map document that was used as the starting point for every step in the calculations. The new feature class was created in the appropriate Washington State Plane projection to match both the map document data frame and the related data sources.

Step 5. Domains and coded value lists were created (according to the highlighted values in ***Table 7***) to control the attribute values being assigned to 'Cover' and 'SurfCon'.

Step 6. Areas less than approximately 1/4 square kilometer were deemed insignificant and ignored. The scale of mapping was certainly affected by the image resolution (more difficult to distinguish the on-the-ground complexity), such that larger, more distinct color signatures are likely to be more represented than mixed use areas (such as a grassland with two-track roads and small platforms).

Distortion in some locations (apparently from the mis-aligned overlap of images) was accounted for by assessing features relative to identifiable displaced features (e.g. roads), and then using the center of the displacement as a baseline for the new geodatabase feature being created.

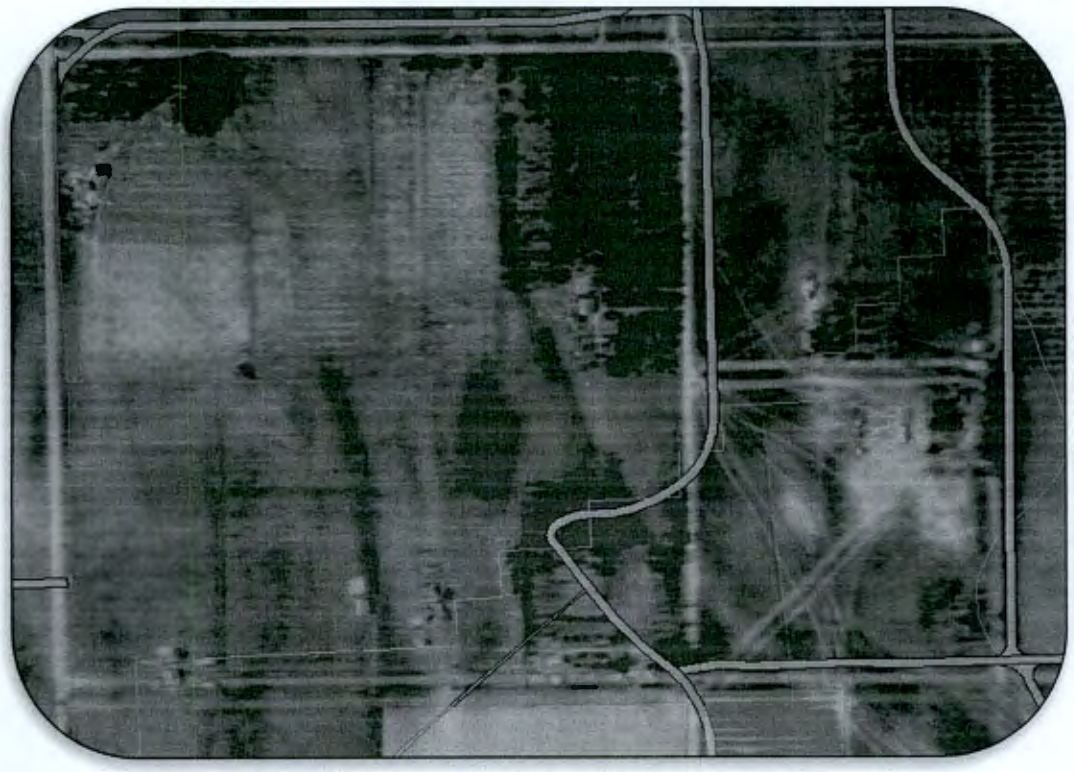

Figure 15 An area of the 1943 USGS imagery that demonstrates feature distortion that is likely the result of a variation in the camera angle on multiple passes over the same location.

6.3 Rank Data Sources for Use in Defining Surface Condition

Step 1. A list of possible data sources for establishing surface boundary condition were evaluated for inclusion in the current calculation. Data sources that were considered are provided in **Table 1**, and the values in "Function" and "Usage for ECF-HANFORD-15-0019" give an indication of whether the source was used as part of the current calculation, and how.

Table 8 provides a summary of the data sources that were finally chosen for this calculation.

Step 2. Part of the evaluation of the sources in **Table 1** included an evaluation of the scale, accuracy, availability, and relative importance of the data sources. For those sources that were considered, and researched, additional details which can be used in future calculations are provided in the "Notes on Data Fields".

For those data sources used in this calculation, the relevant attributes are identified in the last five columns of ***Table 8***.

Step 3. Column 2 "Time_Valid" in ***Table 8*** provides the time periods of applicability for the data sources used in this calculation. It is a combination of the "Time_Valid" which is evaluated at the level of each feature class, with the ranking described in Step 4, which provides the logic for the ranking applied in the automation script.

Step 4. Each data source in ***Table 8*** contains a number that ranks both the polygon feature ("Extent") as well as the attributes for each layer. In the current calculation, the outcome of that ranking results in facilities extents and attributes being the most important data such that when they exist (based on model year and layer validity for that model year), their value for surface condition and cover will be combined with the soil types to establish a recharge for that location. If a building does not exist at a location, then the data for waste sites will be used next, and so on. In the absence of any other data for a particular location, the vegetation cover and surface condition specified in the vegetation (BRMP) will be used.

Step 5. The interim feature classes that are created as part of the process automation are saved in the output database for each model year. It is these feature classes that represent the assumptions for each data source, in both the presence of a feature and in the attributes for cover and surface condition, which will have changed in some cases to reflect the effect of secondary succession on the vegetation. The metadata for the interim data products are not currently being updated.

Table 8 Priority Ranking and Attribute Definitions for Data Sources Used in Calculations of Recharge[a].

Name	Time Valid	Extent	Operations Time Start	Operations Time End	Reclamation Time	Cover Type[b]	Surface Condition[b]
Facilities[c]	1943 - Present	1	Disposition!Date_ Begin or 1943 n/a	Disposition!Date_End or Date_Disposition n/a	Disposition!Date_Disposition and/or Disposition_TPA_Date 1	"HanfordDispositionBaseline"Wkbook.Disposition!Disposition -> "NRBC_LookupTables"Wkbook.SurfCondDisposition!CoverType or default "Bldg" 1	"NRBC_LookupTables"Wkbook.SurfCondDisposition!CoverType -> "NRBC_LookupTables"Wkbook.SurfCondDisposition!SurfCond or default "Barrier/MinRchrg" 1
Waste Sites[d]	1943 - Present	2	Disposition!Date_ Begin or 1943 n/a	Disposition!Date_End or Date_Disposition n/a	Disposition!Date_Disposition and/or Disposition_TPA_Date 2	"HanfordDispositionBaseline"Wkbook.Disposition!Disposition -> "NRBC_LookupTables"Wkbook.SurfCondDisposition!CoverType or default "Gravel..." 2	"NRBC_LookupTables"Wkbook.SurfCondDisposition!CoverType -> "NRBC_LookupTables"Wkbook.SurfCondDisposition!SurfCond or default "Cheatgrass" 2
CVP's[e]	1998 - Present	2	n/a	n/a	Key_WSRF 3	"Artificial Regeneration" 3	"Developing" 3
2011 NAIP Polys[f]	1944 - 2050	4	n/a	n/a	n/a	Cover 4	SurfCon 4
1943 USGS Polys[g]	1880 – 2050[h]	4	n/a	n/a	n/a	Cover n/a	SurfCon 5
BRMP Veg[i]	1880 - Present	5	n/a	n/a	n/a	Cover_Type 6	Cover_Type -> "NRBC_LookupTables"Wkbook.SurfCondRecharge!SurfCond 6
Roads[j]	1944 - Present	3	n/a	n/a	n/a	"Gravel/Industrial/Non-Vegetated/Exotic Weed" n/a	"Cheatgrass" n/a
Roads – 1943[k]	1880 - 1943	3					

Notes:

a Cells that are shaded gray are those for which rules do not apply or have not yet been developed.

b Values indicated within quotation marks are hard-coded in the absence of better information.

c Includes Facilities and Buildings (**bggenxs_15Jan2014** and **bggensit**) with Hanford Baseline Disposition details as they exist. Otherwise set to Barrier/MinRchrg as a building.

d All the waste site polys (**ehsit**) with Hanford Baseline Disposition details as they exist.

e **Cleanup Verfication Packages**; Contain a date, and will be presumed to be developing as artificial regeneration from that date.

f **NRBC_SurfaceCondition_2011NAIP**; polygons to best represent cover types most likely to affect recharge rates (primarily "disturbed" and "gravel"); will be used instead of 2011 BRMP anywhere they exist

g **NRBC_SurfaceCondition_1943USGS**; polygons to best represent cover types most likely to affect recharge rates (primarily "irrigated" and "bare"). Hanford operations came online in 1943, at which time all current irrigation ceased per condemnation proceedings.

h Marked as active agriculture until 1943

i **Vegetation_2011BRMP**; This will become the default cover type unless more accurate data sources are identified.

j Includes four feature sources.

k Can be created by unselecting roads from current roads that are not in the 1943 imagery.

6.4 Automate the Calculation of Recharge Sitewide

Step 1. Following are the necessary geoprocessing steps required either in advance of the process automation or as part of it, as well as information about how the steps were each addressed.

a) Create a database to contain the interim data products, and organize the contents for the **UPDATE** procedure to be applied. Name the geodatabase in a way to reflect the model year to which it applies.

b) Determine which layers are valid for the desired time period (model year).

c) Select those features within each valid layer which are valid for model year)

d) Identify valid attributes as indicators of surface condition and condition dates for each feature.

e) Define the appropriate surface condition and succession start dates for each feature, using lookup tables that are user-maintained.

f) Consume the valid **Coded Values** within each domain from a lookup table that can be maintained outside of the GIS. The **NRBC_LookupTables_Final_v*.xlsx** contains two tables (worksheets) used in the automation: SurfCondDisposition (see ***Table 5***) and SurfCondRecharge (see ***Table 6***).

g) Apply approved rates of secondary succession such that features are updated to reflect conditions for the model year.

h) Merge (via UPDATE) the features from each layer such that any valid features are retained in lieu of other, lower ranked features, until a full disconnected coverage of surface condition and cover type exists sitewide.

i) UNION the output surface condition feature class with the soils feature class, and apply approved recharge rates for each unique combination of Surface Condition, Cover Type, and Soil Type.

j) Remove unwanted interim data products and attributes from the output feature classes.

k) Update the metadata for each feature class with standard language that best reflects the date therein.

Step 2. Python scripting was used to automate the geoprocessing steps above, and is confirmed to perform these steps:

a) Format the automation as a customized ArcGIS™ tool that can be run within ArcToolbox™. The custom tool is called **"Create Surface Condition Features"**.

b) Provide a graphical user interface (GUI) where the user will enter a value for the Model Year and will enter (by typing or browsing) the data sources to be used in the analysis:
   - Sitewide Disposition Baseline table
   - NRBC reference lookup tables
   - Data Sources on Surface Condition, currently including: BRMP, from the user via ArcGIS™

c) Creates a new geodatabase named "NRBC"_<YYYY>, where YYYY is the Model Year

d) Determines which feature classes are valid for the Model Year

e) Copies valid feature classes to the new geodatabase

f) Adds new "surface condition" and "cover type" fields to the feature classes

g) Uses lookup tables and secondary succession rules for the Model year to update the "surface condition" and "cover type" fields

h) Sequentially overlays features over one another in a predetermined order to create an "UpdatedFeatures" feature class. This step includes a categorical exclusion of HAZSITE_ID 2732 which apparently is not a true disturbance feature but instead indicates an area of potential contamination via rodent feces.
i) Renames "final update" features from "_temp" to "<filtered data source>_YYYY", such as *BRMP_1943*
j) Deletes other temporary features from geodatabase
k) Creates a new feature class, called *RechargeEstimates*, by implementing a union of the "UpdatedFeatures_YYYY" feature class and the "Soil" feature class.
l) Looks up recharge rates from a lookup table using the combination of cover, surface condition, and soil type as a key
m) Cleans up final output by deleting all interim fields except 'SurfCond', 'CoverType', 'Source', 'TEXT_SYM', 'SOIL_NAME', 'RechargeRate'

Following is a summary of the business rules for missing values and changes in secondary succession that are being applied within the automation script to features (as above in Section 6.4, Step 2g) for the Model Year.

1. If no soil feature is present, then the script is defaulting to the first column in the lookup table, which will apply the rate of the Quincy Sands ('Qy').
2. If a waste site (ehsit) lookup key (HAZSITE_ID) finds a matching record in the Baseline Disposition table, but the Disposition attribute is blank, then a default value is assigned to the recharge rate. However, if there is no matching record in the Baseline Disposition, then surface condition is set to 'undefined' and the recharge rate becomes -9999.
    a. NOTE: In some cases, the succession calculation continues on the surface condition attribute, but the recharge rate will remain -9999.
3. If Surface Condition and/or Cover type are blank, then the recharge rate is set to -9999.
4. Any features with the data source BRMP are not passed through the successional changes. This was an attempt to capture the natural mosaic pattern of vegetation sitewide that results from fire and other natural disturbance, rather than have all areas evolve to mature shrub-steppe.
5. The SurfCond and CoverType in the final RechargeEstimates represent the current status of the location, with succession already applied. For example, a site with a disposition date of 2050 will progress from Bare to Cheatgrass to Developing in the 10 years leading up to the Model Year 2060.

Step 3. Data outputs from the automation script were reviewed by both the script developer as part of unit testing of the script itself, and again by another analyst to confirm that values in the output reflect the actual values from the input or the expected derivations based on the application of the secondary succession rules for the Model Year. Sample data validations performed and results documented during testing are provided below.

a) Test: Confirm that records with an invalid recharge rate (-9999) are indeed missing some key attributes (such as vegetation cover type) instead of the error being in the calculations.

   Outcome: The 2060 Recharge Estimates contains 21,840 features, of which 2355 are missing a valid recharge rate. These 2355 features make up 75 km^2 (18,513 acres) of the total model domain area of 890 km^2 in model year 2060. This is essentially the extent of the southernmost area of the model domain where the vegetation classification is unavailable for 2060.

b) Test: Confirm resulting recharge rates make sense relative to business rules and successional rules that have been applied in the automation script.

Outcome: The generalization of rules is evident in some areas that will be over- or underestimated at the local level. For example, in ***Figure 16***, the absence of a vegetation survey for 1943, the conditions on the ground were assumed to be the same as the vegetation map from 2011 (BRMP).

Figure 16 Testing Results: An example of undisturbed habitat in the 1943 imagery that gets classified as gravel per 2011 data, because there is no vegetation map available for 1943.

c) Test: Confirm why some Cover and SurfCond values are being returned as 'undefined'.

Outcome: In some cases, such as with ehsit_1944 in ***Table 9***, the disposition data are inconsistently formatted so the data association fails.

Table 9 Testing Results: Attributes in Disposition and Related Lookup Tables must be consistent (see "LastKnownCond" = 'No action').

Source	SurfCond	CoverType	Site_ID	SuccessionBegin	LastKnownCond	StartDisp
ehsit	Cheatgrass	Gravel/Industrial/Non-Vegetated/Exotic Weed	100-B-11	2004	No action	Cheatgrass
ehsit	Cheatgrass	Gravel/Industrial/Non-Vegetated/Exotic Weed	100-B-2	2005	No action	Cheatgrass
ehsit	Cheatgrass	Gravel/Industrial/Non-Vegetated/Exotic Weed	100-B-24	2006	No action	Cheatgrass
ehsit	undefined	undefined	UPR-200-E-40	2021	no action	undefined
ehsit	undefined	undefined	UPR-200-W-52	2028	no action	undefined
ehsit	undefined	undefined	UPR-200-W-83	2030	no action	undefined
ehsit	undefined	undefined	UPR-200-W-95	2016	no action	undefined

d) Test: Confirm that Quicy Sand ('Qy') recharge rates are applied to any locations where soil data are absent (NULL or 'XX').

Outcome: From the contents of the 2060 RechargeEstimates, it appeared (from a sample of 245 records missing a soil type) that in fact the recharge rates may be defaulting to a rate other than the Quincy Sand. In this case (see ***Table 10***), the script was incorrectly assigning rates for soil type Ri (the first column in the lookup table) instead of Qy. The short-term fix was to re-order the lookup table but future updates to the script should make this exception more explicit.

Table 10 Testing Results: Recharge Rates in Model Year 2060 where soils data are absent (NULL): actual versus expected.

Inputs	Count	Recharge Current	Recharge Expected
bggenexs_Barrier/MinRchrg_Bldg	1	0	
bggenexs_Cheatgrass_Gravel/Industrial/Non-Vegetated/Exotic Weed	1	46	
bggensit_Barrier/MinRchrg_Bldg	1	0	
bggensit_Cheatgrass_Gravel/Industrial/Non-Vegetated/Exotic Weed	32	46	
BRMP_2011_Barrier/MinRchrg_Riparian/Wetlands/Aquatic Habitats	10	0	
BRMP_2011_Cheatgrass_Bluebunch Wheatgrass - Sandberg's Bluegrass	3	4.8	22
BRMP_2011_Cheatgrass_Bunchgrass Mosaic	1	4.8	22
BRMP_2011_Cheatgrass_Sand Dropseed - Sandberg's Bluegrass - Cheatgrass	1	4.8	22
BRMP_2011_Cheatgrass_Sandberg's Bluegrass	3	4.8	22
BRMP_2011_Cheatgrass_Sandberg's Bluegrass - Cheatgrass	23	4.8	22
BRMP_2011_Developing_Rabbitbrush/Bunchgrass Mosaic	6	3.4	8
BRMP_2011_Developing_Rabbitbrush/Sandberg's Bluegrass - Cheatgrass	13	3.4	8
BRMP_2011_Mature_Big Sagebrush - Bitterbrush/Bunchgrass Mosaic	5	3.4	4
BRMP_2011_Mature_Big Sagebrush - Rigid Sagebrush/Bunchgrass Mosaic	1	3.4	4
BRMP_2011_Mature_Big Sagebrush - Spiny Hopsage/Sandberg's Bluegrass - Cheatgrass	6	3.4	4
BRMP_2011_Mature_Big Sagebrush/Bluebunch Wheatgrass - Sandberg's Bluegrass	3	3.4	4
BRMP_2011_Mature_Big Sagebrush/Bunchgrass Mosaic	3	3.4	4
BRMP_2011_Mature_Big Sagebrush/Sandberg's Bluegrass - Cheatgrass	7	3.4	4
BRMP_2011_Mature_Bitterbrush/Bunchgrass Mosaic	1	3.4	4
BRMP_2011_Mature_Gravel/Industrial/Non-Vegetated/Exotic Weed	23	46	
BRMP_2011_Mature_Rigid Sagebrush/Sandberg's Bluegrass	2	3.4	4
cvp_Mature_undefined	24	-9999	4
ehsit_Developing_Gravel/Industrial/Non-Vegetated/Exotic Weed	24	46	
ehsit_Mature_Disturbed	40	4	
ehsit_Mature_Gravel/Industrial/Non-Vegetated/Exotic Weed	11	46	

Notes:

Step 4. The python script outputs debugging remarks that indicate the purpose of each step as it progresses. Durability of the coding is provided by grouping functions vulnerable to change, and using ESRI's python toolbox template to handle input.

7 Results/Conclusions

7.1 Results

The new features captured for 1943 and 2011 representing man-made disturbance (irrigation, gravel, urban, etc) add over 93 km^2 to the previously documented 38 km^2 identified in the existing vegetation map (BRMP) within the model domain boundary. Combined with mapped locations of waste sites and facilities (at 62 km^2), the area affected by ground disturbing activities approaches 193 km^2 at any one time within the site.

Sample model years were run through the automation script to capture the breadth of variability expected relative to the data inputs. For example, 1943 was run to capture the recharge while the newly mapped irrigated fields are considered active, and for contrast 1944 was run to capture those same fields moving from active to abandoned and all the known waste sites and facilities becoming active. The year 1987 was run to capture the primary operations with the irrigated fields of 1943 dropping into a 'Mature' lower recharge state and while the effects of site cleanups (per the Disposition) are not yet in full effect. Finally, 2023 and 2060 were run to capture the effects of secondary succession resulting from site cleanup activities and ultimately the target disposition of 2050 for most sites.

The results in ***Table 11*** indeed reflect the above conditions. The number of features that are output for each model year, as well as the recharge normalized by the area calculated, reflect low total recharge rate prior to operations (1943), with a peak in 1944 and 1987, tapering off back to a more natural vegetative state by 2060. The chart in ***Figure 17*** provides a visual summary of the same.

Table 11 Recharge Summary for the Calculation Area within the Model Domain Boundary.

	1943	1944	1987	2023	2060
Total Features (for each unique soil + cover + condition)	3268	21911	22749	24620	21840
Total Area of All Features (km^2)	889.5	888.6	890.9	891	890.3
Total Recharge (m^3/yr)	5803513	9467084	9566361	9304556	4837975
Total Recharge (L/yr)	5.80E+09	9.467E+09	9.566E+09	9.3E+09	4.84E+09
Valid Features (with recharge calculation)	2975	21722	22748	22559	19485
Area of Valid Features (km^2)	820.8	887.4	890.9	888.5	815.4
Invalid Features (RechargeRate = -9999)	293	189	1	2061	2355
Recharge Normalized by Area of Valid Features (L/yr/km^2)	**7070436**	**10668514**	**10737723**	**10471756**	**5933361**

Notes:

a Normalized Recharge = Total Recharge / Area of Valid Features.

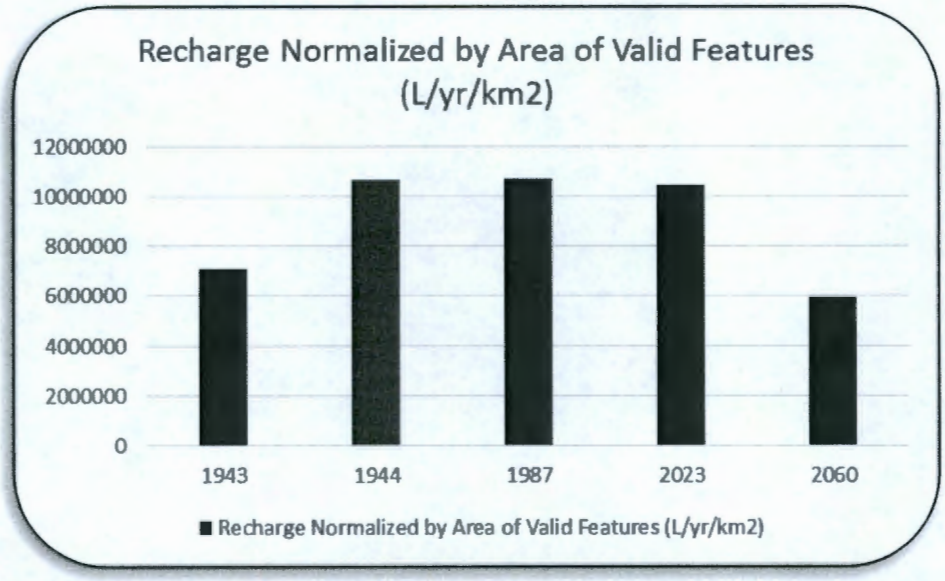

Figure 17 Chart of Recharge Normalized by Area for sample Model Years pre-operations, operations, and post-operations.

The variability in recharge rates for different model years are demonstrated for a location at the northernmost end of the model domain boundary (***Figures 17, 18, 19, 20***).

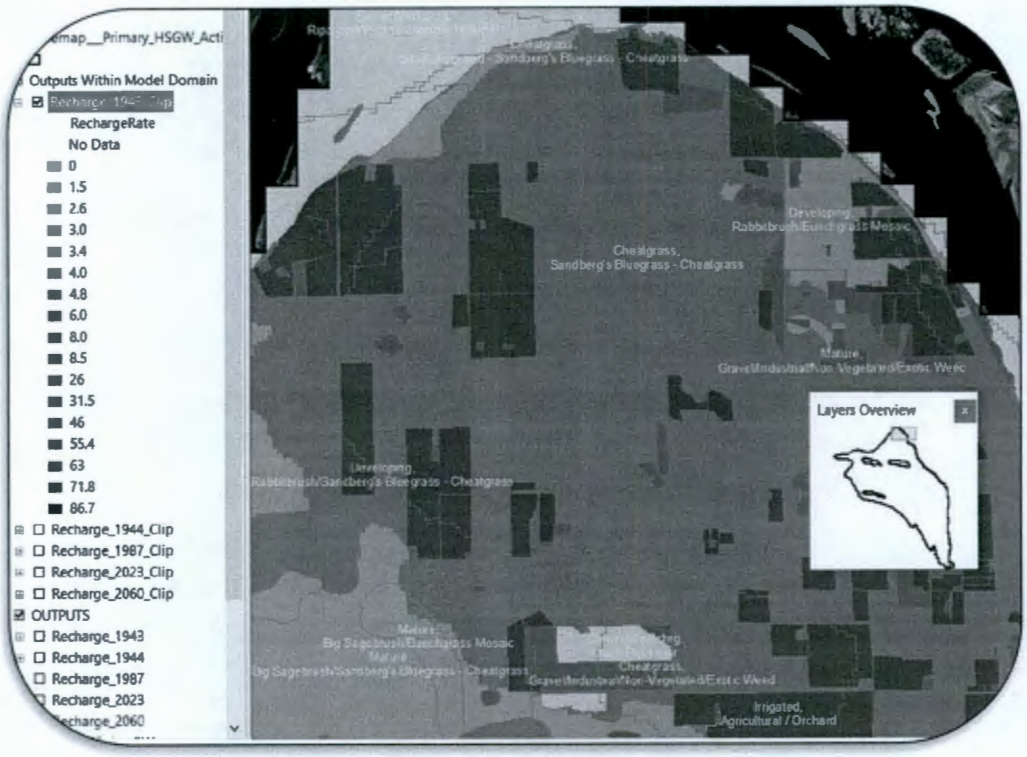

Figure 18 Map of Estimated Recharge (mm/yr), 1943.

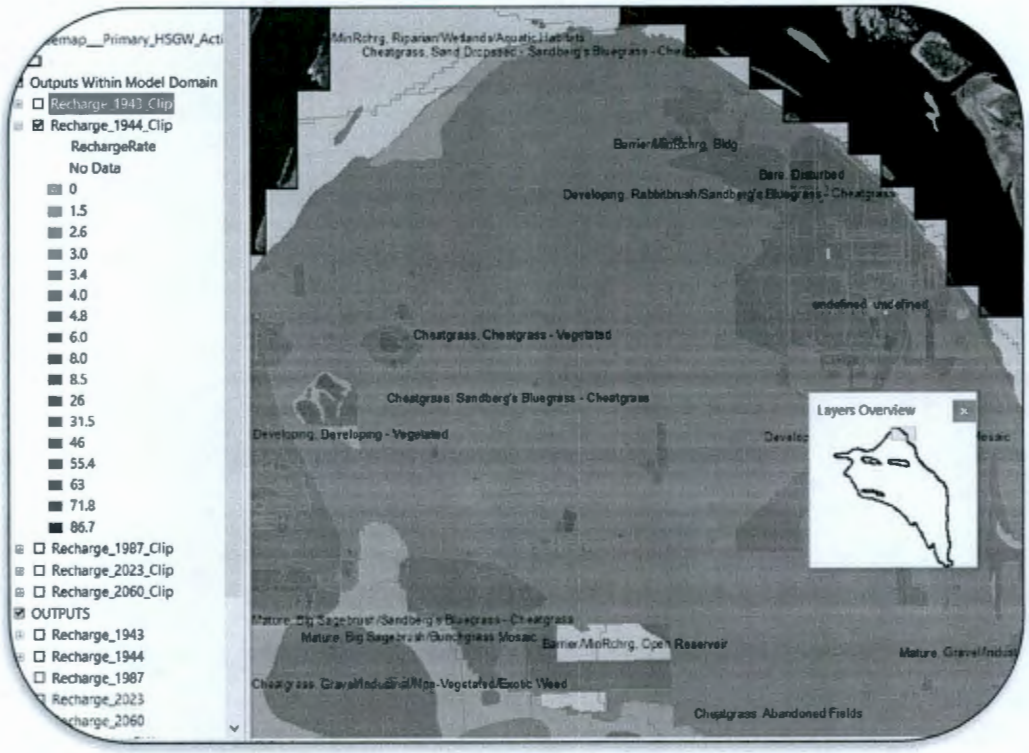

Figure 19 Map of Estimated Recharge (mm/yr), 1944.

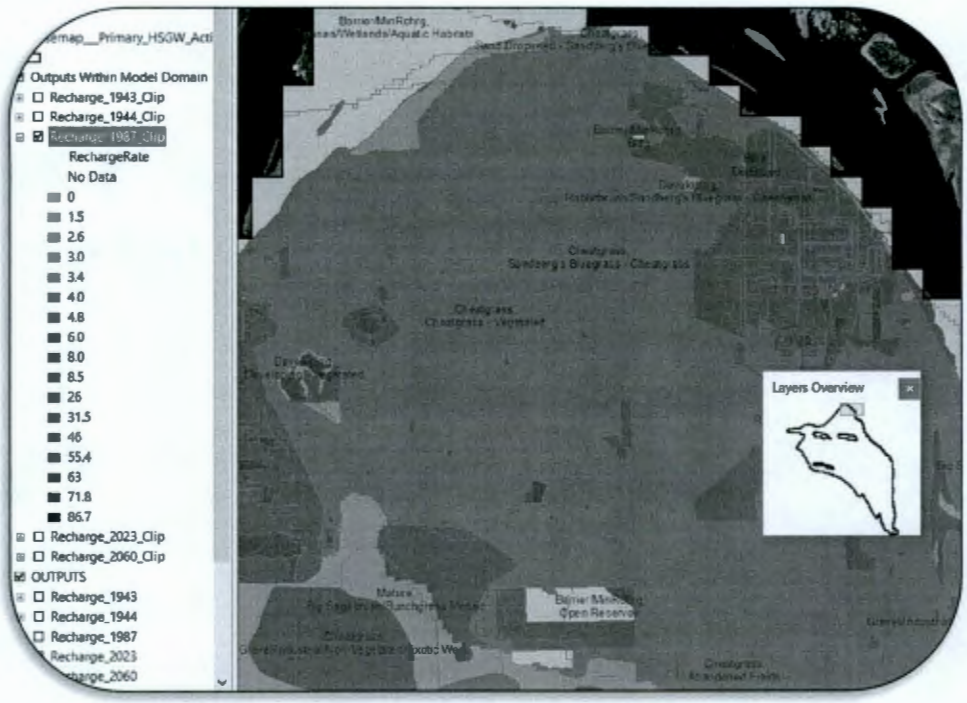

Figure 20 Map of Estimated Recharge (mm/yr), 1987.

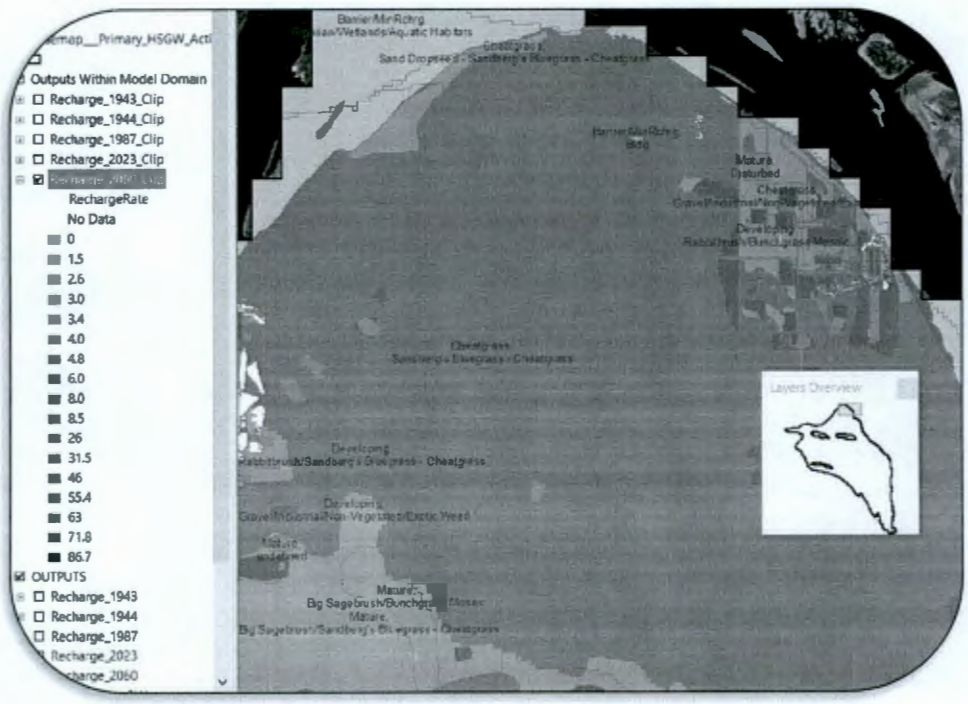

Figure 21 Map of Estimated Recharge (mm/yr), 2060.

Of the 3351 waste sites that are mapped, 2658 have a matching record in the Hanford Disposition Baseline, which provides specific information used to infer surface condition, as well as changes over time. In most cases this mismatch in record numbers is presumed to be because the waste sites (*ehsif*) were mapped from all records in WIDS, whereas the Disposition Baseline does not include sites that were decontaminated prior to 2015 (EMDT-BC-0008). The current business rules for assigning recharge rates currently leaves sites with no corresponding record in the Disposition Baseline as 'undefined' and does not assign a recharge value (RechargeRate = -9999).

As indicated in ***Table 12***, there are some features that remain unaccounted for in the automation results. For example, because the vegetation map in the southernmost area of the model domain was not added to the default vegetation feature class, these features drop out of consideration prior to operations in 1944 and after 2050. Further, there are still some CVP and ehsit features which, in the absence of any other disposition information, are being assigned an 'undefined' value for cover and surface condition, and thus are output with an invalid recharge rate.

Table 12 Unique features produced by the combination of Cover Type, Surface Condition, and Soil Type for each Model Year tested.

Original Feature Class	Total Features	Features with Invalid RechargeRate	Cause of Invalid Records
RechargeEstimates (1943)	5729	430	226 per Irrig vs Cheatgrass 214 per no default vegetation
RechargeEstimates (1944)	24544	187	ehsit with undefined cover and surface condition
RechargeEstimates (1987)	25411	187	ehsit with undefined cover and surface condition
RechargeEstimates (2023)	27283	2049	CVP and ehsit with values of 'undefined'
RechargeEstimates (2060)	24464	2255	CVP and ehsit with values of 'undefined' = 2049 206 per no default vegetation

Notes:

7.2 Conclusions

The use of site specific information on surface conditions at different times in the history of operations at Hanford has the potential to result in substantially different outcomes from groundwater flow models. The ability to combine the baseline disposition information on waste sites and facilities with additional validation of on-the-ground disturbance through air photo interpretation has resulted in adjusted recharge estimations for over 20% of the groundwater model domain extent (193 of 888 km^2).

During the Quality Assurance review of the RechargeEstimates for each Model Year, a few patterns stood out that may over or underestimate actual conditions. The value of improvements to each data sources must be weighed against the cost and benefits. For example, in the absence of a vegetation survey for 1943, the conditions on the ground were assumed to be the same on average sitewide as the vegetation map from 2011 (BRMP). In other words, each vegetation polygon from 2011 was applied in 1943 unless another contemporary polygon feature existed. The problem with this rule is that the 2011 data include disturbed areas ('Gravel/Industrial/Non-Vegetated/Exotic Weed') that do not exist in 1943 (see . While this would tend to overestimate the recharge rates for 1943, the fact that the sitewide average (103 mm/yr/km2) is 10 times smaller than that during operations implies that perhaps refinement of this number is a lower priority for the sitewide analysis. Given that fate and transport models are more dependent on local conditions, refinement of these data may indeed be warranted.

When considering the amount of invalid records it is important to remember that these features likely represent a smaller amount of actual sites or disturbed area features because each surface condition value is cut into smaller features according to the variability in the underlying soils. However, certainly a goal of this calculation was to improve recharge estimations around the operational areas, and a visual review of the areas with invalid recharge rates indicates many are within the primary operational areas and so further inquiry into the cause of the mis-

calculations is warranted. In the short term, the recharge estimates for each model year have been loaded into a summary geodatabase which can be updated manually, at least for those features where source data exists but the automated output is miscalculated.

It is interesting to consider how the current calculations compare to the previous sitewide estimations of recharge. For example, Reference Table 4.3 in PNL-10285-UC2010 (***Figure 16***), proposes annual recharge volumes for each land use/soil type, sitewide.

Table 4.3. Annual Recharge Volume for Each Combination of Soil Type and Vegetation/Land Use Within the Boundaries of the Whole Site. The recharge estimate for each combination is based on either measurements, modeling, or inferences from other combinations, as explained in Section 3.0.

Vegetation/Land Use		Annual Recharge Volume (L)																
		Soil Types															Vol. per Veg. Type (L)	Percent of Total Volume
Index	Description	Ri	Rp	Hc	Kf	Ba	El	La	Eb	Ki	Wa	Sc	P	Qu	Br	D		
1	Shrub-steppe on slopes	4.0E+07	9.7E+05	0.0	0.0	1.0E+05	0.0	8.1E+07	0.0	8.4E+06	3.2E+07	1.6E+05	0.0	5.8E+05	0.0	0.0	1.6E+08	1.6
2	Shrub-steppe on plain/uplands	1.9E+07	6.1E+08	4.3E+07	7.2E+06	2.6E+08	9.4E+07	0.0	1.6E+07	2.5E+07	1.1E+08	7.8E+05	1.2E+06	2.5E+07	8.5E+06	0.0	1.3E+09	13.0
3	Recovering shrub-steppe on plain/uplands	1.1E+06	2.6E+09	4.1E+07	4.1E+06	1.6E+08	5.2E+07	0.0	2.6E+06	7.9E+06	2.7E+07	4.3E+04	6.6E+05	3.1E+07	0.0	1.0E+08	3.1E+09	30.0
4	Bunchgrass on slopes	1.6E+08	0.0	4.4E+05	8.3E+04	3.0E+06	2.2E+06	6.7E+07	0.0	4.2E+07	2.4E+08	2.7E+07	0.0	4.1E+06	0.0	0.0	5.5E+08	5.4
5	Hopsage/grasewood	0.0	0.0	2.7E+06	0.0	6.0E+05	3.9E+04	0.0	0.0	2.5E+05	4.3E+04	0.0	0.0	1.9E+06	0.0	0.0	5.6E+06	0.1
6	Cheatgrass	0.0	4.1E+08	3.2E+07	8.2E+05	6.1E+07	2.0E+08	0.0	3.4E+07	1.3E+06	3.3E+07	5.3E+06	2.7E+05	3.8E+07	3.5E+07	0.0	8.5E+08	8.3
7	Abandoned fields	6.6E+06	2.4E+08	0.0	0.0	5.3E+07	2.2E+07	1.8E+05	0.0	1.2E+04	3.3E+07	0.0	2.7E+05	0.0	1.5E+07	0.0	3.5E+08	3.5
8	Riparian	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	Agricultural areas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	Sand dunes	0.0	7.1E+08	8.2E+07	0.0	4.7E+07	1.2E+06	0.0	0.0	0.0	0.0	0.0	0.0	3.0E+06	4.2E+05	7.1E+08	1.6E+09	15.3
11	Disturbed/Facilities	4.6E+05	1.2E+09	1.8E+06	2.4E+05	4.1E+07	1.1E+08	4.8E+05	8.2E+07	1.1E+06	8.7E+05	0.0	1.9E+05	1.6E+06	1.0E+07	0.0	1.4E+09	14.1
12	Water	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	Basalt outcrops	0.0	3.3E+06	0.0	0.0	2.1E+07	6.4E+07	3.7E+08	5.3E+08	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.9E+08	9.7
	Annual Volume (L) per Soil Type =	2.3E+08	5.8E+09	2.1E+08	1.2E+07	6.5E+08	5.4E+08	5.2E+08	6.7E+08	8.7E+07	4.6E+08	3.4E+07	7.5E+06	1.0E+08	6.9E+07	8.2E+08	1.0E+10	
	Percent of Total Volume =	2.2	56.8	2.0	0.1	6.4	5.3	5.1	6.5	0.8	4.5	0.3	0.1	1.0	0.7	8.0		

Figure 22 Annual Recharge Volumes for Each Combination of Soil Type and Vegetation/Land Use Within the Boundaries of the Whole Site (from PNL-10285-UC2010)

A similar calculation was made for this report of the annual recharge volume for Rupert/Quincy Sand, sitewide, taking into account the unique recharge rates assigned by cover type and surface condition in the current calculations. These results (***Table 13***), indicate substantially lower total volumes that were estimated previously. Whether this will hold true after many of the Future Considerations below are addressed remains to be seen.

Table 13 Comparison of Annual Recharge Volumes for Quincy Sand in PNL-10285 versus the current calculation.

Vegetation / Land Use	'Rp' (*now* 'Qy')	'Qy' in 1943	'Qy' in 1944	'Qy' in 1987	Qy' in 2060
Shrub-Steppe on Slopes	9.70E+05	GIS query (TEXT_SYM = Qy, NOT RechargeRate = -9999) returns 874 features out of 3268; area of 362698875.059122 m²	GIS query (TEXT_SYM = Qy, NOT RechargeRate = -9999) returns 11021 features of 21911; area of 362405868.205751 m²	GIS query (TEXT_SYM = Qy, NOT RechargeRate = -9999) returns 11667 features out of 22749; area of 400736791.428287 m²	GIS query (TEXT_SYM = Qy, NOT RechargeRate = -9999) returns 10294 features out of 21840; area of 362048950.712265 m²
Shrub-Steppe on plains/uplands	6.10E+08				
Recovering Shrub-Steppe on plains/uplands	2.60E+09				
Bunchgrass on Slopes	0.00E+00				
Hopsage/Greasewood	0.00E+00				
Cheatgrass	4.10E+08				
Abandoned Fields	2.40E+08				
Riparian	0.00E+00				
Agricultural Areas	0.00E+00				
Sand Dunes	7.10E+08				
Disturbed/Facilities	1.20E+09				
Water	0.00E+00				
Basalt Outcrops	3.30E+06				
Annual Volume (L) per Soil Type	5.77E+09	2.46E+09	2.51E+09	4.13E+09	2.19E+09
Total Area (km²) per Soil Type[a]	3.65E+02	363	362.4	400.7	362

Notes:

a Area for the Rp soil calculation in PNL-10285 was taken from Table 4.2 of same publication.

7.3 Future Considerations

7.3.1 Expand the Data Sources

It would be valuable to review the list (ehsit_NoMatchToDisposition.dbf) of sites that are mapped with no corresponding Disposition Baseline record, to confirm that these 693 records are indeed intentionally absent in the Disposition Baseline.

Further, in the current automation, every spatial feature present in the waste sites layer is included in the calculation of recharge, regardless of whether the site is tracked as part of the Disposition Baseline. For those uncontaminated sites without a corresponding record in the Disposition Baseline, the surface condition was assumed to be 'Gravel/Industrial/Non-Vegetated/Exotic Weed' for the time period of 1944 to 2050. This assumption could be refined to better reflect the actual disposition of these uncontaminated sites. This process could include a method for identifying and excluding areas within sites, for example, that remain in their natural vegetative state.

Similarly, assumptions have been made about the temporal progression in surface condition for features that were added by this calculation for 2011 and 1943. Currently all newly added features are treated as active for the time period 1944 to 2050, but a more informed supposition could likely be made by, at a minimum, assuming the attributes (dates and disposition) of adjacent or overlapping waste site or facilities features.

As new information on surface condition in different time periods become available, refine the ranking of data sources and update the process automation to incorporate the new sources. For example, there is multispectral aerial imagery available for 1976, which could provide a more accurate representation of actual operations relative to the

current assumptions. In this case, sections of the existing ArcPy™ code can be copied and re-purposed with a few minor updates.

In areas of greatest concern and/or containing highly variable surface conditions, it could be valuable to add a review of oblique imagery to help distinguish digging activities (which implies the soils have been displaced for Hanford Sands sediment) versus bare or gravel-covered ground which leaves the surface soil condition intact.

After completing the sitewide calculation, it is apparent that the value of capturing all the recently cultivated fields from the 1943 imagery is not necessarily to capture the irrigation activity itself, but instead to accurately represent the natural succession of those locations from bare to mature shrub-steppe for the years after 1943. Further, the irrigated land in 1943, as captured in this calculation, were only those fields with active irrigation in the image. Fields that were tilled or recently fallow were not likely captured. Therefore, this layer currently lends a conservative outlook on recharge sitewide. As such, it could be worthwhile to re-visit the aerial photo interpretation of the 1943 USGS imagery. Another pass could be particularly valuable if certain extents were replace with higher resolution scans of the original images.

Another source of variable surface conditions surround road features. The current transportation feature classes provide accurate information on the location of features, and at least some information about the condition (trails and two-track roads that have grown-over will differ from regularly maintained gravel or paved roadways). Further, if the collective influence of roadways on local recharge is deemed valuable, then it would be fairly quick to develop a pre-operations road layer, by first evaluating which of the existing roads were already active in 1943, and then adding any additional ones that were present in 1943 but not part of the current transportation feature sets.

Fire scars and the natural vegetation mosaic that existed in 2011 were presumed to be, on average sitewide, constant temporally (1880 to present) for undisturbed areas. The locations of and specific outcomes resulting from natural disturbances could certainly also be addressed more specifically as data are available.

Basalt subcrops and outcrops within the Hanford Site were not considered as part of the current calculation because these locations are currently outside the groundwater model domain. However, because the recharge rates (PNNL-10285-UC2010) for this substrate are very high (86.7 mm/y) relative to all other soil types considered, future sitewide recharge calculations may want to account for these areas.

Finally, this calculation applies a single rate for recharge for each unique soil and surface condition, but there may be some instances where including alternate/reference case values would be important.

7.3.2 Refine the current automation process

Many of the following refinements are relatively simple to implement but were not included in the current calculation for lack of time and resources.

1. Fill the remaining gaps in soils data (see ***Figure 6***).
2. Create a new *NRBC_Vegetation* feature class that includes both the current vegetation (BRMP) as well as polygons to represent natural vegetation cover in the southernmost area of the model domain (largely from *NRBC_SurfaceCondition_2011NAIP*). As it is, the 2011 NAIP polygons drop out of the model considerations prior to 1944, leaving no default vegetation in the southernmost tail of the model domain.
3. Update the succession calculations to account for locations that were previously disturbed but in the current model year will have progressed through natural succession. This is important because lands that have been disturbed have a distinct recharge over time as compared to those that have not been disturbed (PNNL-14072 Rev1). For example, Cover_Type 'Disturbed' with SurfCond 'Cheatgrass has a recharge rate of 31.5 mm/yr, whereas Cover_Type 'Disturbed' with SurfCond 'Developing' has a recharge rate of 8 mm/yr.

4. Update the behavior of the script to explicitly specify soil type 'Qy' when a location has no other value for soil (is NULL or 'XX').
5. Change the feature class names in the script code to reflect the names adopted for the project deliverable (Ex. what was previously called *NAIP_1943* is now *NRBC_SurfaceCondition_1943USGS*).
6. Modify the feature class attribution for *NRBC_SurfaceCondition_1943USGS*, such that the cover type 'Abandoned Fields' are changed to 'Irrigated / Orchard', and reverse the related logic in the automation script to reflect this more accurate perspective on the change in cover, from 'Irrigated / Orchard' for the pre-operational period until 1943 to 'Abandoned Fields' for the operational period starting in 1944.
7. Include the model year in the *RechargeEstimates* feature class name.
8. Have the tool persist the file path settings from one session to another.
9. Explicitly save the path settings into a ReadMe or other metadata reference within the geodatabase package.
10. Write the spreadsheet tables to the geodatabase so they become part of the geodatabase package for each model year.
11. Rename the feature layer prompts in the GUI (ex. clarify that "Existing sites" is actually building sites, *bggensit*)
12. Apply metadata to all the outputs of the script, including the geodatabase itself. For example, currently the *RechargeEstimates* carries forward metadata from the vegetation classification (BRMP).
13. Consider the application of the **Multipart to Singlepart** tool on the newly created soils and vegetation feature classes to standardize calculations and reporting.
14. Document instructions on how to use the tool.

8 References

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Attachment A

Digital Content

The following table summarizes the content provided in digital format along with this ECF.

Table 14 Index to the Digital Content provided with ECF-HANFORD-15-0019, REV. 0.

Description	Relative Location in Digital File System
Assumptions and Inputs	
Index to Original GIS Data Sources	..\NRBC\Deliverables\NRBC\GIS\Metadata\NRBC_CalculationsReference_v1.xlsx
Geodatabase	..\NRBC\GIS\Geodatabase\NRBC_Final_v1.gdb
Lookup Tables	..\NRBC\GIS\Tables\NRBC_LookupTables_Final_v1.xlsx
Disposition Baseline	..\NRBC\GIS\Tables\HanfordDispositionBaseline_20150917.xlsx
Soils (full coverage)	..\NRBC\GIS\Geodatabase\NRBC_Final_v1.gdb\NRBC_Soils
Default Vegetation (from BRMP, missing tails)	..\NRBC\GIS\Geodatabase\NRBC_Final_v1.gdb\Sources___Primary_BRMP_Hanford_Cover_Post_2000_to_2011_Fires
New polys 2011 NAIP (without gaps)	..\NRBC\GIS\Geodatabase\NRBC_Final_v1.gdb\NRBC_SurfaceCondition_2011NAIP
New polys 1943 USGS	..\NRBC\GIS\Geodatabase\NRBC_Final_v1.gdb\NRBC_SurfaceCondition_1943USGS
Metadata	.. \NRBC\Deliverables\NRBC\GIS\Metadata
Rank Data Sources for Use in Defining Surface Condition	
Layer and Feature Ranks	..\NRBC\Deliverables\NRBC\GIS\Metadata\NRBC_CalculationsReference_v1.xlsx
Automate the Calculation of Recharge Sitewide	
Automation Script (ArcToolbox Tool)	..\NRBC\Deliverables\NRBC\GIS\Scripts\SurfaceClassification.Tool.pyt\
Calculation Outputs	
Model Year 1943	..\NRBC\GIS\Outputs_Recharge\NRBC_1940.gdb
Model Year 1944	..\NRBC\GIS\Outputs_Recharge\NRBC_1987.gdb
Model Year 1987	..\NRBC\GIS\Outputs_Recharge\NRBC_2005.gdb
Model Year 2023	..\NRBC\GIS\Outputs_Recharge\NRBC_2023.gdb
Model Year 2060	..\NRBC\GIS\Outputs_Recharge\NRBC_2060.gdb
Manually Updated Recharge Estimates, within the Model Domain Boundary (for Model Years 1943, 1944, 1987, 2023, 2060)	..\NRBC\GIS\Outputs_Recharge\NRBC_RechargeSum_20150930.gdb
Environmental Calculation File	
ECF-HANFORD-15-0019, REV. 0	..\NRBC\ECF\ECF-Hanford-15-0019-r0_content.docx